Experimental Study on Heating a Greenhouse Using Geothermal Energy in Ouargla, Southern Algeria

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Abstract

Plant damage and slow growth because of cold during winter are considered the main problems facing greenhouse farming in the Ouargla region, southern Algeria. The possibility of exploiting hot geothermal wells available in the region, from which water flows naturally and has a constant temperature, was considered as a direct and economical option to solve this problem. In this study we tested the use of a heat exchanger inside the greenhouse operating with hot geothermal water in three operating modes: operating one exchanger placed on the surface of the soil, operating one exchanger buried under the surface of the soil at a depth of 40 cm, and operating both exchangers together. We compared each situation with the normal situation in which no heat exchanger is used for heating. The results showed a significant improvement in the thermal climate inside the greenhouse in the three modes compared to the normal mode, with a clear preference for the mode of operation of the two heat exchangers together, as the air temperature improved by approximately 16 degrees Celsius and the soil temperature improved by 14 degrees Celsius. This study has clear importance in promoting the sustainable development of protected agriculture and the effective use of available natural resources.

Keywords: Greenhouse heating, geothermal energy, buried heat exchanger, thermal comfort, off-season production.

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Introduction

Agricultural greenhouses are used to provide appropriate climatic conditions for the growth and development of plants and to obtain production outside the season when prices are at their highest levels, which generates abundant profits for farmers. However, it faces the problem of low internal temperature on cold winter nights when the surrounding external temperature drop. This decline affects plant growth and production, both quantitatively and qualitatively, and incurs huge financial losses on farmers. This is because greenhouses rely, in their operating principle, on absorbing the sun's heat during the day and trapping it inside so that plants can benefit from it during the night. However, due to the low outside temperature and the long nights in winter, the thermal performance in these houses collapses a few hours after sunset, leading to physiological problems for the plant, including slow growth and sometimes even cessation of growth and damage to the roots. This is due to the importance and impact of temperature which affects plant growth[1], whether it is air or soil temperature[2].Heating is very necessary to avoid the collapse of the thermal performance of greenhouses and to promote plant growth [3]. Therefore, multiple heating methods were used, differing firstly according to the type of energy used and secondly according to the methods used for heating.First, regarding the choice of energy used for heating, many researchers have conducted studies on heating systems for protected houses, starting with the use of fossil energy for heating. The use of fossil energy is decreasing due to high financial costs and significant environmental risks, and it is gradually being replaced by renewable energy sources such as solar energy, biomass energy, and geothermal energy [4]. The use of solar energy as a heat source, for example, is widely popular among many farmers due to its efficiency in areas with high sunshine levels. Numerous studies have been conducted on it, such as the study by Joudi et al. [5], who used six solar panels with the dimensions (2.3 m × 0.6 m) above a sloped glass greenhouse with an area of (7.6 m^2). The solar panels heat the air and pump it into the greenhouse, and the results showed that when covering 45% of the surface area, the solar energy system can meet the heating needs. However, the thermal performance of solar heating systems is unstable due to intermittent sunshine, so they are often used in conjunction with thermal energy storage systems, such as water storage systems [6, 7], rock bed storage systems [8, 9, 10], and phase change material storage systems [11, 12]. Kool et al. (2015) studied the effect of the night closure on the insulated greenhouse using a solar air heater with latent heat storage. They showed that the nighttime temperature inside the greenhouse equipped with solar air heating and latent heat storage system was maintained up to 15 degrees Celsius while the outside temperature dropped to 8 degrees Celsius [13]. Bouadila et al. (2014b) conducted a comparative experimental study between two greenhouses and examined the thermal performance of a solar air heater system with latent heat storage during the daytime and the release of stored heat at night. The results showed that the recovered heat at night for the solar system amounted to 31% of the total heating needs [14]. These storage systems can enhance the thermal performance stability of solar heating systems to a certain extent, but they undoubtedly increase investment costs and complicate maintenance management [15].As for the use of biomass, despite its clear advantages in thermal performance stability and lower investment costs, it is relatively environmentally polluting [15]. Additionally, it requires bioresources that are not available in all places, such as arid areas.Numerous studies have been conducted on the use of biomass energy, such as the study conducted by Chao and others [16]. They provided an economic analysis of a 7.5-hectare greenhouse heated by biomass boilers in Colombia. The Net Present Value (NPV) indicates that installing a biomass boiler to meet 40% of the annual heat demand is more economical than using a natural gas boiler to provide all the heat.

