Effects of the Organic Fertilizers and Modified Evaporative Cooling System on the Productivity of Tomatoes Greenhouse in Hot and Humid Regions

Gaber D.M. Youssef [1], Samir M. Saleh [2]

ABSTRACT

In hot and humid climates such as the tropics, coastal areas of the subtropics and Mediterranean basin, crop growth in greenhouses during hot and humid summer is almost impossible because of the high temperatures occurred inside cause plant stress and death. The aim of this experimental work was to investigate the effects of a developed evaporative cooling system and using different rates of dried biogas digester residues as organic fertilizer on the growth, productivity, and fruit quality of tomato crop. Two similar gable-even-span greenhouses were utilized at EL-Sabahia Horticultural Research Station, Alexandria, to grow and produce tomato crop during the summer seasons of 2014 and 2015. Each greenhouse was equipped with a complete evaporative cooling system. One of them was modified (MECS) by utilizing a solid desiccant. The other one used fan-pad system, (FPECS). The obtained data revealed that the average indoor temperatures, relative humidity and vapor pressure deficit of the MECS greenhouse were lower than the FPECS greenhouse. At noon, the maximum greenhouse temperatures decreased below the outside temperature by 2.2 ^{o}C for MECS while, it increased by 1.6 ^{o}C for FPECS. The maximum indoor temperatures were 42.2, 28.8 and 31.7 ^{o}C for un-cooled, MECS, and FPECS greenhouses, respectively. The greenhouse temperatures decreased at noon below the outside temperature for MECS 3.2 and 1.3 ^{o}C while, it increased by 1.6 and 1.6 ^{o}C for FPECS, for the emissive and highly solar radiation days, respectively.

Organic fertilizers, (dried biogas digester residue at 30, 20, and 10 m^3/fed and farm yard manure at 20 m^3/fed) were applied to investigate their effects on growth, yield and quality as well as chemical constituents of tomato plants. Results of this work showed that the application of 30 m^3/fed of dried biogas digester residue significantly increased the vegetative growth, yield and fruit quality of tomato crop. Meanwhile, there were no significant differences between the application of 30 and 20 m^3/fed applications in most studied characters. The results 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. The increase percentages in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan were 21.28, 14.28, 14.60, 7.56, 23.03 and 23.03%, respectively for 30 m^3/fed dried biogas residue over farm yard manure, (20 m^3/fed) while, they were 18.91, 13.57, 6.40, 20.65 and 20.65% in 2014 and 2015 seasons, respectively. It can be concluded that application of 30 m^3/fed dried biogas residues was the best treatment to produce the highest vegetative growth, yield and quality of tomato plants.

Keyword: greenhouse-tomato-organic fertilizer-evaporative cooling-silica gel

INTRODUCTION

Fertilizer is an organic or inorganic material, containing one or more essential nutrients. It provides 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 for crop production enhancing. Firstly, they make crop plants grow better causing high productivity. Fertilizers give vigorous plants and increase vegetative growth such as; plant height, stem diameter, leaf area, and leaf chlorophyll content 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, Yakout *et al.,* 2014). According to statistics of Food and Agriculture Organization of the United Nations (FAO), 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, Mostafa *et al.,* 2015).

Adding organic manure to soil improves 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, sewage sludge 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*

[1] Protected cropping Dept., Horticultural Research Institute, ARC, Giza, Egypt
[2] Central Laboratory for Agricultural Climate (CLAC), Dokki, ARC, Giza, Egypt
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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. It is an important vegetable crop all over the world. 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. Vollenweider and Gunthardt-Goerg (2005) mentioned that 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. 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).

Air cooling is desirable in many Mediterranean greenhouses in order to prevent plant stress and produce crops of marketable quality. Various equipments can efficiently contribute to maintain greenhouse air temperature and relative humidity at acceptable levels during warm periods, (Kittas *et al.,* 2003). Forced greenhouse crops are common means of cultivation worldwide. Surface area dedicated to such crops about 700,000 ha, 150,000 of which are located in the Mediterranean basin (Franco *et al.,* 2014). High spring-summer temperatures in the Mediterranean basin make evaporative cooling systems necessary. Excess heat causes air temperature to become hotter than the desired level resulting in detrimental effects on crop growth and production (Montero, 2006). Reducing temperatures is one of the main problems facing greenhouse management during daylight in hot-humid summer conditions such as in Egypt (Abdellatif *et al.,* 2010), they mentioned also, that air temperatures in Egyptian greenhouses either covered with polyethylene or fiberglass reinforced plastic can easily exceed 50 °C during the hot summer if they are not equipped with evaporative cooling system.

The evaporative cooling of greenhouses is based on the evaporation of water in mass of dry and warm incoming air, thus allowing a decrease in the air temperature and increases the air relative humidity, (Kittas *et al.,* 2003, Montero, 2006, Farmahini *et al.,* 2012 and Jamaludin *et al.,* 2014). The air saturation efficiency of the pad-fan system is greater than that of the fog system (Katsoulas *et al.,* 2009), it is also cheaper (Sethi and Sharma, 2007) and it consumes less water and energy (López *et al.,* 2012), evaporative cooling unit with perforated ducts kept the air temperature distributed uniformly throughout the greenhouse and kept the greenhouse temperature at the optimum acceptable level, (Youssef *et al.,* 2015). Also, Youssef and Yakout, (2015) found that evaporative cooling system with local pad materials, (rice straw, loaf and cotton thread) when utilized with black shading net 60% permitted the cooling demands of greenhouse in summer of Egypt.

Evaporative cooling efficiency is higher in dry environments (Montero and Segal, 1993). Bhatia (2012) mentioned that evaporative cooling is best suited to hot and dry environments where humidity is less than 30%. As humidity rises the efficiency falls, (Evaptainers, 2014) reported that evaporative cooling is most effective in climates where average relative humidity is less than 30% so that as humidity increases the cooling capability declines. Evaporative cooling system is widely used in greenhouses in hot and dry regions but this relies on the dryness of the ambient air, (Garzoli, 1989). The evaporative cooling technology is a cost effective and eco-friendly alternative but can provide thermal comfort conditions only under low humidity conditions, (Rafique et al., 2016).

Evaporative cooling, especially the fan-pad system, has proved to be very efficient in dry and hot climates, (Lychnos, 2010). Liquid desiccation with solar regeneration is considered as a means of lowering the temperature in evaporatively cooled greenhouses, (Davies, 2005), therefore, numerous researchers worked in enhancing the efficiency of the evaporative cooling systems for greenhouses in humid regions using both liquid and solid desiccant materials, (Bourouni, 2008, Lychnos and Davies 2008, Lychnos, 2010, Joudi and Hasan, 2013,. Franco, *et al.,* 2014).

Many investigators included the author in previous paper; (EL-Bakhashwan *et al.,* 2013) investigated the regeneration of wetted silica gel and concluded that silica gel can be regenerated using solar drying system at temperatures over 60 ^{o}C then reused again and again without significant decrease in the efficiency.

Hot and humid climates restricts the growing season for crop cultivation whereas, the growing season can be unlimited if the greenhouse air temperature is maintained to a desired optimum value for crop cultivation. Therefore, the aim of this research work is to investigate; 1) the performance of two cooled greenhouses by different evaporative cooling systems such as; F-P evaporative cooling system (control) and developed evaporative cooling system, (In the proposed cycle, the air is dried prior to entering the evaporative cooler. This lowers the wet-bulb temperature of the air). 2) the effect of replacing fraction of mineral fertilizer by organic source (dried biogas digester residue) on the productivity of greenhouse tomato.

MATERIALS AND METHODS

Materials

Greenhouses

Two identical mechanically ventilated gable-even-span type greenhouses were utilized in summer seasons of 2014 and 2015 at El-Sabahia Horticultural Research Station, Alexandria. Each greenhouse has gross dimensions of 8.0 m long, 4.0 m wide and 3.1 m high. The two greenhouses are covered with single layer of polyethylene sheet of 200 µm. Each greenhouse has three basins; each has the dimensions of 7.0 x 0.80 x 0.35 m. Drip irrigation system was utilized for watering plants.

