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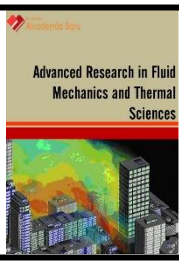

Study the Possibility of Using Solar Panels on the Rooftop of Plastic Greenhouse for Power Generation During Iraqi Climate

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ABSTRACT

The greenhouse environmental works can be controlled very well for higher production of agricultural crops and conserves energy during the same greenhouse land. The present study focused on examine the possibility of constructing PV panels on the roofs of greenhouse to work within Iraqi climate conditions. Basically, based on analysing the effects of different panel's arrangement patterns over the roof of the greenhouse on the agricultural crops, taking into consideration producing high crop production with high electrical energy. The study evaluated the climatic conditions inside the greenhouse where solar panels with different numbers and arrangements installed on the greenhouse roof. The experimental work based on describing the variation in the relative humidity, temperature and light intensity distribution within the greenhouse, also the effect of shade resulting from the arrangement of solar panels on eggplant yield in the Iraqi climatic conditions during winter in January, February and March 2019. The finding of this research shows that, the highest production in the third zone 6567 kW/year, which is contain 12 solar panels and has the best income, without significant impact on the agricultural production. The results also showed that the combination of PV modules and greenhouse reduced the sunbeam by 35% - 45% compared to the greenhouse without solar panels. In addition, the shading of solar panels reduced the greenhouse air temperature by up to (5-15°C). It has a negative effect in the cold climatic conditions and a positive effect in the hot climatic conditions, because it protects the plant from the risks of overheating, so can reduce water consumption by reducing the evaporation rate. While, the annual performance of the PV unit was designed and analysed by PV-syst 6.7.0 software for all zones of the greenhouse.

1. Introduction

Protected agriculture in the greenhouse has become a preferred way to avoid climate change, by providing relative humidity, temperature for air, luminance, water, the concentration of carbon

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dioxide in the greenhouse, environmental control systems work well and are required to achieve high production to conserve energy at the lowest possible cost. However, cooling and heating greenhouses are high cost factors in the greenhouse. Fossil fuel is often used to heat greenhouses, which increases the emission of carbon dioxide or used electric heater, which requires the high electricity consumption. In recent years, many studies have been conducted through the use of photovoltaic panels and their integration with the greenhouse by placing them on the roof of the greenhouse to protect the plants from the rise of solar radiation and temperature and the use of electricity to cover the need of the greenhouse, Photovoltaic systems can reduce the emission of CO_2. However, photovoltaic cannot be installed at high levels because it affects plants through internal shading from solar panels. Plant growth and production are affected by the intensity of light, as low light intensity leads to diseases and rot in plants [1]. A major achievement has been added to the field of agriculture through the use of green technology, because it enables agriculture in the off-season and increase crop production.

In the agricultural sector, renewable energy has been used, among which are; photovoltaic panels, wind turbines to produce electricity, or use of solar energy for the purpose of producing heat [2].

Many researchers have observed limited effects on crop yields and growth when solar panels are combined with a greenhouse at 20% of the total surface area [3]. Renewable energy sources have become a potential role, such as wind and solar energy, of increasing importance because they provide alternatives to fossil fuel energy, especially in relation to environmental safety and health, and at a lower cost [4-5]. This energy becomes increasingly used. Moreover, this energy was the most used and the most widespread in the world. Therefore, the use of photovoltaic energy in greenhouses is a major objective of sustainable greenhouse crop production [6]. In the last few years, many researchers and manufacturers have had the idea of using solar panels on the roof of the greenhouse by [7-14]. The panels can be in the production of electrical and thermal energy, adding that the reduction of the solar radiation falling on the greenhouse in the summer, which reduces the load of cooling, particularly in areas with high solar radiations [15]. However, Agricultural crops are adversely affected by shading from solar panels and also affect climate conditions within the greenhouse, to date, research on this subject is lacking and reflects mainly to the effects of PV panels according to the degree of shade in greenhouses and the positioning of these panels [16]. For instance [6]. A study on the effect of shade resulting from the distribution of two types of arrangement of solar panels on the roof of a greenhouse on the growth of onion was the first distribution arrangement of chess and the second straight-line and the shading ratio 12.9% of the roof area, Where the results showed that the electrical energy generated from the array PV for both arrangements is similar and that the distribution of solar radiation in the order of chess is more consistent than the order of straight-line [11]. Theoretical and experimental investigation of an integrated photovoltaic system on the greenhouse roof have been investigated in the weather conditions of India, where the results indicated that the annual thermal recovery of the modules photovoltaic is 12.8kW/h. The annual net electric power is 716kW/h [3]. A study on the coverage of 10% of the roof area of a greenhouse with solar panels and its effect on the tomato crop. The results showed that the shading of the solar panel did not affect the price of the tomato crop, although there are some negative effects on the colour and size of the crop.

According to the literatures, there is None attempts to use the technology (solar panels installed on the greenhouse roof) was discussed in the Iraqi climate.

The main problem that motivates us to do this work is the continuous power outages in Iraq and the greenhouse remote from the source of the national electricity grid and the limited areas allocated to agriculture. In this research study, an investigation on the possibility of employing PV panels on the roofs of greenhouse within Iraqi conditions. This study, based on analysing the effects of different panel's patterns over the greenhouse on the agricultural crops looking for producing high crop production and high electrical energy.

2. Materials and Methods

2.1 Experimental Work and Crop Selection

The study was performed in Iraq - Baghdad in a greenhouse occupying an area (9*40 m) in Abu Grarib town, with a global location in (latitude 33.33°N and longitude 44.4°E) and the greenhouse orientation is on (East-West). The greenhouse under investigation was composed of an iron structure covered by polycarbonate (4 mm thickness and 80% light permeability). The ventilation inside the greenhouse is provided by DC fans. The electricity is supplied by the solar system and can be operated automatically by the control system through humidity and temperature. The ventilation holes and fan position on the south side of the wall and fans were installed in the middle of the wall, Fans are operated using temperature and humidity sensor (DH22), and an Arduino system used when the internal air temperature exceeded 30°C.

The fertilization system is equipped with a fertilizing pump (Groundwater) by drip irrigation. The experimental crop was Eggplant. Plants were grown on 15/1/2019 (spacing 0.5 m, distance between rows, 1.5 m for the plants). The greenhouse was divided into four zones, depending on the arrangement of the solar panels above the south roof of the greenhouse, where the first zone contained the order of the straight line with (8 solar panels) as shown in Figure 1 and Figure 2, As for the second zone adopted the vertical and horizontal line arrangement with (12 solar panels), as shown in Figure 3 and Figure 4. The third zone, has the arrangement of solar panels similar to the arrangement of chess as shown in Figure 5 and Figure 6, the fourth zone is called the control area, where it is without solar panels and used for comparison with the other zones as shown in Figure 7 and Figure 8.