Zhang et al. [17]used a burning cave for heating a solar-powered greenhouse in northern China. The experiment showed that the heating effect of the system was higher than that of a solar greenhouse without heating facilities by 3 to 8 degrees Celsius annually.

Geothermal energy boasts thermal performance stability, environmental safety, continuity, and low cost compared to other renewable heating systems [18]. It is often used to heat greenhouses by extracting heat directly from the ground using heat exchangers operating with hot groundwater or using another heat transfer medium, such as treated water or air pumped into the exchanger, transferring heat from the ground to the greenhouse. This is known as a ground-source heat pump [19, 20, 21]. One of its positive aspects is its non-depletion and availability at all times and places. Many studies have been conducted on heating using geothermal energy, including Anifantis et al. 2016 [22], who studied the experimental heating of a greenhouse in Italy using a heat pump connected to a ground heat source.

The results of experimental measurements have shown the effectiveness of this method and its relationship to the thermal potential of the ground source. Al-Helal [23] studied the possibility of using geothermal energy for heating and cooling in arid regions.

The results indicated that the optimal depth for burying Earth–Air Heat Exchanger (EAHE) pipes is 3 meters, maintaining the ground temperature at 32 degrees Celsius in summer and 29 degrees Celsius in winter. It provides a maximum cooling/heating capacity of 1000/890 megajoules per cubic meter of air emitted from the greenhouse per day.

Chai et al. [24] conducted a systematic evaluation of the economic and environmental benefits of using a ground-source heat pump system for greenhouse heating in northern China (Beijing). The results showed a 41.9% reduction in carbon dioxide emissions compared to traditional coal-fired heating systems. Nem's et al. [25] conducted an economic analysis of a ground-source heat pump system for greenhouse heating in the Polish climate, showing a 62% cost savings compared to a coal-fired boiler heating system.

In addition to the importance of choosing a suitable heat source for greenhouse heating, the heating method is also crucial in providing an ideal thermal environment for plant growth inside the greenhouse. The traditional method, which only involves heating the greenhouse air, has evolved with scientific advancements to consider the physiological needs of plants, such as nutrient absorption from the soil and the impact of low temperatures on the root zone. Therefore, heating the soil inside the greenhouse, including heating the air through ground radiation, has gained more attention in research on plastic greenhouses. Zhang et al. [17] experimentally studied the effect of a soil heating system with hot water pipes. These buried pipes, 20 cm deep under the soil, raised the soil temperature to 20-23 degrees Celsius, which is 5 degrees Celsius higher than the soil temperature in an unheated greenhouse. The energy saving rate for the entire heating system was 46.14%.

Adaro et al. [26] studied the possibility of using a geothermal water source with a constant temperature estimated at 28 °C, flowing naturally, with the addition of a plastic curtain to reduce system heat loss in order to heat a greenhouse of a typical design of 105 m in the winter in a region of southern Argentina. He connected underground water pipes with a length of 60 m inside the greenhouse and manually controlled the operation from five in the evening until nine in the morning. The results showed an improvement in the temperature compared to external conditions, and the system's efficiency reached of 37.6%.

Bakos et al. [27] studied the possibility of using geothermal water with a constant temperature of 100 °C to heat a greenhouse in northern Greece. They used a heat exchanger that reduced the temperature by 20%. The results showed that the system could maintain an internal temperature of 20 degrees Celsius when the external temperature was 7 °C. When the external temperature dropped to 2 °C, it was possible to achieve an internal temperature of 15 °C.

The Ouargla region is located in the south-east of Algeria, between latitudes 31.57 and 31.59 north and longitudes 5.19 and 5.21 east [28]. It is rich in thermal energy resources, as it is located above an aquifer (CI) reservoir in Al-Bayan, and covers an area of 600,000 km. It is mainly exploited through widespread wells for domestic and agricultural purposes [29].