Cooling Systems

One greenhouse was equipped with the traditional pad-fan system (control treatment), (FPECS) as shown in Fig. (1a). The cooling pad dimensions were 3.0 x 0.6 x 0.1 m with a face area of 1.8 m^2. One suction fan (single speed, direct driven, 60 cm diameter and 8000 m^3/h discharge) was located on the leeward side of the greenhouse, while the cooling pad was placed on the opposite side. The system was supplied with 0.5 hp water pump discharges 24 (L/h) to circulate water. The other greenhouse was equipped with an evaporative cooling unit, (Fig. 1b). It was modified by attaching three residences of desiccant sieves, (Modified Evaporative Cooling System, MECS) is shown in Fig., 1c). The unit has a square base with the dimensions of 1.20 x 1.20 m and 0.80 m height. The cooling unit has three openings from three sides, each 1.0 x 0.6 m to hold the cellulose pad (three pieces each 1.0 x 0.6 x 0.1 m). The three cellulose pads have a gross area of 1.8 m^2 as the same area for the fan-pad system. The fourth side has an extracting fan that directly connected with a duct 0.35 x 0.45 m and 1.0 m long. The water distribution system was located above the cellulose pad openings, which consists of three channels, 1.0 m long and 0.10 m wide with 3 (mm) holes 5 cm apart. It was supplied with 0.5 (hp) water pump to circulate the water with a discharge rate of 24 (L/min). There was also, a control valve to control the water flow rate over the cellulose pad. The basin of the evaporative cooling unit has the dimensions of 1.20 x 1.20 x 0.10 (m) which form a gross volume of 144 liters. It was acted as a water sump. The evaporative cooling unit supplies a 7.0 m rectangle duct inside the greenhouse with a cross section of 0.45x0.35 m. It has rectangular holes 0.50 m apart on each side. It is shown in Fig. (1d). The duct was hanged across the longitudinal axis of the greenhouse above the plant canopy to uniformly distribute the cooled air through the greenhouse. A schematic diagram of the whole system is illustrated in Fig. (2).

Tomato hybrid (Agiad 7) was utilized to investigate the effects of different macroclimatic conditions and the organic fertilizer on fruit yield and quality. The experimental treatments were two evaporative coolings, (FPECS and MECS); three rates of organic fertilizer; (30, 20 and 10 m^3/fed of dried biogas residues). The control was farm yard manure fertilizer at rate of 20 m^3/fed. Seeds were sown in the nursery on February 3rd and 1st in 2014 and 2015 seasons, respectively. Seedling transplant was performed on March 8th and 10th in 2014 and 2015 seasons, respectively. Planting distance was 50 cm apart. Each plot had 14 tomato hybrid plants. Chemical fertilizers were added according to the recommended rates (Bulletin, No.902, 2004). They were applied weekly for all season for both greenhouses. The micro-minerals; iron, copper, manganese, zinc, magnesium and born were applied as foliar spraying. The bio-fertilizer Microbin was also, added as 4L/fed for both greenhouses. It was applied as suspension in the fertigation system in two times; the 1st with transplanting, while the 2nd at the time of initiation of flowering. 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 used was a complete randomized block design with three replicates. Thus, the treatment combinations were 8 treatments and can be listed as follows:

T_1: FPECS + 30 m^3/fed organic fertilizer (OF)
T_2: FPECS + 20 m^3/fed organic fertilizer (OF)
T_3: FPECS + 10 m^3/fed organic fertilizer (OF)
T_4: FPECS + 20 m^3/fed (FYM)

a- Fan-pad evaporative cooling system

b- Evaporative cooling unit

c- Modified evaporative cooling system with desiccant filter housings

d- Perforated duct hanged across the greenhouse longitudinal axis

Fig. 1. the two evaporative cooling systems

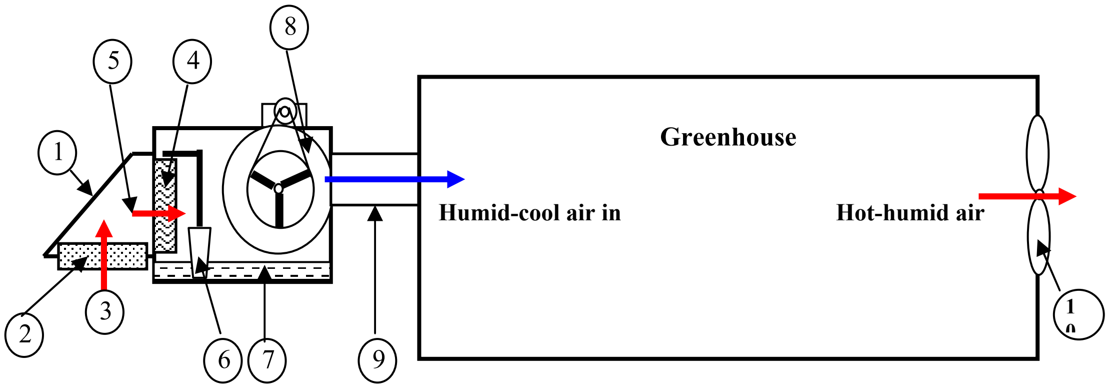


Fig. 2. A schematic diagram of the developed evaporative cooling system with solid desiccant filters

1- silica gel filter housing
2- silica gel sieve
3- hot-humid air inlet
4- cellulose pad
5- hot-dry air inlet
6- water pump
7- water sump
8- air blower
9- cool-humid air inlet
10- suction fan

Table 1. Physic-chemical properties of organic fertilizers (dried biogas digester residue and farm yard manure)

Element / Sample	N	P	K	Fe	Zn	Cu	Cd	Ni	Cr	Pb
			%	(meq/l)						
Dried biogas residue	5.01	5.00	5.41	868	74.0	60.0	16.0	184.0	0.00	54.00
Farm yard manure	1.06	1.80	1.20	383	76.0	20.0	18.0	168.0	0.00	96.00

The percentage of total nitrogen (N), total phosphorus (P), total potassium (K) was calculated from their relative contents in 100 g dry samples.

Table 2. Physical and chemical characteristics of soil samples

Physical properties	Clay %	Silt %	Sand %	OM	Soil texture	*PH	**EC (dSm^{-1})
2014	45.2	35.1	21.8	22.4	Clay loam	7.6	3.35
2015	39.5	37.2	23.4	25.7	Clay loam	7.7	3.32

Chemical properties

	Soluble cations (meq/l)				Soluble anions					
	Ca^{++}	Mg^{+}	K^{+}	Na	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_2^{--}	Total N%	Available phosphorus
2014	3.8	3.6	21	7.2	3.1	1.7	5.5	2.9	0.18	30.9
2015	4.6	2.9	19	7.4	3.3	1.9	5.6	3.2	0.19	30.7

* measured in 1:25 soil water suspension.

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

T_5: MECS + 30 m^3/fed organic fertilizer (OF)
T_6: MECS + 20 m^3/fed organic fertilizer (OF)
T_7: MECS + 10 m^3/fed organic fertilizer (OF)
T_8: MECS + 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”. It was financially supported by the Agricultural Development Program (ADP). It was also, Implemented at the Tractors and Machinery Research and Test Station, Alexandria city, Agricultural Engineering Research Institute. The physic-chemical properties of the organic fertilizers and the soil samples analysis are presented in Tables (1 and 2), respectively.

Procedure and instrumentation

Pre-experiments were performed to find out the optimal silica gel weight required to dehumidify the ambient air before passing through the cooling pad. Three weights of silica gel were utilized; 15.0, 25.0 and 30.0 kg for each sieve. Granule silica gel was bought from the Egyptian Chemical Stores. The silica gel was in spherical form, 2 to 5 mm diameter. It was used in each sieve as desiccant filter. The acceptable range of relative humidity of the air out of the desiccant sieves ranged from 0.0 to 30.0% throughout the experimental work. This was to attain maximum cooling efficiency. The silica gel sieves were replaced with anther regenerated ones.

The measurements were carried out from April to July of both 2014 and 2015 seasons. The meteorological data from a meteorological station (5 KUE SKH 2013) included the measurements of solar radiation flux incident on a horizontal surface, dry-bulb air temperature, wind speed and its direction, and air relative humidity outside the greenhouses. The instruments used to measure theses variables were Pyranometer, ventilated thermistor, cup anemometer and wind vane, and hygrometer, respectively. The data were collected and sent through the network of the Central Laboratory for Agricultural Climate (CLAC), Dokki, ARC. The air temperatures and relative humidities prior and behind the desiccant sieve and after the cooling pad of the first greenhouse, prior and behind the cooling pads of the other one, with fifteen minutes intervals and the hourly average were recorded using Data-loggers type SATO, SK-L200 II- Japan. Microclimate variables within the greenhouses such as the temperature and relative humidity at the middle of the two greenhouses and just prior to the extracting fan were measured using thermocouple sensors type K. These sensors were connected to a digital multimeter to record the data throughout the experimental work.

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

1. Vegetative growth characteristics

1.1. Plant height (cm).

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

1.3. Number of leaves per plant.

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

1.5. Stem diameter

2. **Chemical composition**

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

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

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

2.3. Potassium (%) was determined by flame photometer as described by Ranganna, (1979).

2.4. 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).

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

2.6. 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).

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

2.8. 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).

3. Fruit physical characteristics:-

3.1. Fruit length (cm)

3.2 fruit diameter (cm).

3.3. Shape index (L/D)

3.4 flesh thickness (cm).

4. Yield and its components:-

4.1. Early yield (kg\plant).

4.2. Total yield (kg\plant).

4.3. Number of fruit per plant.

4.4. Average fruit weight (gm).

4.5. Total yield (ton\ feddan).

Statistical analysis:-

The collected data were statistically analyzed using the computer package program, SAS Ver.9.2 in order to obtain the least significant differences among treatments.