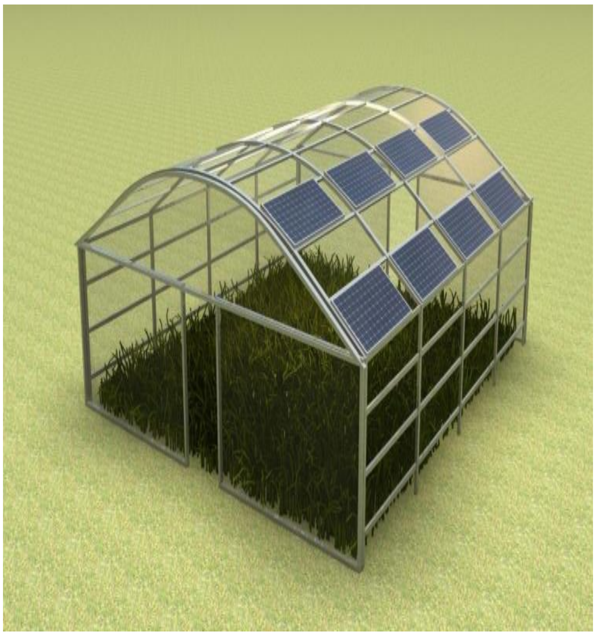

Fig. 1. The external appearance of zone 1

Fig. 2. The internal appearance of zone 1

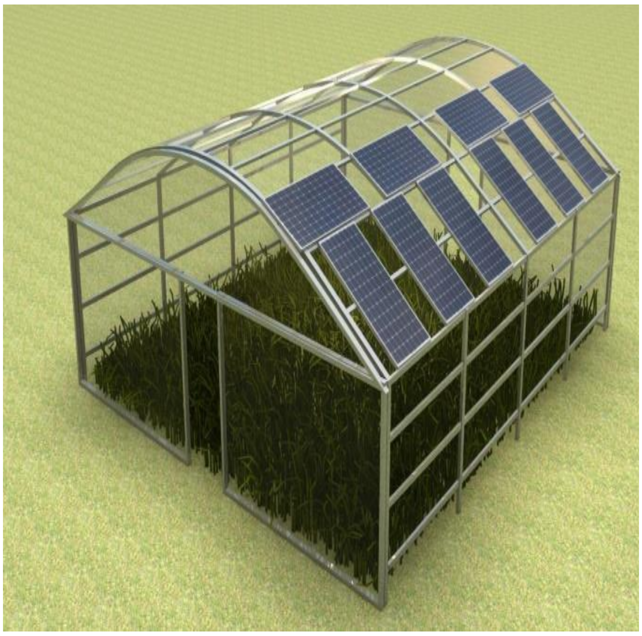

Fig. 3. The external appearance of zone 2

Fig. 4. The internal appearance of zone 2

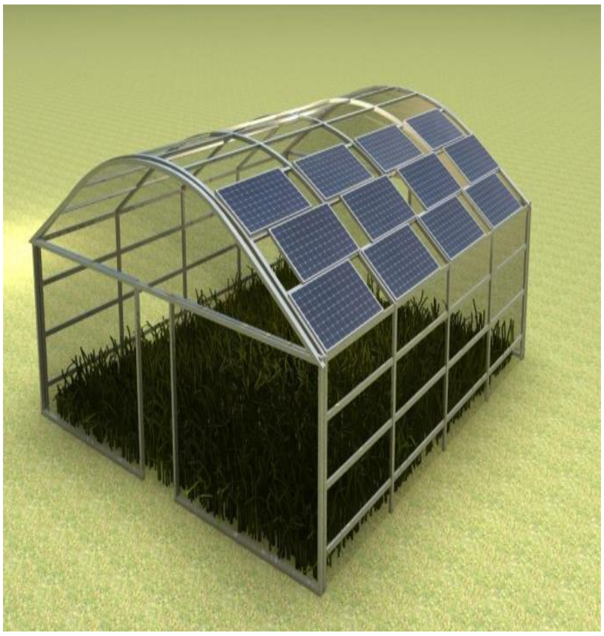

Fig. 5. The external appearance of zone 3

Fig. 6. The internal appearance of zone 3

Fig. 7. The external appearance of zone 4

Fig. 8. The internal appearance of zone 4

2.2 The Experimental Instrumentation Setup
2.2.1 PV panels

The PV panels used in this experiment solar panel (NO 8, 10 and 12) Depending on the zones divided into the greenhouse (1650 * 991 * 35 mm), the specifications are shown in Table 1.

Table 1
Characteristics of the photovoltaic panels

Name	Model type: mts 260 p-60
Solar cell type	156.75*156.75mm
Peak power	260 w
Voltage at maximum power	30.6 v
Current at maximum power	8.5a
Open circuit voltage	38.1v
Short circuit current	9.01a
Module weight	20 kg
Module efficiency	15%
Total number of cells	37 cells

2.2.2 Control charger

Control Charger type (max power point tracking) MPPT showing in Figure 9 was used to regulate the charging of batteries by converting the voltages out of the solar panels into a voltage suitable for battery charging using (13-12v), where the MPPT specification are listed in Table 2.

Table 2
The specifications of the Control Charger

Max input PV voltage	200 v
Max input current	30A/30A
Battery voltage	12/24/48V auto
Rating output current	40A/50A/60A opt
Rating input MPPT voltage	100V
DC output control	30A

Fig. 9. The Control Charger

2.2.3 Fans and control system of ventilation

The fan shown in Figure 10 utilized to change the internal air of the greenhouse once every minute, in order to avoid overheating inside the greenhouse, as well as to reduce the concentration of carbon dioxide, the air velocity was measured using an anemometer. The ventilation was provided through the sides of the greenhouses, depending on the solar panels for operating the ventilation fans (Fan (DC) 12 V, 5 A). A special system has been set up to operate the greenhouse fans automatically through using an electric energy process from the solar panels (PV) combined with an Arduino system based on sensing the temperature and humidity through different sensors distributed all around inside the greenhouse, when the outside limits are allowed. The fans operate automatically to provide suitable environmental conditions inside the greenhouse as the special control system is illustrated in Figure 11.

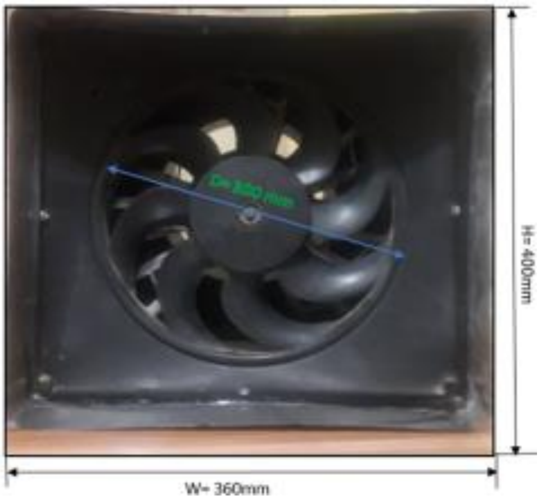

Fig. 10. The DC fan

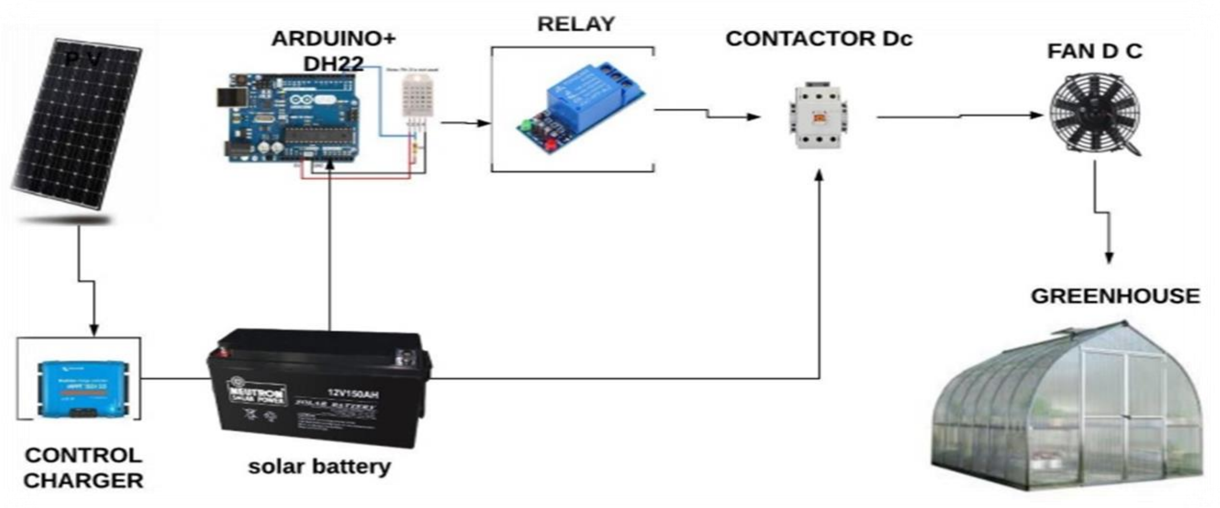

Fig. 11. Fans and control system of ventilation

2.2.4 Batteries

Energy storage is important in the PV systems because of the difference in solar radiation during daylight hours. Moreover, the difference in energy demand as well. It is known that solar cells do not generate energy at night, so it is important to store excess energy generated during the day for use at night or at high demand hours. Therefore, two of deep cycle batteries with capacity of 90Ah for each one is connected in parallel, so that to be used for storing energy generated by the solar panel during daylight hours. It is storing the excess energy which the user does not need and use that stored energy to provide power to personal use at night and also to the system components, the type of battery is shown in Figure 12.