This research paper presents an experimental study to test the possibility of exploiting hot groundwater, which flows naturally from wells located on farms and has a constant temperature, to heat a plastic greenhouse during cold winter nights that characterize the climate of the region, by designing a heating system using two identical tubular heat exchangers made of Polyethylene. The first is buried 40 cm deep under the soil and the second is placed above the soil surface.

The aim of this experimental work is to test and evaluate the thermal performance of a traditional greenhouse and compare it with a greenhouse coupled with a designed heating system in the following situations: first, using a single heat exchanger above the soil, second, using a single heat exchanger buried in the soil, and third, using both exchangers together. We make simultaneous temperature measurements of the outside air, indoor air and soil inside the greenhouse in the two greenhouses and then collect, analyze and discuss the data.

2- Materials and Methods

-1. Experimental Greenhouses These are two identical greenhouses in terms of shape, dimensions, orientation, and materials. Both greenhouses are tunnel-shaped, with the same dimensions (length 8 m, width 3 m, height 2 m). Each greenhouse has a lightweight iron structure covered with a transparent plastic (polyethylene) cover, oriented longitudinally: north-south (Figure 01). No crops were planted in the greenhouses during the experiment.

Figure 01: the experimental greenhouse.

2-2. Heat Exchangers

The heat exchangers consist of two polyethylene tubes, each with a length of 80 m, a diameter of 40 mm, and a thickness of 1.6 mm. Each tube takes a helical shape with the same dimensions as the greenhouse (Figure 02). Each tube has one inlet and one outlet.

Figure 02: Experimentalheat exchangers (surface and buried).

2-3. Thermal Insulation

Polyester panels with a thickness of 10 cm were used as thermal insulation.

2-4. Temperature Measurement Devices

The portable measuring device HM-QX13 was used.

3- Experimental Setup and Methodology

3-1 Description of the experimental work

The experiment was conducted in an agricultural area in Elhadjira, Ouargla region, located in the southeast of Algeria (between latitudes 31.57 and 31.59 North and longitudes 5.19 and 5.21 East). The region has a dry desert climate characterized by very cold winter nights. The experiment was carried out over four nights randomly selected from the winter season of 2021: the first night on December 21, the second night on December 25, the third night on January 3, and the fourth night on January 7.

Two identical greenhouses were installed, one left without heating intervention representing the traditional greenhouse, and the other with a heating system installed by placing one heat exchanger above the soil surface and burying the other at a depth of 40 cm (Figure 03). A layer of polyester was placed under the buried heat exchanger to insulate it from the soil below. The sides of the greenhouse soil were insulated from the external soil in all four directions with polyester material (Figure 03).

The heat exchangers were connected to a source of hot groundwater that naturally flows from the artesian well with a constant temperature of 65°C and a constant flow. The operation was manually controlled by allowing the water to flow from the well through the tube heat exchanger. The operating time was during the night from 8:00 PM to 8:00 AM.

In this experiment, the portable measuring device HM-QX13 was used to monitor changes in soil temperature, indoor air temperature, and outdoor air temperature in both greenhouses simultaneously. Experimental data were recorded and manually processed once every 2 hours.

Locations for temperature measurement:

Outdoor air temperature: 1 m above ground surface.

Indoor air temperature: 1 m above ground surface.

Soil temperature: 0.15 m below the soil surface.

Temperature measurement period: Nighttime from 8:00 PM to 8:00 AM.