Effectiveness of evaporative cooling system

The efficiency of the evaporative cooling system is mainly associated with the cooling effect (T_{out}–T_{evp}), wet-bulb depression (T_{out}–T_{out-wb}), and water consumption in the evaporation process. The cooling efficiency (η, %) can be computed in terms of the cooling effect and the wet-bulb depression using the following equation (ASHRAE, 2005):

$$\eta = \frac{T_{out} - T_{evp}}{T_{out} - T_{out-wb}} \times 100, \% \qquad (1)$$

Where; T_{out}, is the air temperature after the silica gel filter in ºC, T_{evp}, is the cooled air temperature just leaving the cooling pads in ºC, and, T_{out-wb}, is the wet-bulb temperature of the air after the silica gel filter in ºC.

Vapor pressure deficit of the greenhouse air (VPD) was calculated using Autogrow Spreadsheet Excel Software, (Autogrow, 2012). It expresses the combined interaction effect of the indoor dry-bulb temperature and relative humidity.

ESULTS AND DISCUSSION

1. Engineering studies

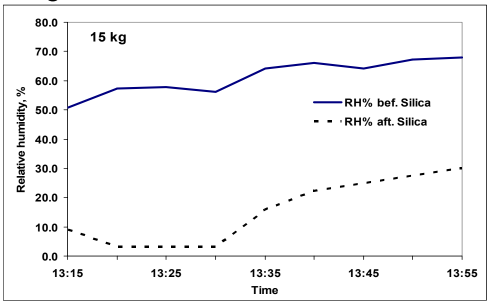
The first objective of present study was to evaluate the effects of two evaporative cooling systems mainly modified evaporative cooling, (MECS) and fan-pad, (FPECS) evaporative cooling systems on the microclimate of greenhouses. The optimization of air temperature, relative humidity, and vapour pressure deficit in greenhouses are particularly important in relation to plant growth, development, and productivity. In order to achieve optimum greenhouse conditions, it is necessary to ventilate and cool the greenhouse, particularly during the hot and humid seasons.

1.1 Effect of the relative humidity of outside ambient air on relative humidity of air after passing on the silica gel sieve

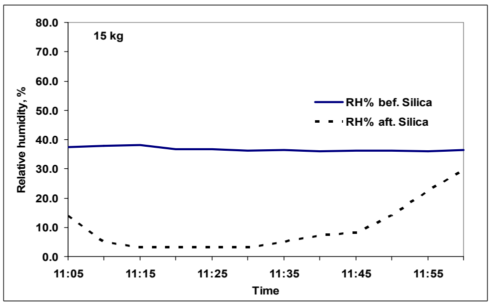
Silica gel's high surface area (around 800 m^2/g) allows it to adsorb moisture rapidly, making it useful as a desiccant (drying agent). The silica-gel has a great capacity to absorb moisture of around 35 to 40% of its dry mass, along with low regeneration temperatures, (Tahat, 2001). Pre-experiments were conducted to find out the appropriate desiccant quantity needed for our investigation. Unfortunately, in the pre-experiment it was found that the weather conditions especially the air relative humidity is the main governing factor for making the desiccant materials rapidly absorbs the moisture from the ambient air. The data for the first weight (15 kg) showed out how different ambient relative humidities can affect the moisture absorption by silica gel as illustrated in Fig. (3). The figure showed that ambient air with high relative humidity increased the silica gel absorption rate of moisture than that of low ambient air relative humidity. Measurements showed that the low relative humidity of ambient air occurred only around noon time of the day. The required time for the passing air through silica gel sieve to reach the maximum acceptable level of relative humidity (30%) was 40 and 65 minutes for low ambient relative humidity (average RH ≅38%) and high ambient relative humidity (average RH ≅63%), respectively. This was in agreement with (Wikipedia, 2013) that mentioned in order to understand how silica gel functions, it is critical to understand the concept of equilibrium moisture content. The quantity of moisture in hygroscopic materials depends on the temperature and relative humidity of the surrounding air. If the temperature or relative humidity changes, the moisture content within the material will change so that it will come into equilibrium with the new condition of the surrounding air.

1.2 Effect of silica gel weight on relative humidity of air after passing on the silica sieve and the grasped moisture:

Calculating the correct quantity of silica gel allows for the cost-efficient selection of an appropriate amount of buffering material. Silica gel has been used as a highly efficient desiccant to remove water vapour from humid ventilation air for human building, livestock and poultry housing, (Pesaran and Mills, 1987). The effect of the silica gel weight on the relative humidity of air after it passed on silica gel sieve and the grasped moisture was illustrated in Figs. (4a, b and c) and (5). Figure (4a, b, and c) showed that increasing silica gel weight increased the time needed by the air to achieve the maximum acceptable air relative humidity.

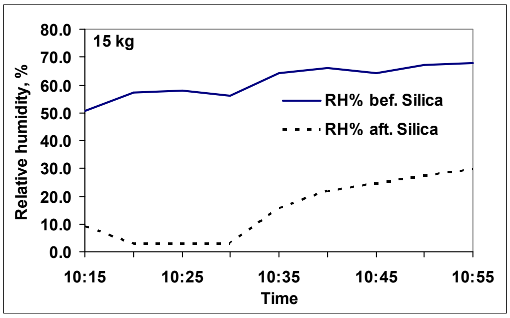


a- ambient air with high relative humidity

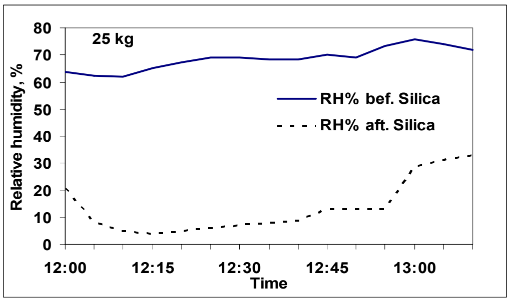


b- ambient air with low relative humidity

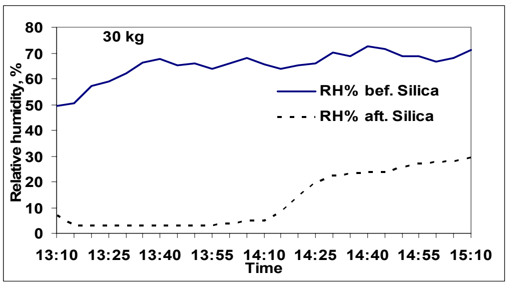
Fig. 3. Effect of ambient relative humidity on the moisture absorption of silica gel



a- 15 kg silica gel

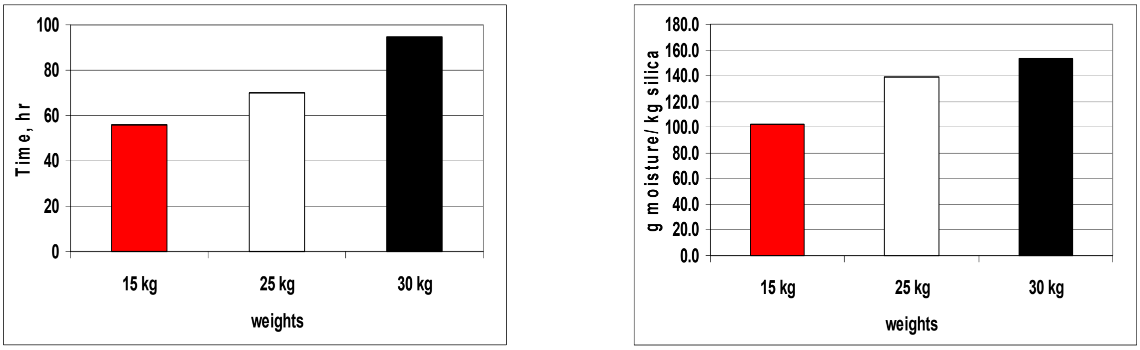


b- 25 kg silica gel



c- 30 kg silica gel

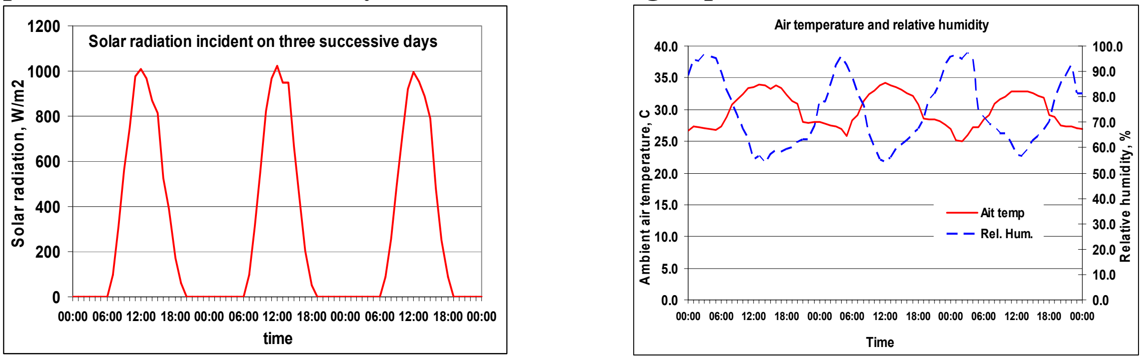
Fig. 4. Effect of silica gel weights on the time to reach the maximum acceptable air relative humidity



a- average time

b- average grasped moisture

Fig. 5. Effect of different weights of silica gel on the average time to reach maximum acceptable air relative humidity and the amount of grasped moisture



a- Solar irradiance in three successive days

b-Ambient air temperature and relative humidity in three successive days

Fig. 6. The solar intensity, ambient air temperature and relative humidity of three successive days in the experimental location, Sabahia-Alexandria