Fig. 12. PV system battery

2.2.5 Solar water well pump

The utilized water pump in experimental work of the study selected as a type that can operates by the electricity generated by the solar panels installed on the roof of the greenhouse instead of the diesel fuel and also by the electrical power grid. This pump is considered as more economical, due to its low maintenance, operating costs and environmentally friendly reverse pumps with internal combustion engines. The water pump is shown in Figure 13 and its specifications are detailed in Table 3.

Table 3
Specifications for well solar water pump

Voltage	24 V
Head	40-60 M
Material	Submersible steel pump deep well solar
Power	400w
Max Flow	$3m^3/H$
Outlet	1.25"

Fig. 13. Well solar water pump

2.3 Experimental Measurements

The measuring instruments consist of air temperature and relative humidity and digital light sensor.

2.3.1 Air temperature and relative humidity

A measuring device with (NO-20) humidity and temperature probes (DH22) shown in Figure 14 connected to the Arduino mega card the probe is put in a cork cup to avoid direct sun array. The sensor can detect;

i. Humidity in the Range 0-100 % within 2-5% accuracy
ii. Temperature in the Range -40°C to 80°C with ±0.5°C accuracy

Fig. 14. The DH22 sensor

The distribution of the locations of the probes are shown in Figure 15.

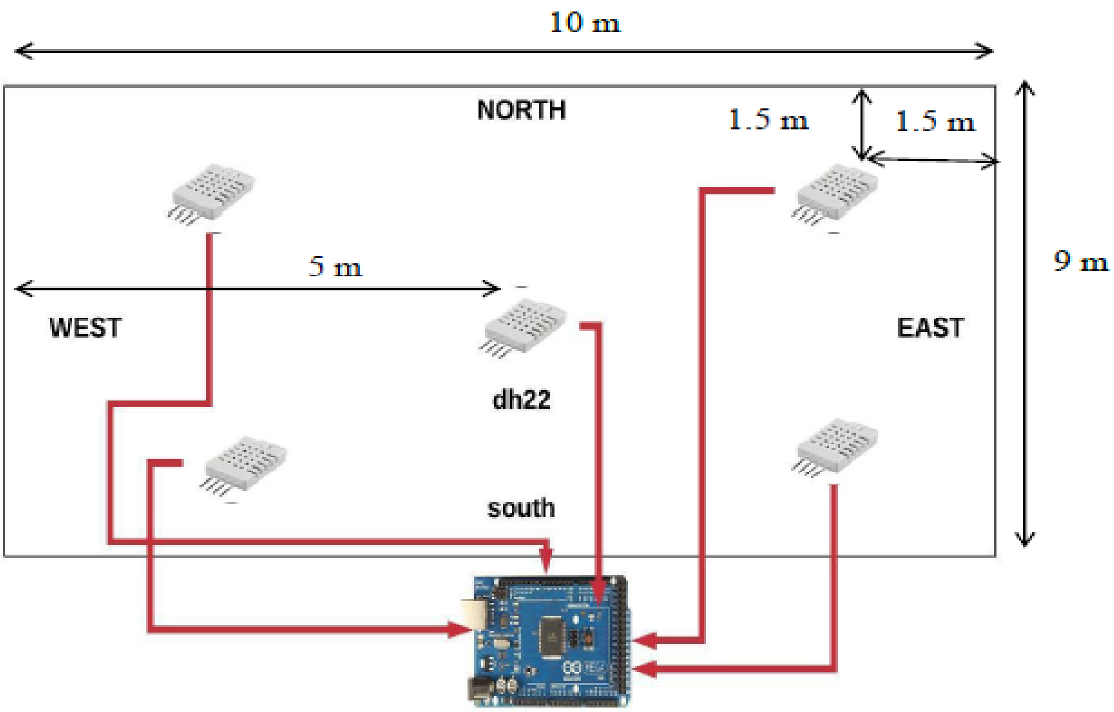

Fig. 15. Diagram showing the distribution of (DH 22) sensors within the greenhouse

2.3.2 BH1750 Digital Light Sensor (LUX)

To measure the intensity of illumination inside the greenhouse (NO 16) sensor light meter BH1750 FVI (Digital Light sensor lux meter was used. Measuring range of (0–65535 lux it measures IL luminance (lux), as the ratio between the luminous flux (Lumens), passing through a surface, and the surface area of the area considered (m^2). It was installed at a height of 2.5 m to avoid the shade produced by the plants and was distributed within the greenhouse as shown in Figure 16.

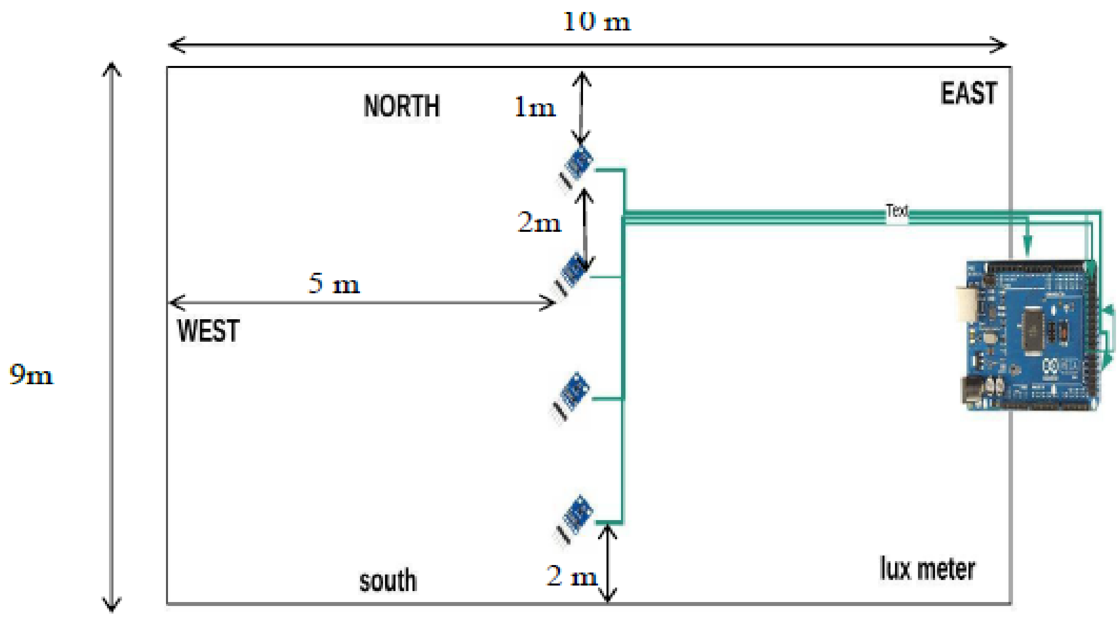

Fig. 16. A diagram showing the distribution of light sensors inside the greenhouse

3. Results and Discussion

The internal climate of greenhouses has a significant and effective influence on the crop production, especially the effect of air temperature.

3.1 The Effect of PV On Greenhouse Air Temperature

In Figure 17, it shows the installation of solar panels above the greenhouse for the purpose of producing electrical energy and agricultural production on the same agricultural area.

Fig. 17. The installation of solar panels on the greenhouse

It was found that, the highest air temperature surrounding the city of Baghdad during the period of readings was in March, while the lowest temperatures in January. To understand the internal conditions of the greenhouse that affected the presence of solar panels on the roof of the greenhouse, work was done to divide the greenhouse into four zones with different distribution types of solar panels on the south roof. The temperature was measured during the day for three months period, and plotted against time in winter days as in Figure 17 to Figure 19 respectively. It is clear that the greenhouse temperature was greater than the ambient temperature due to greenhouse phenomena.