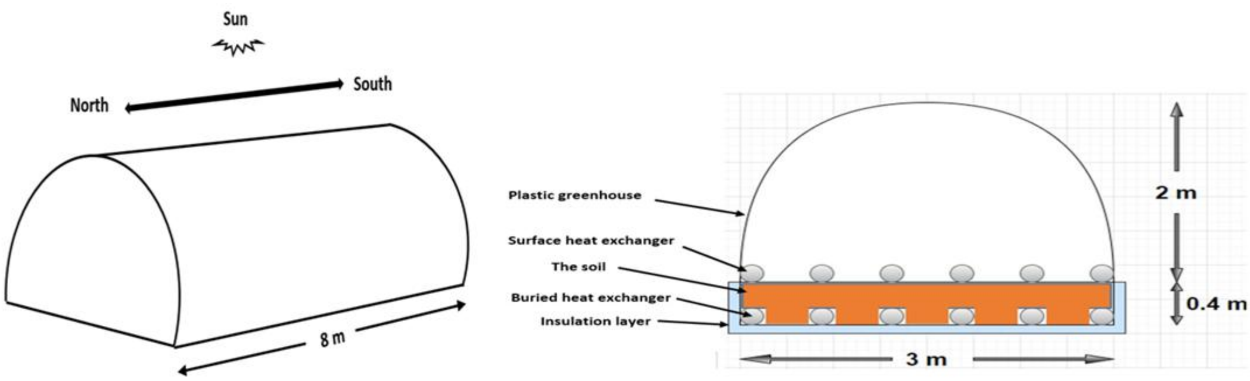

Figure 03: Illustration of experimental work.

3-2 .Experiment Steps:

On the first day of the experiment, we measured the outdoor air temperature, indoor air temperature, and soil temperature for the traditional plastic house to evaluate its thermal performance.

On the second day of the experiment, we operated the (water-air) heat exchanger placed on the soil surface alone and took simultaneous measurements for outdoor air temperature, indoor air temperature, and soil temperature in both the heated and unheated plastic houses for comparison.

On the third day of the experiment, we operated the (water-soil) heat exchanger buried under the soil surface alone and took simultaneous measurements for outdoor air temperature, indoor air temperature, and soil temperature in both the heated and unheated plastic houses for comparison.

On the fourth day of the experiment, we operated both heat exchangers together and took simultaneous measurements for outdoor air temperature, indoor air temperature, and soil temperature in both the heated and unheated plastic houses for comparison.

4 - Results and discussion

4-1 Evaluate the thermal performance of an unheated greenhouse on a typical winter day

Figure 04: shows the changes in the outside air temperature with time for the first day of the experiment, which represents a normal randomly selected winter day. We notice that the temperature during the entire day was below the minimum temperature for the plant's thermal comfort, as its maximum value reached 14.3°C during the day within the limits of It is two o'clock after midday, and this is due to solar radiation. The outside air temperature reached its lowest value during the end of the night and the beginning of the first hours of the day 1.5°C. This shows large differences in temperature between night and day in the dry desert climate, which highlights the need to use agricultural greenhouses in order to provide a suitable thermal climate for summer plants.

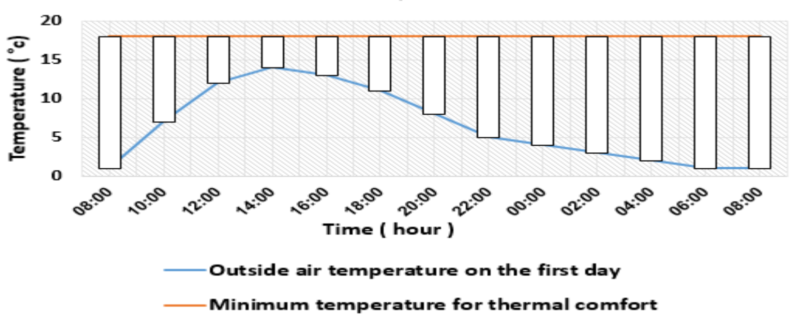

Figure4: The variations of the outside air temperature over time for the first day of the experiment

Figure 05: shows the temperature changes with time of the air inside the traditional unheated greenhouse for the first day of the experiment, where we notice that the temperature is above the minimum range of thermal comfort during daylight hours from ten in the morning until eight in the evening. This shows the positive effect of the plastic greenhouse in improving the thermal climate of the plant during the day, the highest temperature reached 25.1 °C as for at night. We notice that the temperature dropped to less than the minimum temperature for thermal comfort from ten o'clock at night until eight in the morning, which is the period in which the greenhouse needs to be heated, as the lowest temperature recorded is 2.3 °C.