1.3 Microclimate data of the weather station outside the two greenhouses

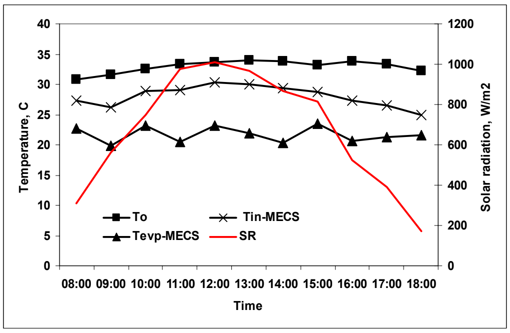
The presented data in the following sections based on hourly average measurements were recorded during the experimental period (April, May, June, and July). The hourly averages solar radiation flux incidents outside the greenhouses, ambient air temperatures and relative humidities throughout three successive days are illustrated in Fig. (6a and b). The figure showed highly irradiance of solar radiation, high ambient air temperature and relative humidity. The solar radiation incident at or around noon reached the level of more than 1000 W/m^2, ambient air temperature was exceed 33.0 ^{o}C while relative humidity did not fall down the level of 55% in the experimental location, (Sabahia, Alexandria) as a humid costal region.

The hourly averages solar radiation flux incident outside the greenhouses were 513.1, 598.9, 645.3, and 631.4 W/m^2 for April, May, June, and July, respectively. While, this amount recorded inside the greenhouse during the same time was 267.7, 344.3, 465.3, and 433.8 W/m^2, respectively. Consequently, the hourly average effective transmittances of the polyethylene cover were 67.1.53%, 69.9%, 72.1%, and 69.7%, respectively.

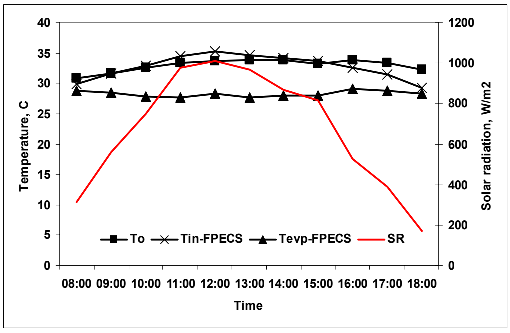
1.4 Effects of both cooling systems on the indoor temperatures of greenhouses

To show the effect of both evaporative cooling systems in this study on greenhouse temperatures, data of two days were demonstrated as samples such as; 1) highly solar intensity (900> SR<1000 w/m^2), hot (<30.0 ^{o}C) and humid day (>50%), (HSHH) and 2) excessive solar intensity (SR> 1000 w/m^2), very hot (>30.0 ^{o}C) and humid day (>50%), (ESVHH).

To monitor the performances of the two greenhouses as affected by the two evaporative cooling systems, the solar radiation incident, (SR), ambient air temperatures outside the two greenhouses, (T_o), the temperatures of air jest leaving the cool pad for both modified evaporative cooling system, ($T_{evp\text{-}MECS}$), and fan-pad evaporative cooling system ($T_{evp\text{-}FPECS}$) and the indoor temperatures of both greenhouses, ($T_{in\text{-}MECS}$) and ($T_{in\text{-}FPECS}$) for the two days were illustrated in Fig. (7).

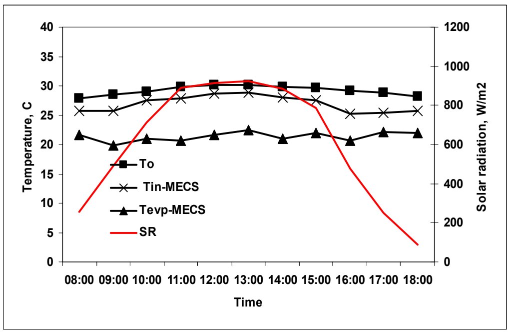


a- MECS greenhouse performance

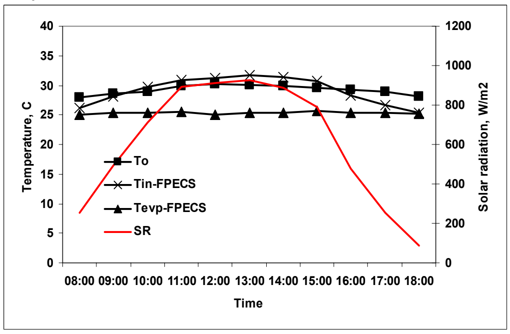


b- FPECS greenhouse performance

1- ESVHH day



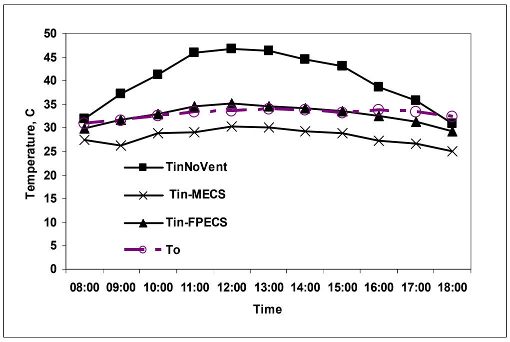
c- MECS greenhouse performance



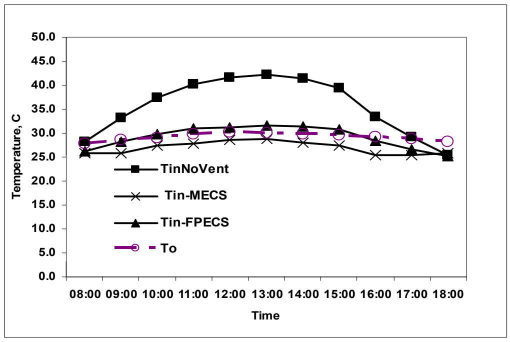
d- FPECS greenhouse performance

2- HSHH day

Fig 7. The Solar radiation incident, (SR) ambient temperature, (T_o), the temperature of air just leaving the cool pad for both modified evaporative cooling system, ($T_{evp\text{-}MECS}$) and fan-pad evaporative cooling system ($T_{evp\text{-}FPECS}$) and The air temperatures for both greenhouses, ($T_{in\text{-}MECS}$) and ($T_{in\text{-}FPECS}$)



a- the greenhouses performance of ESVHH day



b- the greenhouses performance of HSHH day

Fig. 8. Effect of both evaporative cooling systems on the temperatures of both greenhouses

The figure showed that the temperatures of air just leaving the cooling pad for MECS greenhouse were lower than that of FPECS greenhouse as affected by introducing the silica gel sieve before the cooling pad to firstly grasp the moisture from the ambient air before passing on the cooling pad. Consequently, the temperatures of the inside air of MECS greenhouse were lower than that of the FPECS greenhouse for both days. Also, the indoor temperatures of the MPECS greenhouse were decreased than the outside ambient temperature specially, at and around noon time for both days. On the other hand, the indoor temperatures of FPECS greenhouse exceeded the outside ambient temperature at and around noon time for both days. The maximum indoor temperature were 35.2 and 31.7 ^oC, respectively at noon in the ESVHH day for FPECS and MECS greenhouses whereas, they were 30.4 and 28.8 ^oC for the HSHH day, respectively. The maximum indoor temperatures decreased below the outside temperature by 3.2 and 1.3 ^{o}C at noon for MECS while, it increased by 1.6 and 1.6 ^{o}C for FPECS, for the ESVHH and HSHH days, respectively. Shamshiri and Ismail, (2014) suggest that integrated scheduling of natural and mechanical ventilation with appropriate cooling techniques in peak-hours can efficiently manipulate greenhouse environment and improve production efficiency.

A computer program was previously developed by Youssef, *et al.,* (2015) was run with the outside weather condition to imagine out the indoor temperature of the greenhouse without evaporative cooling system to explain the importance of operating the two evaporative cooling systems on the temperatures of both greenhouses. The result of the computer run plotted with the actual measurements of the indoor temperature for both MECS and FPECS greenhouses in Fig (8). The maximum indoor temperatures at noon were 47.6, 30.4 and 35.2 ^{o}C for the unventilated, MECS and FPECS greenhouses, respectively, in the ESVHH day while, they were 41.6, 28.7 and 31.2 ^{o}C in HSHH day, respectively. The percentages decreases in indoor temperature at noon were 34.9 and 24.6% less than the un-cooled greenhouse for MECS and FPECS in ESVHH day whereas; they were 31.0 and 25.0% for HSHH day, respectively.