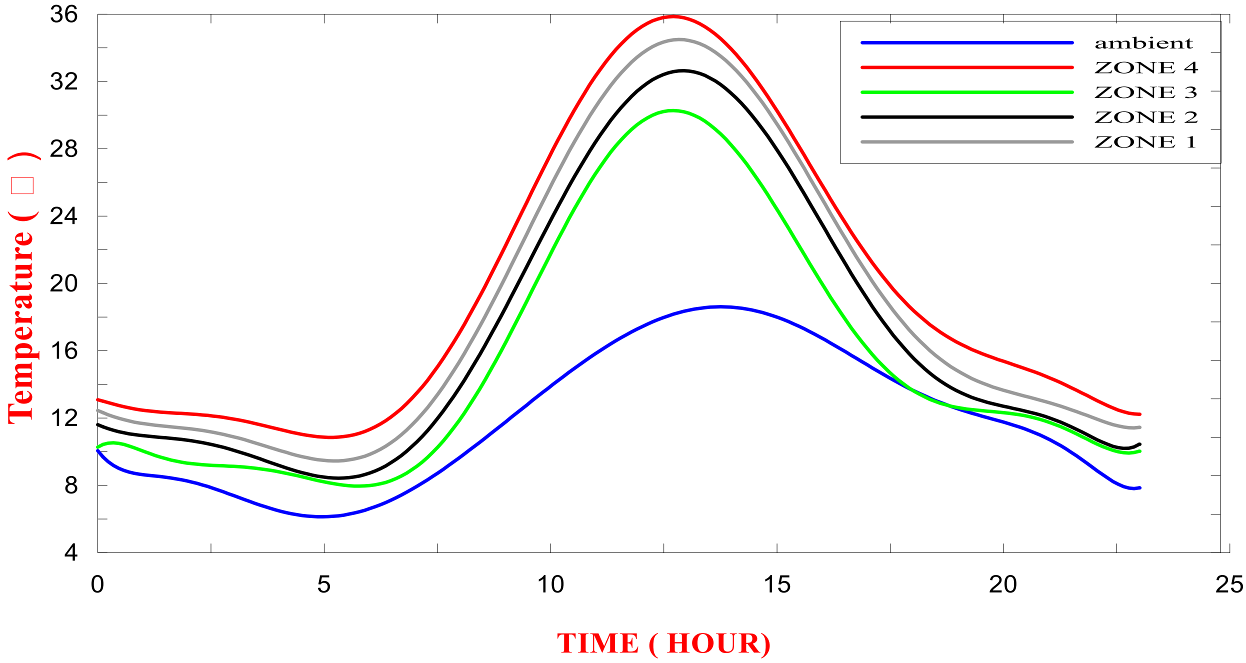

Fig. 18. Temperature variation of the inside air for different zones with ambient temperature per time during average day in January month/2019

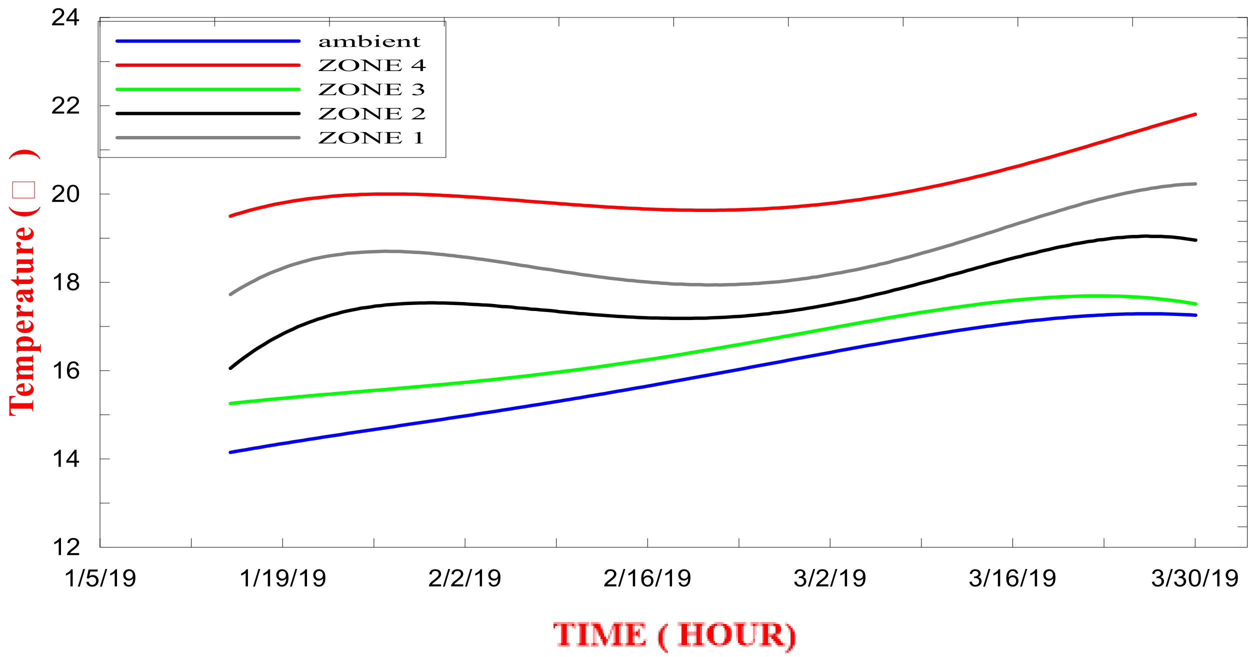

Fig. 19. Temperature inside the different greenhouse zones, and outside behavior with time for the average day from January to March

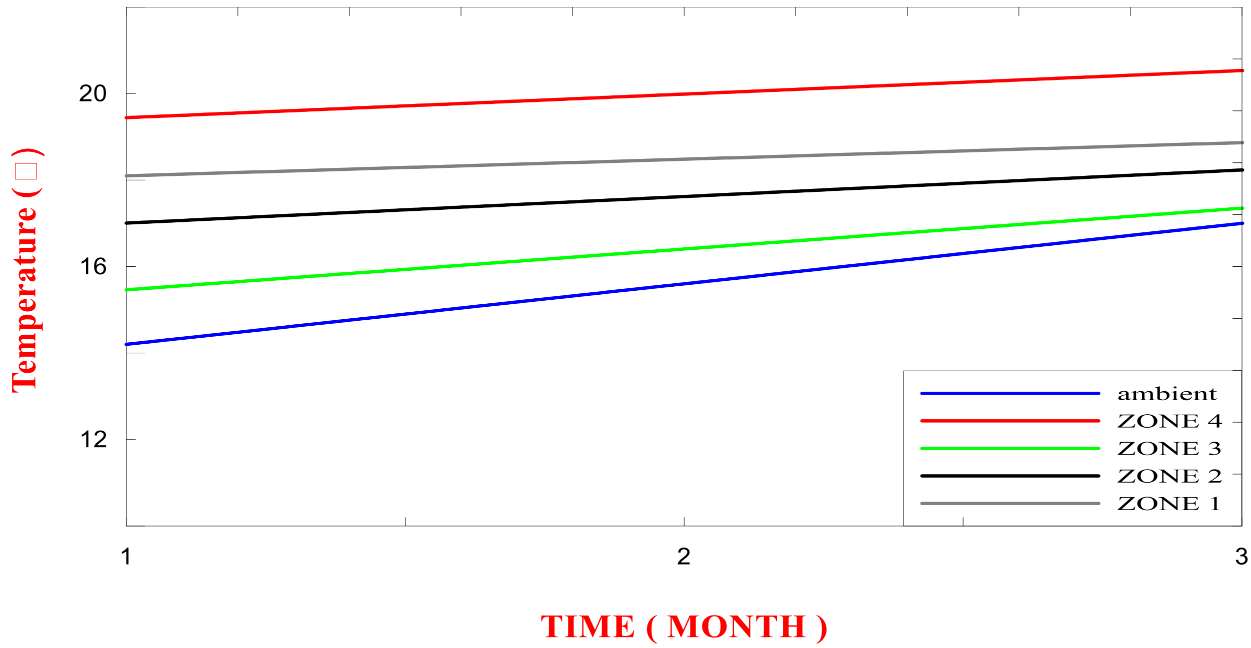

Fig. 20. Temperature distribution inside the different greenhouse zones, and outside during the average month from January to March/2019

From Figure 18 to Figure 20, it is noted that the temperature decreases when increasing the proportion of shading done by the solar panels, to reduce the proportion of solar radiation inside the greenhouse. It was also observed that the highest temperatures during the month of March in the afternoon, and may reached 40 degrees according to the proportion of shading, the lowest value of the temperature was in the month of January in the period before sunrise and may reached 5-6 Celsius may be even equal to the degree outside air temperature.