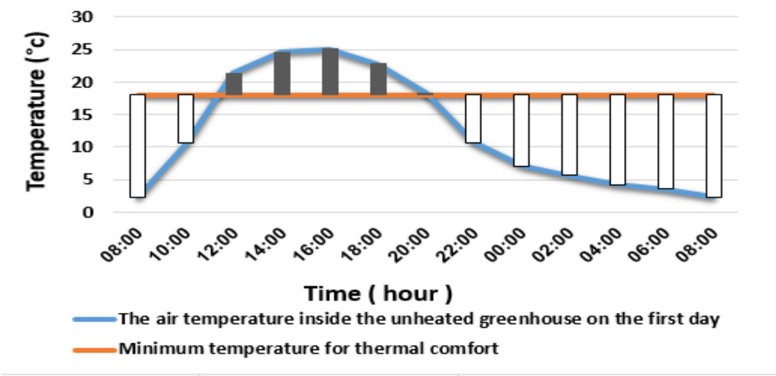

Figure.5: The variations of indoor air temperature over time for the first day of the experiment

Figure 06: shows the changes in soil temperature with time in the unheated greenhouse during the first day of the experiment, where we notice that there are temperatures during the day above the minimum thermal comfort limit for the plant. This shows the positive use of the plastic greenhouse in the study area, where the highest temperature value was recorded at 28.1 °C at four o'clock in the evening. As for the night hours, we notice that temperature fall below the minimum level of thermal comfort, which highlights the need for heating during this period. The lowest temperature value recorded is 5.2 °C.

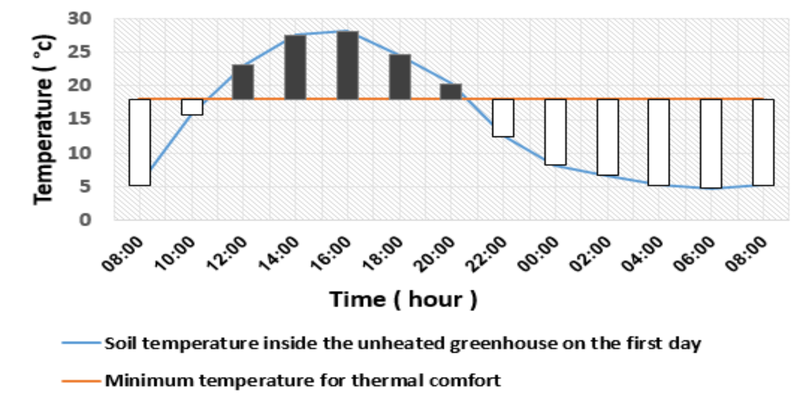

Figure.6: The variations of soil temperature over time for the first day of the experiment

4-2-Evaluating the thermal performance of a greenhouse heated by a heat exchanger (air-water) placed above the soil surface.

Figure 07: Shows the temperature changes of the outside air during the second day of the experiment. We notice that all the recorded temperature values are less than the minimum thermal comfort limit for the plant. Its highest value reached 17.1 °C at 2 o'clock in the afternoon, and the lowest value is 2.2 °C at the end of the night and the beginning of the da, which confirms the low temperature and their variation between night and day in the study area.

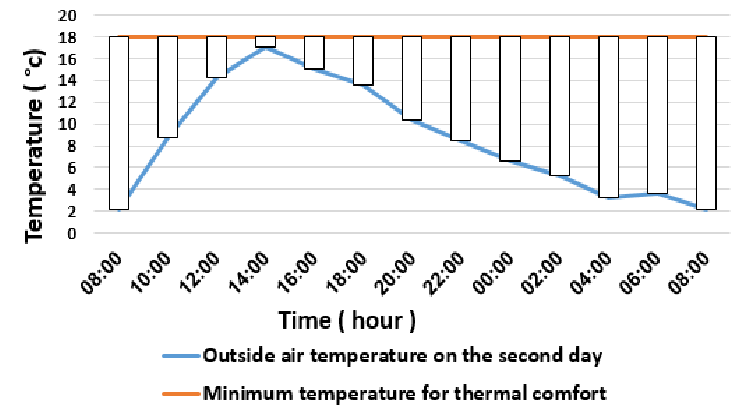

Figure.7: The variations of the outside air temperature over time for the second day of the experiment