1.5 Understanding the evaporative cooling process on psychometric chart

The cooling process can be explained on the psychometric chart to understand the cooling effect, wet-bulb depression and evaporative cooling efficiency. The cooling effect is the difference between the temperatures of outside dry bulb and temperature just leaving the cooling pad. The wet-bulb depression is the difference between the dry and wet bulb temperatures. It is expected that the cooling effect is a fraction of wet-bulb depression. The cooling processes for both evaporative cooling systems were illustrated in Fig. (9). The state of ambient air was point 1. The cooling process for FPECS was explained by points 1, 2 and T_{wb} . The cooling effect is the distance between points 1 and 2. (i.e. 28-24=4 ^{o}C) , while, the wet-bulb depression was the distance between points 1 and T_{wb} (i.e. 28-22=6 ^{o}C). So, the efficiency was 66.67%. On the other hand, for the developed evaporative cooling system, the cooling process is represented by points 1, 2', 3' and T'_{wb}. The process from points 1 and 2' was dehumidifying the ambient air by the silica gel, but unfortunately this is a heat release process, so the temperature of the ambient air increased while the relative humidity deceased. Hence, the cooling effect is the distance between points 2' and 3' (i.e. 40.0-19.5=20.5 C) whereas; the wet-bulb depression is the distance between points 2' and T'_{wb} (i.e. 40.0-17.5=22.5). Consequently, the efficiency was 91.1%. Hence, the percent increase was 36.64% in the efficiency of MECS over FPECS.

1.6 The wet-bulb depression

The dry-bulb and wet-bulb of ambient air, and the temperatures of air just leaving the cooling pads of the two evaporative cooling systems were demonstrated in Fig. (10a). It is regular that the temperatures just leaving the cooling pad of FPECS were greater than the wet-bulb temperatures of outside air whereas, the system efficiency was lower than 100%. This result was in agreement with Garzoli, (1989) who reported that direct evaporative cooling can not achieve temperatures lower than the ambient wet-bulb temperature and the achieved temperatures were actually higher than the wet-bulb temperature. On the other hand, the temperatures just leaving the cooling pad of MECS were lower than the ambient wet-bulb temperature. Hence, it is important to obstruct the air stream by the silica gel sieve before the air passes through the cooling pad to dry it. Consequently, the air moisture was partially removed causing a decrease in the air relative humidity and wet bulb temperature compared with the outside one. So, the temperature of the air just leaving the cooling pad of MECS was lowered than the ambient web-bulb temperature as shown in Fig. (10-1). The average temperatures of air just leaving the cooling pad were 21.68 and 21.37 ^{o}C for MECS in the first and second day, respectively, for the averages outside ambient air temperatures of 32.9 and 29.23 ^{o}C while the averages ambient relative humidities were 62.5 and 64.6% in the first and second days, respectively. On the other hand, the average temperatures of the air just leaving the cooling pad for FPECS were 28.25 and 25.32 ^{o}C for the same two days, respectively.

The percentage decrease in the temperature just leaving the cooling pad for MECS over FPEVS was 30.30 and 18.48%, respectively, in the ESVHH and HSHH days. The lower percentage in the second day was due to the cooling system which was operated ON and OFF when the desired cooling was achieved. The results of MECS are in agreement with Vox *et al.,* (2010) who mentioned that the outside air temperature can be reduced by as much as 10 to 25°C cooler than ambient temperature in regions with very low humidity. Mehmet and Hasan (2015) also, reported that the hourly mean cooling effect calculated for fan-pad system was determined to be 6.96ºC.

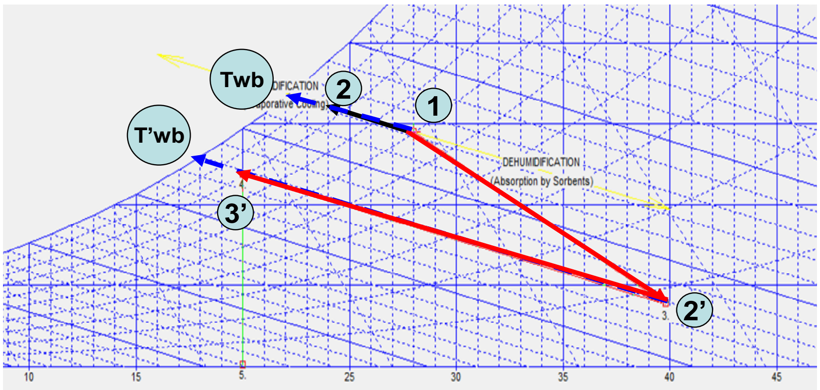
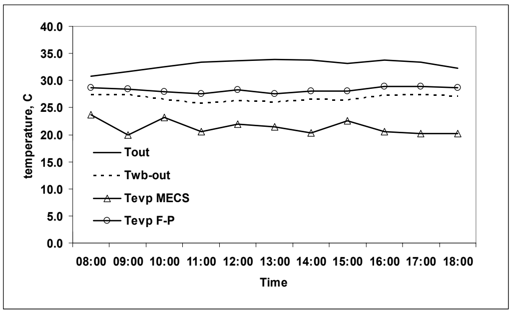
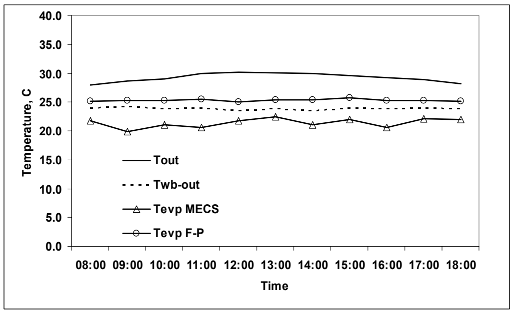


Fig. 9. The cooling processes of both evaporative cooling systems

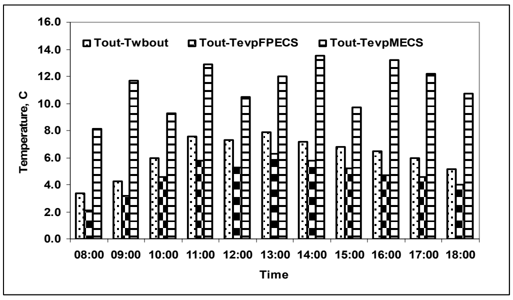


a- ESVHH

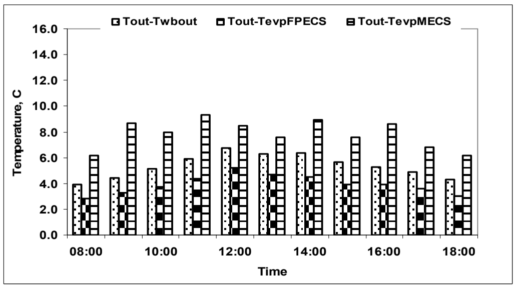


b- HSHH

1- The outside dry, wet-bulb temperatures, and the temperatures of air just leaving the cooling pad of both evaporative cooling systems



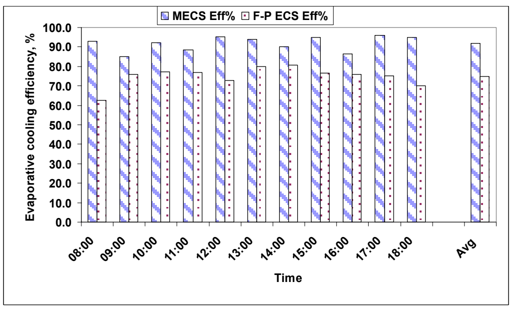
c- ESVHH



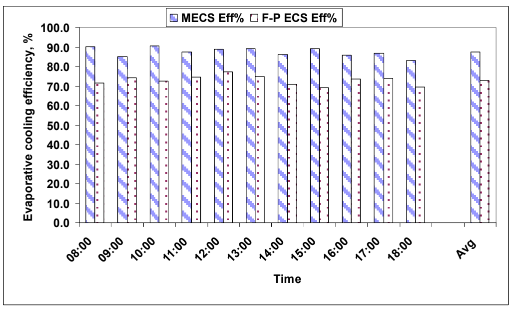
d- HSHH

2- The maximum available drop in the temperatures against the actual gained by the two evaporative cooling systems

Fig. 10. The cooling effect of both FPECS and MECS compared with the wet-bulb depression