3.2 Effect of PV On the Greenhouse Relative Humidity of Air

Relative humidity has a direct and effective relationship with temperature, as low temperature leads to high relative humidity, means that the relationship was inversely between them. Earth's atmosphere contains water in the form of water vapor, ice crystals or precipitation. Relative humidity represents a percentage of water vapor in the air that changes when the air temperature changes. For example, a completely saturated parcel of air at constant pressure cannot hold any more water molecules, giving it a relative humidity of 100 percent. As air temperature increases, air can hold more water molecules, and its relative humidity decreases. When temperatures drop, relative humidity increases. High relative humidity of the air occurs when the air temperature approaches the dew point value. Temperature therefore directly relates to the amount of moisture the atmosphere can hold. The greenhouse relative humidity was greater than the ambient conditions due to the evaporation from the soil, crops and close space. Figure 21 to Figure 23 shown below, present a comparison between different solar panels arrangement zones and the outside air during different months where the experimental work has been done through this period. The percentage of moisture inside the greenhouse increased significantly in January, because of the low ambient temperature in addition to the watering plants continuously in the first month of agriculture. Also, it is noted that, the high relative humidity being at the highest level of crop growth in March, which causes an increase in the evaporation.

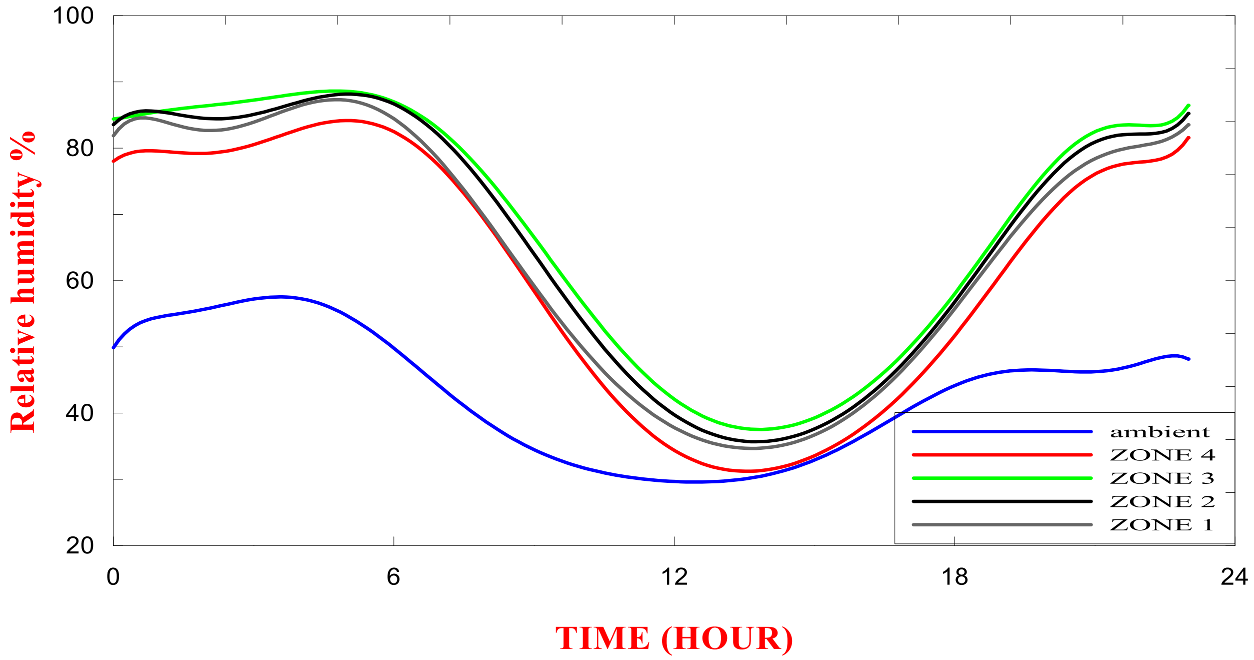

Fig. 21. The comparison for different zones of greenhouse and outside air relative humidity with time during the period of the clocks in January

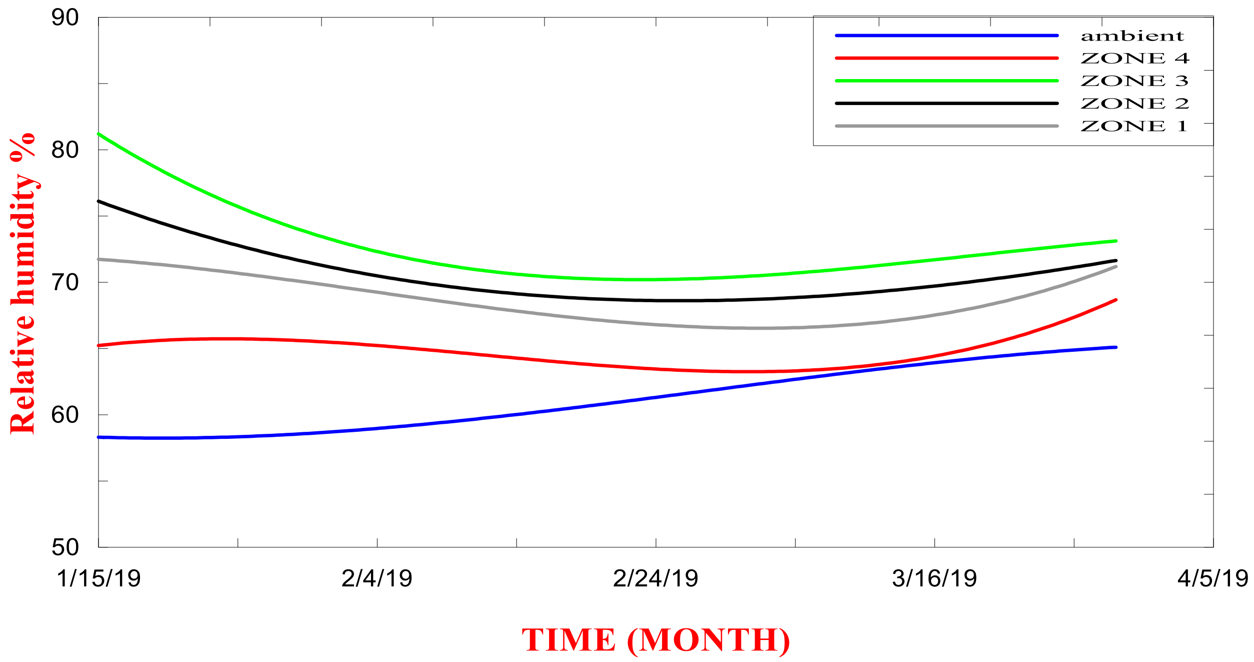

Fig. 22. The relative humidity inside different greenhouse zones, and outside during the average day from Jan to March/2019