Figure 08: Shows that the air temperatureinside the heated plastic greenhouseismuchhigherthanitscounterpart in the traditional plastic greenhouse, as the averagetemperatureduring the entire cold periodreached 22.3 °C, whichis 14.4 °C higherthan the average air temperatureinside the traditional plastic house. It also Shows that the indoor air temperatureduringheatingwashigherthan the lowerlimit of the plant's thermal comfort range for 70% of the time of the cold period, in contrast to the non-heating condition. This confirmsthat the geothermal water heating system using a heatexchanger on the soil surface isvery effective in heating the indoor air. This isexplainedphysically by the transfer of heatresultingfrom the flow of hot water inside the tube to the cold air surrounding the tube through convection currentsresultingfrom the change in air density due to heat, and alsothrough thermal radiation through the surface of the exchanger to the internal air, which leads to an increase in its temperature.

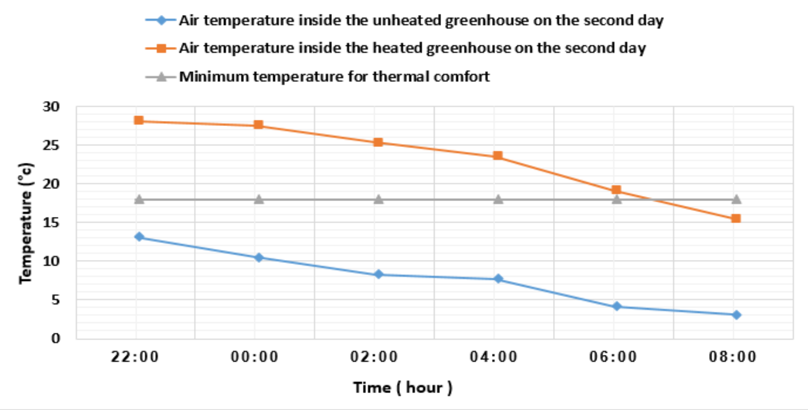

Figure.8: Comparison of indoor air temperatures between the heated greenhouse and the unheated greenhouse for the second day of the experiment.

Figure 09: Shows that the soil temperature inside the heated greenhouse is higher than its counterpart in the traditional greenhouse, as the average value of the soil temperature inside the heated greenhouse during the entire cold period was 18.1°C, while it reached 11.6°C in the traditional greenhouse, difference of 6.9 °c and it shows that the soil temperature in the heated greenhouse was higher than the minimum value of the plant's thermal comfort range for only half of the cold period.

This indicates that the heat exchanger heating system placed on the surface of the soil is insufficient to warm the soil for the entire cold period. This partial improvement is explained physically by the transfer of heat resulting from the flow of hot water inside the pipe to the soil in contact with it through thermal conduction resulting from the temperature difference, which leads to an increase in its temperature.

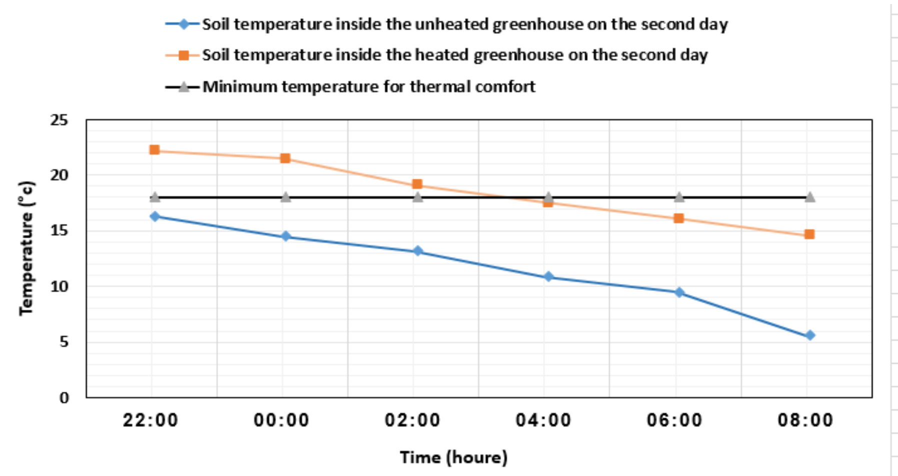

Figure.9: Comparison of soil temperatures between the heated greenhouse and the unheated greenhouse for the second day of the experiment

-4- Evaluation of the thermal performance of a greenhouse heated by a heat exchanger (water-soil) buried under the soil surface.