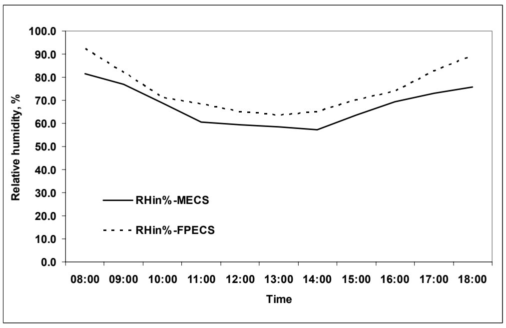


a- ESVHH

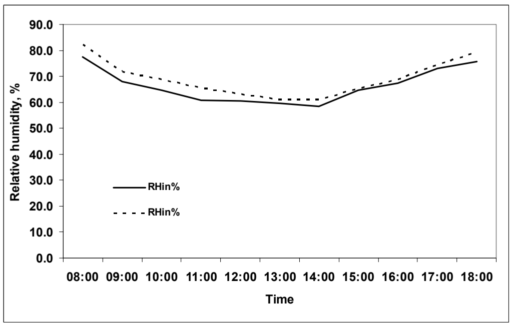


b- HSHH

Fig. 11. The efficiency of both evaporative cooling systems



a- ESVHH



b- HSHH

Fig. 12.The indoor air relative humidities in both greenhouses

The cooling effects of both FPECS and MECS were plotted with the wet-bulb depression of the outside ambient air in Fig. (10-2). The figure clearly proved that the cooling effect of FPECS was always lower than the wet-bulb depression of ambient air. On the other hand, the cooling effect of the MECS was estimated from the temperature of air after passing on the silica gel minus the temperature of air after the cooling pad. The results of the MECS showed that the cooling effect is greater than the wet-bulb depression of ambient air. Hence, the importance of interrupting the air stream by the silica gel sieve in the proposed MECS. A greater decrease in temperature of ambient air was achieved after passing on the silica gel sieve then passing on the cooling pad of the evaporative cooling, consequently, greater cooling effect was occurred. The averages of cooling effect were 11.25 and 7.85 ^{o}C for MECS whereas; they were 4.69 and 3.91 ^{o}C for FPECS in the ESVHH and HSHH days, respectively. These results were in line with Mehmet and Hasan (2015) they found that the hourly mean cooling effect for fan-pad system was 6.96 ºC.

1.7 Evaporative cooling efficiency

The efficiencies of both evaporative cooling systems in both days were demonstrated in Fig. (11). The figure showed the expected increase in MECS efficiency than the FPECS. The average efficiencies were 91.8 and 74.8 % for MECS and FPECS in ESVHH day, respectively while, they were 87.4 and 72.9 % in HSHH day. The MECS possess an increase by 19.94% and 22.6% over FPECS in ESVHH and HSHH days, respectively. Mehmet and Hasan (2015) reported that the hourly mean cooling efficiency for fan-pad system was found to be 76.8%. In addition, Abdellatif *et al.,* (2010) found that the daily average effectiveness of the fan-pad evaporative cooling system was 76.6%.

1.8 The indoor relative humidity in both greenhouses

The indoor relative humidity in both greenhouses is presented in Fig. (12). The relative humidities of FPECS greenhouse showed an increase in greenhouse indoor relative humidity than MECS greenhouse. The decrease in relative humidity of MECS greenhouse may be due to the dryness of air out of the silica gel sieve, when the air was already partially saturated as a humid region before passing through the FPECS cooling pad. Also, more wetting was occurred by the cooling pad. The average relative humidities were 67.7 and 74.9% for MECS and FPECS greenhouses, respectively and they were 66.4 and 69.3% for MECS and FPECS greenhouses in the ESVHH and HSHH days, respectively. The percentage increases were 10.72 and 4.35% in the relative humidities of FPECS greenhouse over MECS, respectively in ESVHH and HSHH days. It is often recommended that greenhouse relative humidity must be maintained in the range of 60% to 80% for healthy growth. At high levels of relative humidity, the risk for condensation on leaves is high (especially at night). Thus, the risk of Botrytis and other fungal diseases would increase Vox *et al.,* (2010). Several studies also (Argus, 2009) showed that, under evaporative cooling using fan-pad system, the air relative humidity at the critical period was ranged from 48.6 to 51.8% which was lower than the optimal level (65 %). Therefore, the air relative humidity must be raised to 65% at that period by increasing the water flow rate through the cooling pads.

1.9 The vapor pressure deficits (VPD) of the two greenhouses

Vapour Pressure Deficit, or VPD, is the difference between the amount of moisture in the air and how much moisture the air can hold when it is saturated. The ideal range for VPD in a greenhouse is from 0.45 to 1.25 kPa. The ideally sitting is at around 0.85 kPa. The danger level is VPD > 2.0 kPa, (Autogrow, 2012). The vapor pressure deficits of the two greenhouses as affected by the two evaporative cooling systems were illustrated in Table (3).

The obtained results of air vapor pressure deficit inside the two greenhouses revealed that the VPD was higher than the higher optimum level (VPD < 1.30 kPa) at and around noon.

Table 3. The indoor air temperatures, relative humidities and vapor pressure deficits of both greenhouses in both ESVHH and HSHH days

	ESVHH day						HSHH day					
	MECS greenhouse			FPECS greenhouse			MECS greenhouse			FPECS greenhouse		
Time	Tin °C	RHin%	VPD KPa	Tin °C	RHin %	VPD KPa	Tin °C	RHin %	VPD KPa	Tin °C	RHin %	VPD KPa
08:00	27.4	81.5	0.67	29.9	92.5	0.20	25.8	77.5	0.75	26.3	82.3	0.61
09:00	26.3	76.9	0.79	31.7	82.1	0.82	25.8	67.9	1.08	28.2	71.9	1.07
10:00	28.9	68.7	0.92	32.9	71.1	1.45	27.5	64.7	1.30	29.8	68.9	1.30
11:00	29.0	60.7	1.58	34.5	68.3	1.73	27.8	60.7	1.47	31.0	65.5	1.55
12:00	30.4	59.4	1.76	35.2	65.0	1.99	28.7	60.6	1.60	31.2	63.2	1.67
13:00	30.0	58.4	1.77	34.6	63.7	2.00	28.8	59.6	1.60	31.7	60.9	1.83
14:00	29.3	57.2	1.75	34.2	65.0	1.88	28.1	58.4	1.58	31.3	61.2	1.77
15:00	28.8	63.5	1.44	33.6	70.2	1.55	27.5	64.7	1.30	30.8	65.4	1.54
16:00	27.2	69.4	1.11	32.6	74.1	1.27	25.3	67.4	1.06	28.3	68.9	1.20
17:00	26.6	72.9	0.94	31.4	82.6	0.80	25.4	72.9	0.88	26.7	74.4	0.90
18:00	25.0	75.7	0.77	29.2	89.4	0.43	25.7	75.7	0.80	25.3	79.2	0.67
Avg	28.1	67.7	1.23	32.7	74.9	1.28	26.9	66.4	1.22	29.1	69.3	1.28
SD	1.71	8.37	0.44	1.98	10.15	0.63	1.35	6.61	0.32	2.28	7.08	0.43

Thus, the greenhouses climatic conditions should be kept underneath 1.30 kPa to avoid injury and death of plant. It is noticeable that MECS greenhouse achieved lower values of VPD than FPECS greenhouse at the same time. This is due to the interrupting of air stream by the silica gel sieve whereas the humid ambient air was dried then absorbed more moisture when it was passing through the cooling pad achieving more reduction in the air temperature just leaving the cool pad. Hence, more cooling effect was occurred. The higher values of VPD means that air had a higher capacity to hold moisture, stimulating water vapor transfer i.e more transpiration into the air whereas, lower VPD on contrary means the air was at or near saturation, so the air cannot accept moisture from plant leaf. The data in Table (3) indicated that the average and standard deviation of VPD were 1.23 and 1.28 KPa for MECS and FPECS in ESVHH day whereas, they were 1.22 and 1.28 KPa in HSHH day, respectively. The table also, showed that the dangerous value of VPD was 2.0 KPa which was achieved at 13:00 once only in ESVHH day by FPECS greenhouse. This results showed more decrease in the VPD values than those mentioned by Abdellarif *et al.,* (2010) who noted that protected cultivation of vegetable crops in Egypt during summer season were exposed to high humidity, massive intensity of solar radiation, air temperature and high vapour pressure deficit during that period. The hourly averages vapour pressure deficit inside the greenhouse equipped with fan-pad system were 1.53, 1.75, 1.83, and 1.53 kPa for April, May, June and July, respectively.

2. Effect of organic fertilizer applications and microclimate conditions on vegetative growth, chemical constituents, yield and fruit quality of tomato

2.1. Vegetative growth of tomato plant

Effect of organic fertilizer treatments and microclimate conditions on vegetative growth was illustrated in Table (4).

Data presented in Table (4) 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 un-significant in 2014 season. The results also, showed that plants fertilized with 30 m^3/fed from dried biogas residue gave the best vegetative growth characteristics; plant height, stem diameter, leaf area, fresh and dry weight per plant 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 weed seeds, 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) they found the superiority of biogas organic fertilizer on plant growth. Plant stems should be thick, about 1.25 cm at 15 cm down from the growing tip. Stems that are thicker indicate that growth is too vegetative, while stems that are thinner indicate too much stress.

High temperatures affect several physiological and biochemical processes dealing finally with yield reduction. Concerning the effect of greenhouse microclimate on vegetative growth, data in Table (4) showed that the plant length of FPECS greenhouse was significantly increased than that of MECS greenhouse in both 2104 and 2015 seasons. Whereas, the number of leaves per plant, dry weight and stem diameter of MECS greenhouse was significantly increased than FPECS greenhouse, whereas, there was no significant difference in 2014 season. Results displayed that the investigated characters such as; leaf area, the number of leaves per plant, dry weight fresh weight and stem diameter of MECS greenhouse was significantly increased than that of the other greenhouse in 2015 season.