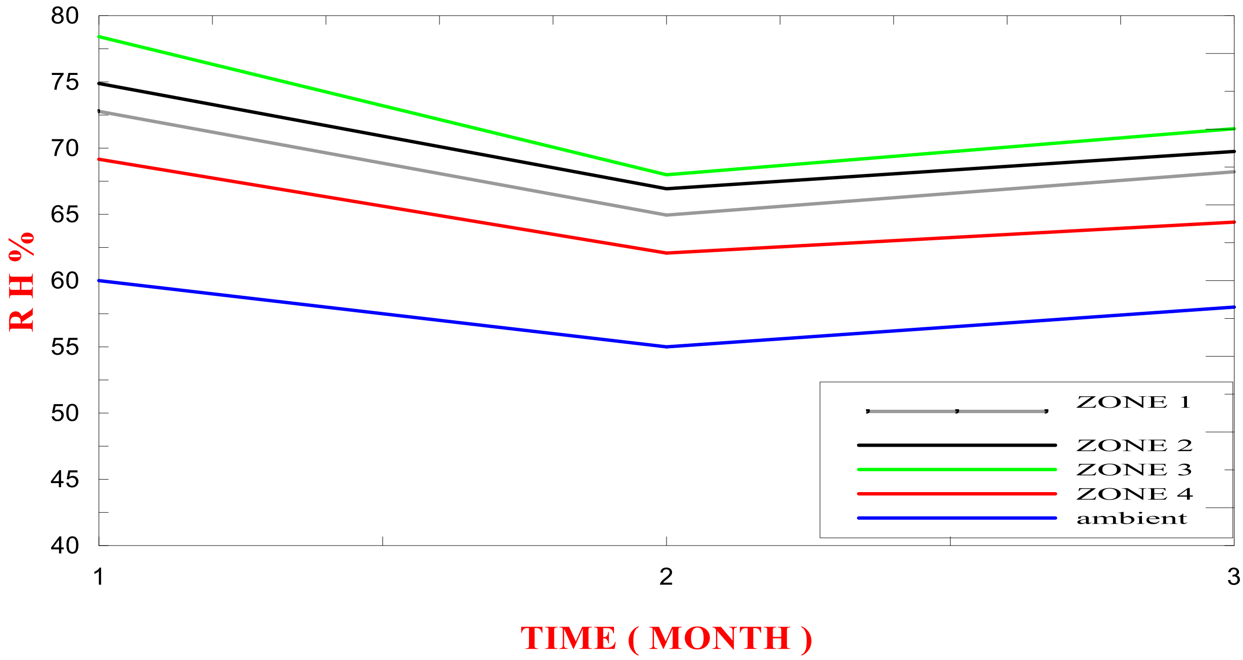

Fig. 23. The relative humidity inside different greenhouse zones, and outside during the average month from January to March/2019

3.3 The Effect of PV On the Intensity of Illumination Inside the Greenhouse

It was found that the intensity of the light under the cover of polycarbonate sheet and the presence of solar panels is low and decreases according to the number of solar panels installed on the roof of the polycarbonate sheet envelope only. Where the plant under the cover of polycarbonate sheet receives a higher amount of solar radiation compared to the covered zones by the solar panels. The results obtained for the intensity of light are shown in the Figure 25 to Figure 27. It is observed that the intensity of the illumination increases when the number of the distribution of solar panels on the roof of the greenhouse is reduced, in addition to the change in the angle of the sun from the greenhouse during all the period of the month as shown in Figure 24. It is noted that, the rate of greenhouse light increased in March because of the rise of the angle of the sun, Moreover, the increase of sunny days as shown in Figure 25 to Figure 27 represent the graphs of the recorded reading values of the intensity of illumination with time inside the greenhouse zones in (lux) units. During the 24 hours and the average days in the months of January, February and March, where the highest value of the intensity of lighting in zone 4, Where the light intensity readings were recorded using the BH1750 Digital Light Sensor (LUX) shown in Figure 16, which is recorded the highest reading inside the greenhouse at afternoon about (45000 lux) in March and the least in January about (38000 lux). The absence of the shading causes the value of lighting increases with a decrease in the number of panels installed on the roof of the greenhouse. Also, show that the lowest intensity recorded was in zone 3 due to the presence of high numbers of solar panels and the intensity of lighting about (28000 lux) in March and about (2200000 lux) in January.

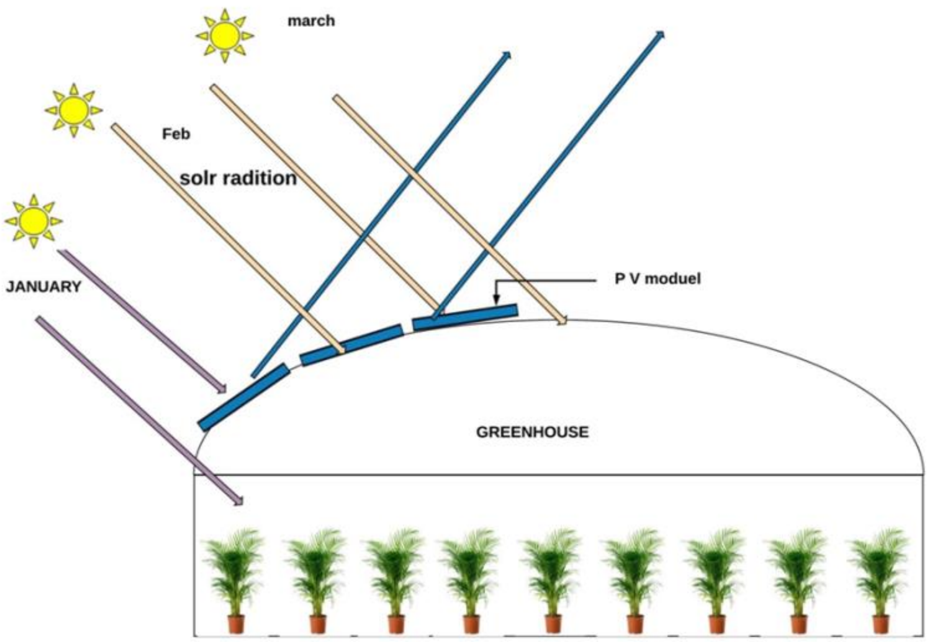

Fig. 24. Location of the sun during the months of the integrated greenhouse with solar panels

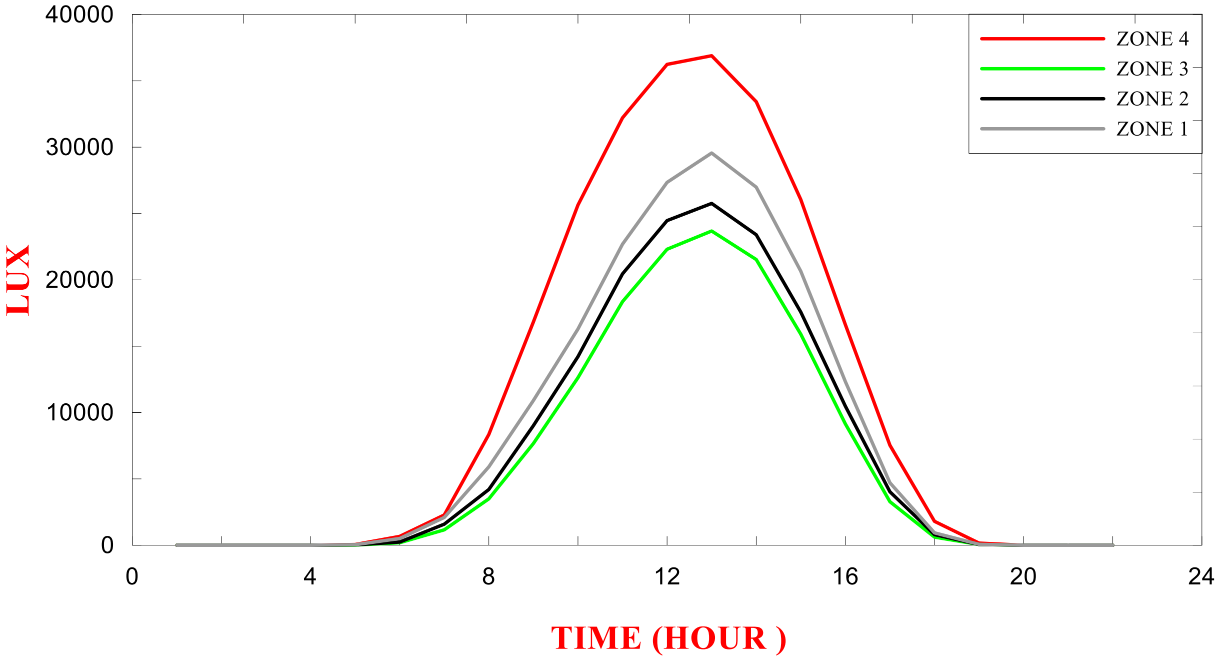

Fig. 25. The intensity of lighting for different zones of the greenhouse distribution with average hourly in January