Figure 10: Shows the changes in outside air temperature for the third day of the experiment. It shows the extent to which temperatures dropped during the night.

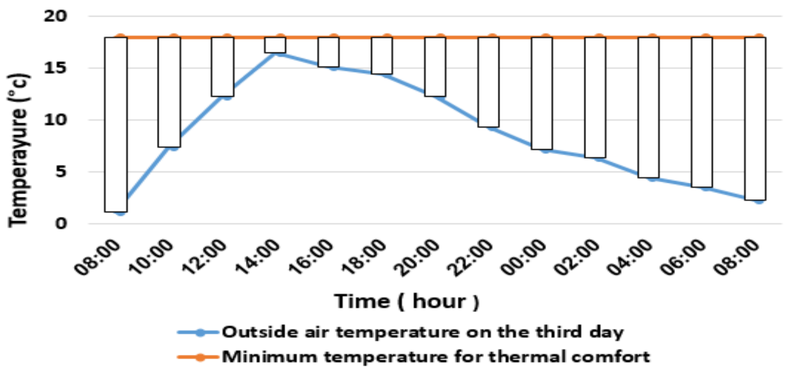

Figure.10: The variations of the outside air temperature over time for the third day of the experiment

Figure 11 Shows that the air temperature inside the heated plastic house is higher than its counterpart in the traditional plastic house, as the average value of the air temperature inside the heated plastic house during the entire cold period was 18.5 °C, while it reached 7.9 °C in the traditional plastic house, i.e. a difference of 10.6 °c. It shows that the air temperature in the heated greenhouse was higher than the minimum value of the plant's thermal comfort range until only three-thirty in the morning, and then dropped below the minimum value of the plant's thermal comfort range. This indicates that the heating system with the heat exchanger buried under the surface of the soil is insufficient to warm indoor air for the entire cold period. The physical explanation for the rise in indoor air temperature is the transfer of heat resulting from the flow of hot ground-water, from the surface of the exchanger to the soil in contact with it through thermal conduction and from the soil to the indoor air through convection and radiation.

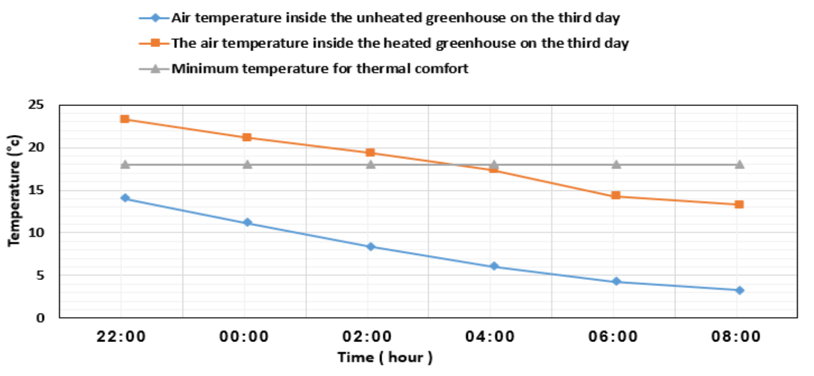

Figure.11: Comparison of indoor air temperatures between the heated greenhouse and the unheated greenhouse for the third day of the experiment

Figure 12shows that the temperature of the soil inside the heated greenhouse is much higher than its counterpart in the traditional greenhouse, as the average temperature during the entire cold period reached 21.6 °C, which is 12 °C higher than the average temperature of the soil inside the traditional greenhouse. It also shows that the soil temperature when heated was higher than the minimum range of thermal comfort for the plant during the entire cold period, but it was close to it at the end of the night, in contrast to the non-heating condition, where the soil temperature was low throughout the night. This confirms that the geothermal water heating system using a heat exchanger buried under the soil surface is effective in heating the soil. The physical explanation for the rise in soil temperature is due to the transfer of heat resulting from the flow of hot geothermal water entering the pipe, by the method of thermal conduction of the soil in contact with it due to the temperature difference between the pipe surface and the Soil surface.