2.2. Chemical composition of plant foliage.

Effect of organic fertilizer treatments and macroclimate conditions on N, P and K uptake was presented in Table (5).

Concerning the effect of organic fertilizer treatments on N, P and K uptake, data of plant leaves analysis showed that increasing the organic fertilizer quantity of dried biogas residue, (10, 20 and 30 m^3/fed) 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 than that of plants supplied with other organic applications or farm yard manure. Iron and manganese content was significantly increased by increasing the dose 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 (5) explained also, that nitrogen and phosphorus uptake was significantly affected by macroclimate variations in both greenhouses. On the other hand, no significant difference was observed with macroclimate variations on potassium uptake in both seasons. Iron content was significantly increased by increasing the dose of organic fertilizer in both seasons. While, the increase in manganese content was significant in 2014 season whereas, it was not significant in 2015 season.

2.3. Fruit physical characteristics.

Effect of organic fertilizer treatments and macroclimate conditions on quality of tomato fruits was showed in Table (6). Table (6) displayed 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 in both 2014 and 2015 seasons. On the other hand, that increase was not significant for length / diameter ratio character in both seasons.

The results in the same table also, confirmed that all studied characters were significantly increased by enhancing the cooling effect of MECS greenhouse than the other greenhouse. 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^{o}C.

2.4. Fruit chemical characteristics.

Effect of organic fertilizer treatments and macroclimate conditions on quality of tomato fruits in 2014 and 2015 seasons was presented in Table (7).

The illustrated results of fruit chemical characteristics exhibited that all the studied characters such as; ascorbic acid, acidity, total chlorophyll and dry matter were significantly increased by increasing the organic fertilizer rate in both seasons. On the other hand, total soluble solids increase was significant in the first season while, it was not significant in the second season.

The results also, illustrated that ascorbic acid, acidity, dry matter and total soluble solids was significantly enhanced by enhancing the macroclimate conditions inside the MECS greenhouse except for total chlorophyll that was not differed in both greenhouses in both 2014 and 2015 seasons.

2.5. Early and total fruit yield and its components.

Effect of organic fertilizer and macroclimate conditions on early and total fruit yield and yield components were demonstrated in Table (8).

The results demonstrated in Table (8) gave us an idea about the response of the yield and its components toward increasing the levels of organic fertilizer treatments. 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 dose in both 2014 and 2015 seasons.

Table 4. Effect of organic applications and macroclimate conditions on vegetative growth in 2014 and 2015 seasons

Treat.	Plant length (cm)	Leaf area (cm^2)	No of leaves/pl	Fresh weight (g)	Dry weight (g)	Stem diameter (cm)
	Season 2014					
OF30	347.8a	182a	95.0a	387.9a	92.67a	2.53a
OF20	328.0a	179ab	87.5a	384.3a	90.00a	2.38b
OF10	284.3b	1681c	79.5b	369.8b	80.00b	1.99c
FYM	302.0b	169bc	79.5b	376.0ab	89.17a	2.27b
$LSD_{0.05}$	25.2	10.1	7.8	n.s.	7.38	0.14
MECS	292.2b	177a	87.9a	383.4a	91.08a	2.44a
FPECS	338.9a	171a	81.7b	375.6a	84.83b	2.14b
$LSD_{0.05}$	17.8	n.s.	5.51	n.s.	5.22	0.099
	Season 2015					
OF30	370.7a	190a	93.0a	399a	94.72a	2.57a
OF20	351.2a	187ab	85.7ab	395a	92.00a	2.45ab
OF10	303.1b	175c	75.6c	379b	81.80b	2.11c
FYM	325.6b	179bc	78.4bc	387ab	89.32a	2.32ab
$LSD_{0.05}$	25.55	9.67	7.53	13.96	7.42	0.131
MECS	315.3b	187a	86.3a	395a	93.65a	2.52a
FPECS	359.9a	179b	80.0b	385b	85.27b	2.20b
$LSD_{0.05}$	18.1	6.84	5.32	9.87	5.25	0.093

Table 5. Effect of organic fertilizer applications and macroclimate conditions on NPK uptake in 2014 and 2015 seasons

OF	2014 season					2015 season				
	N%	P%	K	Fe	Mn	N%	P%	K	Fe	Mn
OF30	3.76	0.55	5.71	331.8	38.83	3.85	0.541	5.46	315	41.12
OF20	3.71	0.50	5.58	311.7	34.33	3.81	0.489	5.33	297	36.64
OF10	3.66	0.44	5.36	291.7	30.50	3.75	0.425	5.12	277	32.30
FYM	3.68	0.46	5.42	289.8	30.83	3.77	0.450	5.22	280	32.79
$LSD_{0.05}$	0.087	0.055	0.113	10.44	1.99	0.127	0.052	0.092	8.93	2.23
MECS	3.77	0.51	5.55	312.5	35.83	3.84	0.497	5.30	310	36.45
FPECS	3.64	0.47	5.48	300.0	31.42	3.75	0.455	5.28	274	34.98
$LSD_{0.05}$	0.062	0.038	n.s.	7.38	1.41	0.089	0.037	n.s.	6.31	n.s.

Table 6. Effect of macroclimate conditions and organic fertilizer applications on quality of tomato fruits in 2014 and 2015 seasons

OF	2014 season				2015 season			
	fruit length (cm)	fruit diam. (cm)	L/D	Flesh thick. (cm)	fruit length (cm)	fruit diam. (cm)	L/D	Flesh thick. (cm)
OF30	6.48	7.06	0.918	0.72	6.58	7.21	0.921	0.73
OF20	6.22	6.77	0.918	0.67	6.32	6.87	0.920	0.68
OF10	5.55	6.01	0.922	0.57	5.67	6.17	0.925	0.58
FYM	5.78	6.28	0.920	0.59	5.88	6.39	0.923	0.61
$LSD_{0.05}$	0.315	0.34	n.s.	0.06	0.313	0.37	n.s.	0.063
MECS	6.44	6.93	0.929	0.70	6.52	7.09	0.927	0.71
FPECS	5.58	6.13	0.910	0.58	5.70	6.23	0.917	0.59
$LSD_{0.05}$	0.223	0.24	0.008	0.04	0.221	0.26	0.008	0.044

Table 7. Effect of organic fertilizer applications and macroclimate conditions on quality of tomato fruits in 2014 and 2015 seasons

OF	2014 season					2015 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 (%)
OF30	18.89	4.71	42.17	21.63	4.26	18.50	4.62	46.45	22.10	4.33
OF20	17.28	4.33	43.70	20.39	3.98	16.92	4.24	43.09	20.83	4.04
OF10	13.95	4.22	38.15	18.30	3.68	13.82	3.97	39.20	18.37	3.76
FYM	15.73	4.05	41.49	19.13	3.75	15.14	4.10	42.12	19.54	3.99
$LSD_{0.05}$	1.39	0.38	3.33	2.10	0.329	1.16	0.29	2.38	2.18	n.s.
MECS	17.59	4.62	41.46	21.22	4.13	17.36	4.50	43.45	21.65	4.31
FPECS	15.34	4.04	41.30	18.50	3.70	14.83	3.96	41.98	18.77	3.75
$LSD_{0.05}$	0.98	0.27	n.s.	1.49	0.232	0.82	0.21	n.s.	1.54	0.29

Table 8. Effect of organic fertilizer levels and macroclimate conditions on early, fruit yield and yield components in both greenhouses in both seasons

OF	2014 season					2015 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)
OF30	1.643	74.57	162.4	12.12	49.69	1.734	76.59	165	12.63	51.79
OF20	1.487	70.92	159.7	11.36	46.56	1.613	73.52	162	11.95	48.98
OF10	1.297	58.12	150.2	8.75	35.87	1.349	61.96	152	9.45	38.76
FYM	1.355	65.07	151.0	9.85	40.39	1.458	67.44	155	10.47	42.92
$LSD_{0.05}$	0.138	2.85	8.40	0.85	3.49	0.11	2.97	7.96	0.91	3.72
MECS	1.541	70.19	161.8	11.39	46.71	1.630	74.14	164	12.23	50.13
FPECS	1.350	64.14	149.8	9.64	39.54	1.447	65.62	152	10.02	41.10
$LSD_{0.05}$	0.097	2.01	5.94	0.60	2.47	0.08	2.1	5.63	0.64	2.63

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 21.28, 14.28, 14.60, 7.56, 23.03 and 23.03%, respectively for 30 m^3/fed dried biogas residue, while they were 9.72, 8.99, 5.77, 15.26 and 15.26% 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 4.31, 10.68, 0.51, 11.20 and 11.20% in 2014 season. Furthermore, the percentages increases in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan for 30 m^3/fed dried biogas residue over those of farm yard manure were 18.91, 13.57, 6.40, 20.65 and 20.65%, respectively, followed by 20 m^3/fed where they were 10.66, 9.02, 4.63, 14.13 and 14.13%. On the other hand, the percentages decrease in those characters for 10 m^3/fed lower than farm yard manure was 7.49, 8.13, 1.58, 9.69 and 9.69% in 2015 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.