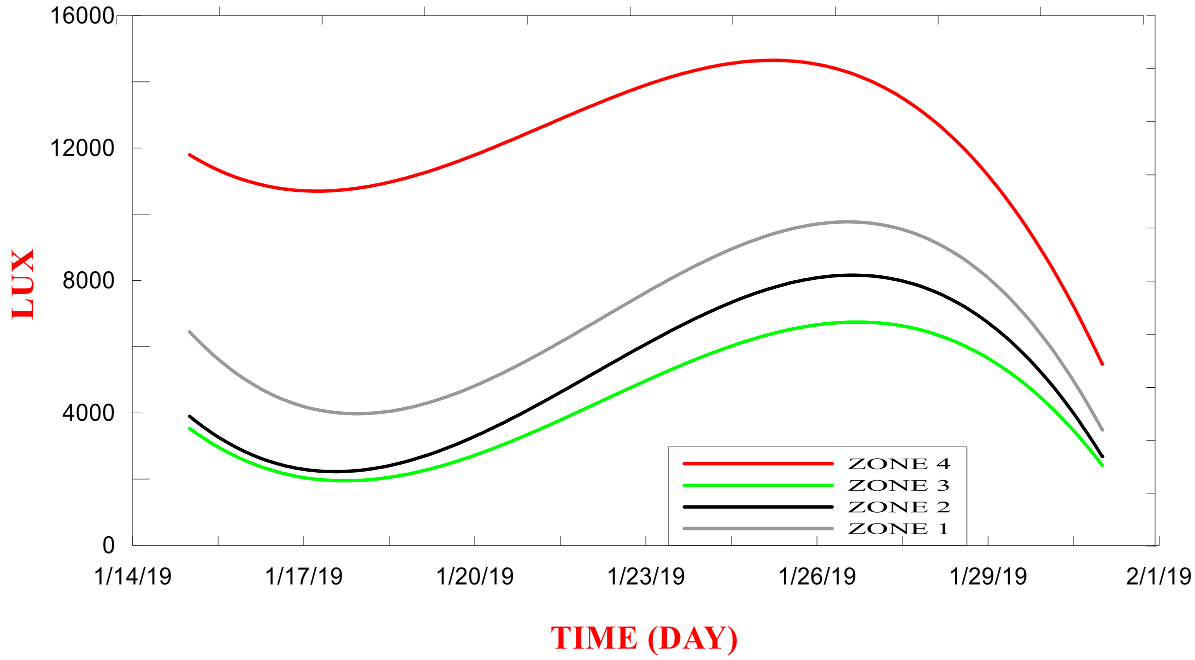

Fig. 26. The intensity of lighting for different zones of the greenhouse distribution with average days in January

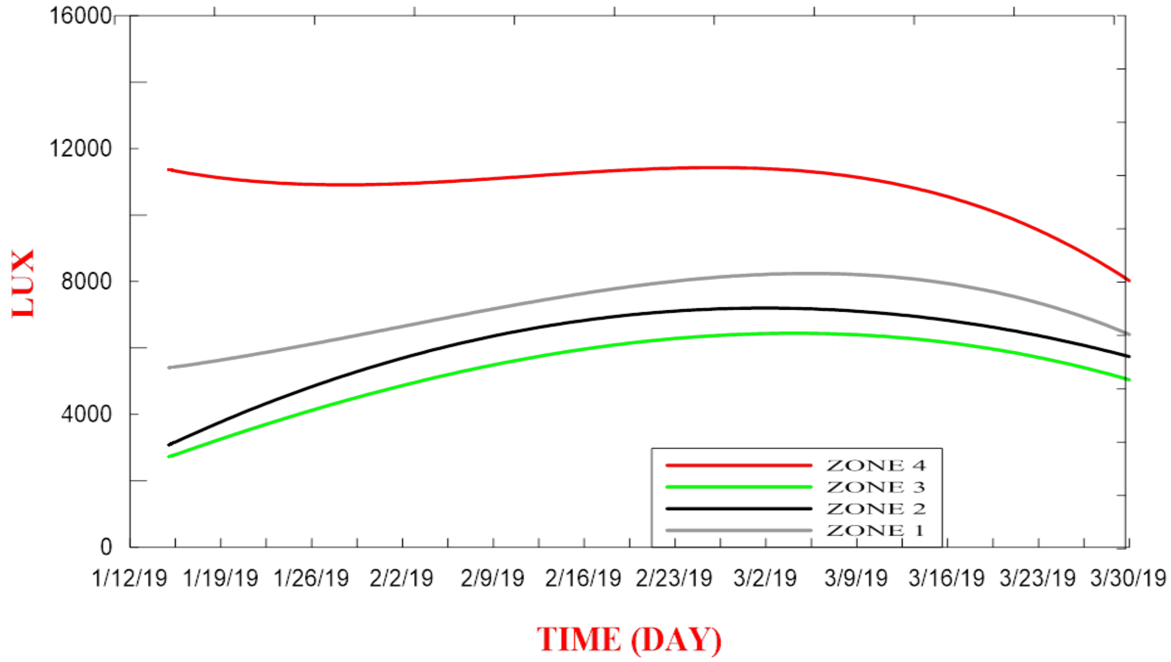

Fig. 27. The intensity of lighting for different zones of greenhouse for average days in the month of March

3.4 Effect of Climatic Conditions on Energy Production of The Photovoltaic System

The annual production of electrical energy produced by each zone is explained in the figures below. The simulation carried out using the program (PV-syst 6.7_pro 30) for the purpose of determining the electrical power output of the solar panels installed on the roof of the greenhouse. The nominal electricidal capacity of the zone 1 was 2080Wp as shown in Figure 27, zone 2 about (2600 Wp) as shown in Figure 28 and the nominal power capacity for zone 3 about (3120 Wp) as shown in Figure 29. In order to explain this process, it should be noted that the panels are installed on the rooftop of the greenhouse, so that, they were affected by the fluctuating of the climate during a day, then during months as the panels works and therefore, effects on the electrical energy production by the panels. Additionally, the arrangements of the panels in different ways on the top of the greenhouse (as they made by separating the greenhouse depending on the type of panels arrangements) could affect the inside climate condition of the greenhouse, so that, it's dependently affects the growth period of the crops. The simulation was based on the weather data for the city of Baghdad and taking from the program that is automatically associated with the PV-sys. 6.7_pro30). Where the amount of electricity increases in the summer months (June, July and August), while the lowest production of electric power from solar panels in December. Where the production of electrical energy for the first zone depending on the (PV-syst) program was about 3940 kWh/year, while, the second zone about 3903 kWh/year and the production of the third zone about 6567 kWh/year. The values of the electric energy produced from solar panels affected by the value of the solar radiation falling, in addition to the dust and temperature and other factors deal with the manufacturing of the solar panels. The electric power produced was used to meet the needs of the greenhouse of electric power to operate the fans, water pumps and control devices, while the surplus energy was exported to the national electricity grid as an additional source for income beneficiary. The third zone providing was the best in terms of electricity production and economically feasible compared to the other zones without a significant impact on agricultural production, Figure 31 shows the amount of solar radiation falling on the horizontal and the inclined surface of the greenhouse site according to the program (PV–syst). The value of global solar radiation was (5.4 kWh/m^2 day) and the value of solar radiation falling on an inclined surface (6.1 kWh/m^2 day).