The data also, indicated that all 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 MECS greenhouse in both seasons. The percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan were 14.14, 9.43, 7.96, 18.13 and 18.13%, respectively for MECS greenhouse over FPECS greenhouse in 2014 season, while they were 12.61, 12.99, 7.90, 21.97 and 21.97%, respectively in 2015 season. These results in line with that mentioned by Jones, (2007), that tomato yields are primarily affected by the climate conditions with highest yields belonging to greenhouse in which have moderate cool air temperature. Also, Hurd and Graves, (1985) reported that elevating the temperature often increases the fruit growth rate, but it has a greater effect in hastening maturity and, as a result, the final mean weight of tomato fruits is reduced.

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°C temperature at pre-flowering and flowering stages. Tomato grows under high temperature produced lower fruit yield (Ho 1996; Adams *et al,.* 2001). Lower fruit yield under high temperature is mainly due to limiting carbohydrate supply. The optimum fruit growth and development occur when night temperature is between 15 and 20°C and the day temperature at about 25°C (Kalloo 1985). Also, Nguyen *et al.,* (2015) stated that greenhouse coverage protects plants from adverse atmospheric agents and, together with suitable equipment, influences and ultimately modifies the crop microclimate, thus lengthening the market availability of the products, improving their quality and allowing higher yields. They mentioned that the applications of organic fertilizers enhanced the leaf area and average fruit weight and yield. High temperatures during the growing season have been reported to be detrimental to growth, reproductive development and yield of several crops (Hussain *et al.,* 2006 Singh *et al.,* 2007).

CONCLUSION

The obtained results revealed that, the average indoor air temperatures, relative humidity and vapor pressure deficit of the greenhouse of modified evaporative cooling system were lower than the greenhouse of fan-pad evaporative cooling system (control). At noon, the maximum greenhouse temperatures decreased below the outside temperature by 2.2 °C for modified evaporative cooling system while, it increased by 1.6 °C for fan-pad evaporative cooling system whereas, outside air temperature, relative humidity and solar radiation intensity were 30.2 °C, 56.7% and 925 W/m^2 respectively, the maximum indoor temperatures of the greenhouses were 42.2, 28.8 and 31.7 °C for un-cooled, modified evaporative cooling system and fan-pad evaporative cooling system greenhouses, respectively.

Result of this work also, showed that the application of 30 m^3/fed of dried biogas residue as organic fertilizer increased significantly 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 of 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. The percentages increase in early yield, number of fruit per plant, fruit weight, total yield per plant and total yield per feddan were 21.28, 14.28, 14.60, 7.56, 23.03 and 23.03%, respectively, for 30 m^3/fed dried biogas residue over farm yard manure, (20 m^3/fed) in 2014 season while, they were 18.91, 13.57, 6.40, 20.65 and 20.65%, respectively in 2015 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.

Abbreviations and Symbols:

Abbr.	**Description**
MECS	modified evaporative cooling system
FPECS	fan-pad evaporative cooling system
FYM	farm yard manure
OF	organic fertilizer
ESVHH Humid day	Emissive Solar radiation, Very Hot and
HSHH day	Highly Solar radiation, Hot and Humid
SR	solar radiation incident
T	Temperature
RH %	relative humidity percent
VPD	vapour pressure deficit
η or Eff.%	Efficiency

Subscript

out or o	outside ambient temperature
evp	Evaporative
wb	wet bulb
in	indoor temperature of the greenhouse
in NoVent	indoor temperature of greenhouse without ventilation

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الملخص العربي

تأثير استخدام التسميد العضوي ونظام تبريد تبخيري مطور على إنتاجية صوب الطماطم في المناطق الحارة الرطبة

جابر داهش محمد يوسف وسمير محمود صالح

في المناطق الساحلية والمناطق الحارة الرطبة مثل المناطق الاستوائية والمدارية وحوض البحر المتوسط، تعتبر الزراعة في الصوب الزراعية في موسم الصيف الحار والرطب مستحيلة حيث وجود درجة الحرارة العالية داخل الصوبة التي تسبب أجهاد وموت النباتات.

يهدف هذه البحث إلى دراسة تأثير نظامي تبريد تبخيري مختلفين بالإضافة ألي استخدام مخلفات مخمرات إنتاج البيوجاز المجففة كسماد عضوي على نمو وإنتاجية وجودة ثمار نباتات الطماطم داخل الصوب الزراعية. تم استخدام صوبتين متماثلتين من النوع الجمالوني متماثل الانحدار بمحطة بحوث البساتين بالصبحية-الإسكندرية لزراعة محصول الطماطم خلال موسمي صيف ٢٠١٤ و٢٠١٥. تم تجهيز كل صوبة بنظام تبريد تبخيري وتم عمل تطوير لإحداهما بإضافة مجفف صاب(سيليكا جل) (نظام تبريد تبخيري مطور) والصوبة الأخرى تم استخدام نظام تبريد الوسادة والمروحة (تبريد وسادة ومروحة) للمقارنة.

أظهرت النتائج أن متوسط درجة حرارة الصوبة الداخلية والرطوبة النسبية والانخفاض في الضغط البخاري للصوبة ذات التبريد التبخيري المطور كانت أقل من الصوبة ذات تبريد الوسادة والمروحة. كما كانت أعلى درجة حرارة لها عند الظهر أقل من درجة حرارة الجو الخارجي بمقدار ٢،٢ درجة مئوية بينما كانت لصوبة

التبريد الوسادة والمروحة أعلى بمقدار ١,٦ درجة مئويـة. كانت أعلى درجة حرارة ٤٢,٢ ٢٨,٨ و٣١,٧ °م لـصوبة غير مبردة وصوبة التبريد التبخيـري المطـور وصـوبة الوسادة والمروحة، على الترتيب. انخفضت درجة حـرارة بـ ٣,٢ و ١,٣ درجة مئوية لصوبة التبريد المطور عـن درجة حرارة الجو الخارجي في يومي مفرط شدة الإشعاع (<١٠٠٠ وات/م٢) وعالي شدة الإشـعاع (١٠٠٠> شـدة الأشعاع <٩٠٠ وات/م٢)، على الترتيب، بينمـا ارتفعـت درجة حرارة صوبة الوسادة والمروحة عن الجو الخارجي بـ ١,٦ و١,٦ درجة مئوية فـي نفـس اليـومين، علـى الترتيب.

وبالنسبة لتأثير مستويات التسميد المختلفـة (٣٠ و ٢٠ و١٠ م٣/فدان من سماد مخلفات مخمرات إنتاج البيوجـاز المجففة) وكذلك سماد الماشية بمعدل ٢٠ م٣/فـدان علـى إنتاجية ونمو محصول الطماطم. أظهرت النتـائج الزيـادة المعنوية في تحسن النمو الخضري متمثلا في ارتفاع النبات وعدد الأوراق وعدد الأفرع للنبات والوزن الجاف للأوراق والأفرع، وكذلك زيادة محتوى الثمار من العناصر الكبرى، والصغرى، مع زيـادة المحـصول لكـل نبـات وكـذلك المحصول الكلي، وأيضا تحسن صفات الجودة، ومحتواهـا من المـادة الـصلبة الذائبـة الكليـة (TSS)، وحـامض الأسكوربيك، وذلك بالمقارنة بالمعاملات السمادية الأخرى باستخدام ٣٠ م٣/فدان من مخلفات مخمرات إنتاج البيوجاز المجففة. كما أظهرت النتائج أن سماد الماشية تفوق علـى معدل ١٠ م٣/فدان من سماد مخلفـات مخمـرات إنتـاج البيوجاز المجففة ولكن بزيادة غير معنوية. كانـت نـسبة الزيادة في المحصول المبكر وعدد الثمار لكل نبات ووزن الثمرة والمحصول الكلى لكل نبات والمحصول الكلى للفدان ٢١,٢٨ و١٤,٢٨ و١٤,٦٠ و٧,٥٦ و٢٣,٠٣ و٢٣,٠٣% لسماد مخلفات مخمرات إنتاج البيوجـاز المجففـة بمعـدل ٣٠م٣/فدان عن سماد الماشية بمعـدل ٢٠ م٣/فـدان فـي موسم ٢٠١٤ بينما كانت نـسبة الزيـادة ١٨,١٩ و١٣,٥٧ و٦,٤٠ و٢٠,٦٥ و٢٠,٦٥% فـي موسـم ٢٠١٥ علـى الترتيب. ومن هنا يمكـن الاسـتنتاج أن التـسميد بـسماد مخلفات مخمرات إنتاج البيوجـاز المجفـف بمعـدل ٣٠ م٣/فدان سجل أفضل النتائج في النمو الخضري والإنتاجية وجودة ثمار الطماطم.