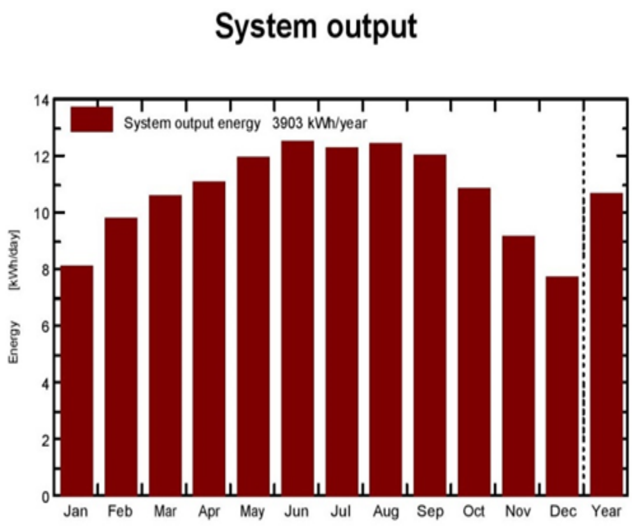

Fig. 28. The production of electrical energy in zone 1

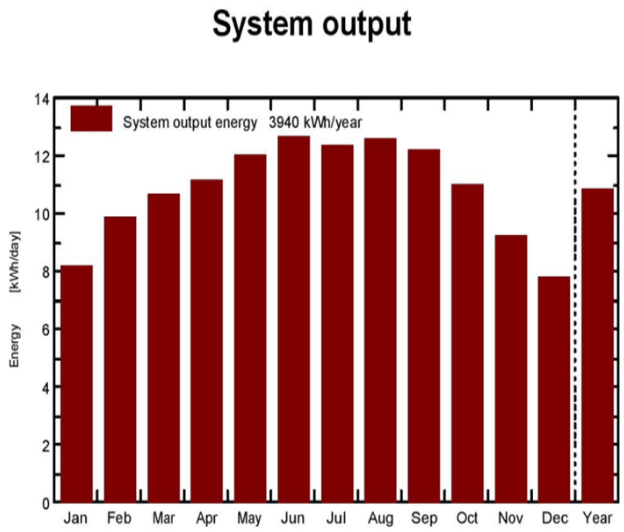

Fig. 29. The production of electrical energy in zone 2

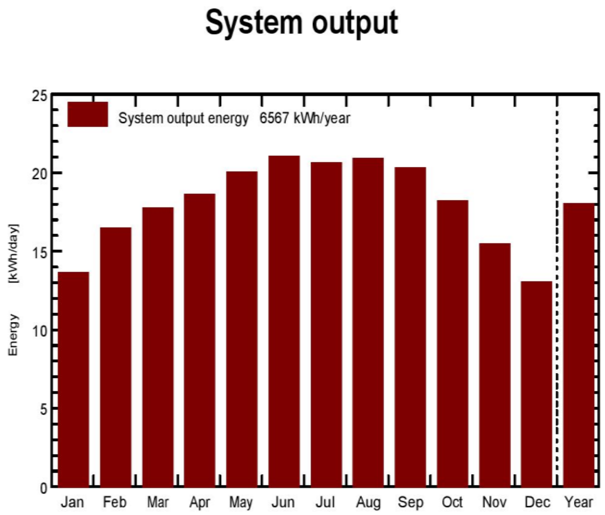

Fig. 30. The productivity of electrical in zone 3

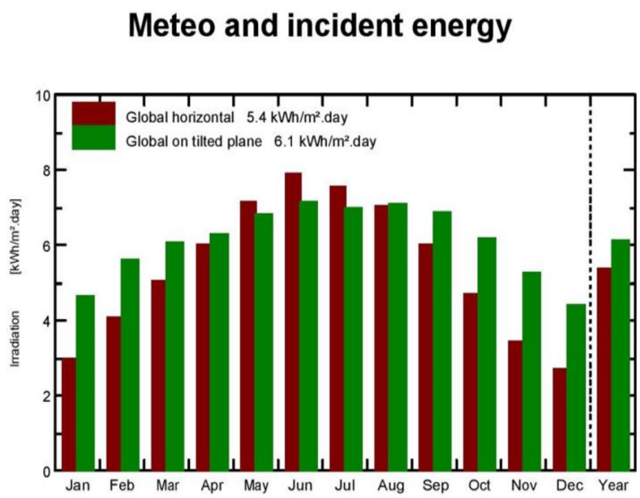

Fig. 31. Solar radiation falling on the horizontal and inclined

3.5 Agricultural Production of Greenhouse With PV

The presence of solar panels on the roof of the greenhouse did not greatly affect the agricultural production inside the greenhouse, although there are some negative effects, because of the increase in the number of solar panels, the long growth period of plants in zones containing high amount of shade, in addition to the height of the plant length and change the color of the plant to yellow, moreover the plant is infected with fungi due to high relative humidity and low temperatures, especially in the winter, either in spring and summer. The adding of solar panels are gaining through the protection of plants from a rise in temperatures and reduce the cooling load as a result of reducing the solar radiation passing inside the greenhouse.

The following is a comparison of the practical recorded data for the agricultural production of Eggplant, where the production data collected during the period (15/3/2019 to 15/4/2019), basically measured through the weight of the agricultural crop for each zone. Noted that the most valuable was the control zone (without solar panels) and agricultural production was reduced as the number of solar panels increases, as shown in Figure 32.

Has to be noticed that the plant growing period inside the greenhouse units was slightly warmer than usual for these months (January, February, March) and thus the PV shading provided a cooler environment, which resulted to less stressed conditions for the plant growing. In addition, the lower solar radiation in the PV covered greenhouse “pushed” the plants to increase their height and leave surfaces, in order to get more light for the photosynthesis. Similar results have been also obtained for eggplant cultivation under an arrangement of PV panels.

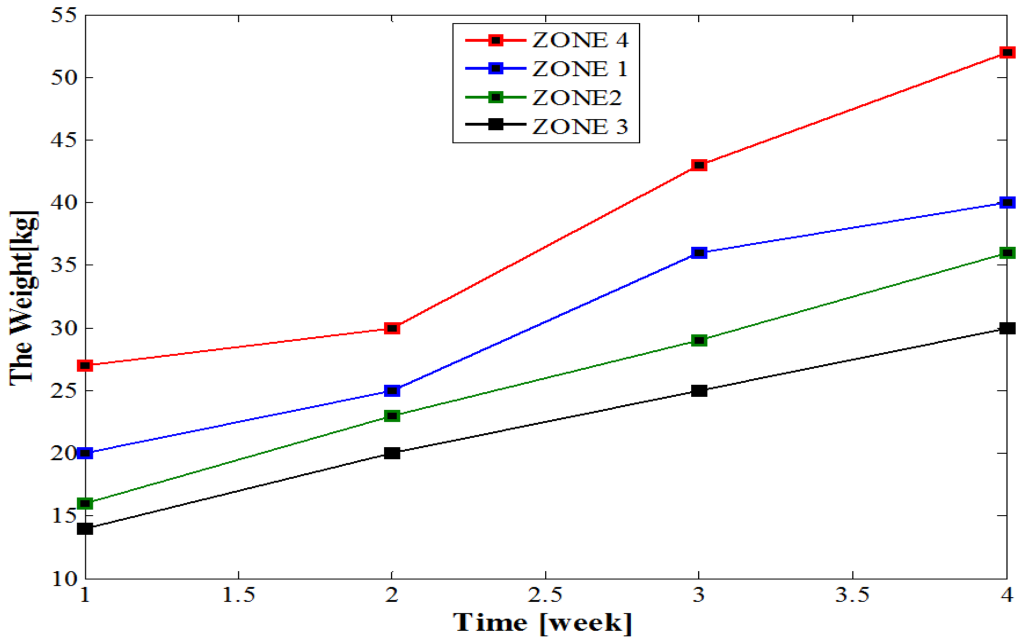

Fig. 32. The agricultural production of greenhouse areas for the period 15/3/2019 - 15/4/2019

4. Conclusions

In this work, solar panels in different arrangements were installed over the greenhouse looking for increase the income according to the electrical and agriculture productions at the same greenhouse land. The study examined for types of panels arrangement zones, which are

i. The first zone contains solar panels on the ceiling in straight line arrangement with the number of solar panels 8.
ii. The second zone contains vertical and horizontal order with 10 solar panels.
iii. The third zone was ranking similar to the order of chess and contains the highest number of solar panels 12.
iv. The fourth zone was called the control area does not contain any solar panels.

The study concluded that, the photovoltaic shading reduces the temperature by 5-10°C depending on how the solar panels are distributed over the greenhouse surface compared to the traditional greenhouse in the clear days. At the same time, it has an effect on increasing the relative humidity due to low temperatures. The incorporation of solar panels decreases the solar radiation by 15% in the first area, 25% in the second zone and 40% in the third region. The effect of the solar panels on the plant type (eggplant) and on the weight of the crop and late growth. The shading of the solar panels did not have a significant impact on agricultural production. Solar panels can provide 50% of the electric consumption of the greenhouse with reduction in the emission of CO_2, moreover, the rate of evaporation or water consumption, and also reduced the load on cooling in summer through reducing the temperature of air inside the greenhouse.

According to the results gained from the investigation, the utilizing of PV panels on the roofs of greenhouse was compatible for electricity production and agricultural crops in the conditions of Iraq climate and can highly cost benefits from the producing crop production and electrical energy at the same greenhouse land.

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