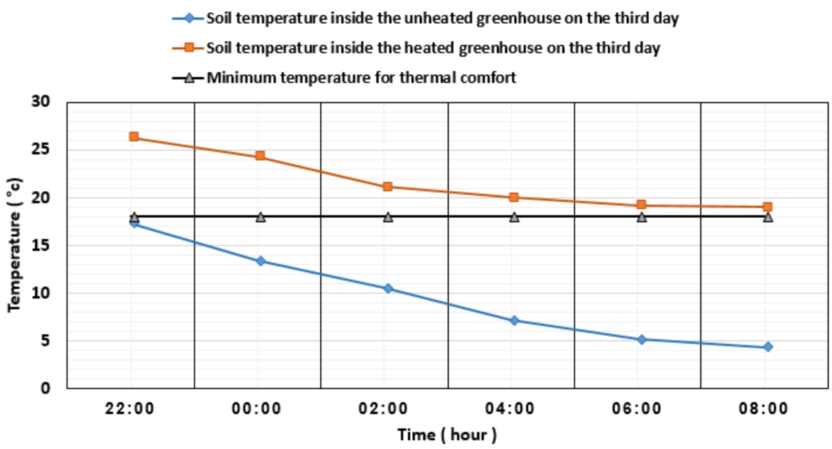

Figure.12: Comparison of soil temperatures between the heated greenhouse and the unheated greenhouse for the third day of the experiment

4-4- Evaluating the thermal performance of the heated greenhouse by combining the two heat exchangers (air-water) with the buried (water-ground) heat exchanger.

Figure 13 Shows the temperature changes of the outside air during the fourth day of the experiment. We notice that all the recorded temperature values are less than the minimum thermal comfort limit for the plant. Its highest value reached 15.6 °C at two o'clock in the afternoon, and the lowest value is 2.3 °C at eight in the morning, which is confirms the low temperatures and their variation between day and night in the study area.

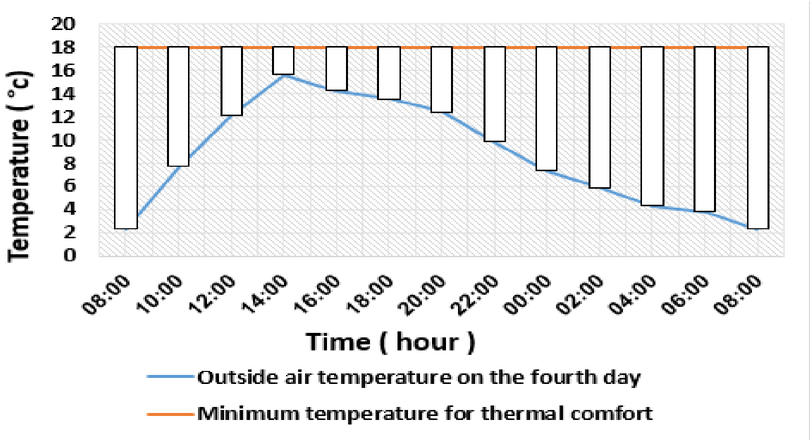

Figure.13: The variations of the outside air temperature over time for the fourth day of the experiment

Figure 14Shows that the air temperature inside the heated greenhouse is much higher than its counterpart in the traditional greenhouse, as the average temperature during the entire cold period reached 26.6°C, which is 16.7°C higher than the average air temperature inside the traditional greenhouse. It also Shows that the indoor air temperature during heating was higher than the lower limit of the plant's thermal comfort range 100% of the time in the cold period, in contrast to the non-heating condition. This confirms that the geothermal water heating system using both surface and buried heat exchangers together is very effective in heating the indoor air. The physical explanation for the rise in indoor air temperature is that the heat resulting from the flow of geothermal water inside the exchanger placed on the surface of the soil was transferred by convection and radiation to the indoor air surrounding the exchanger, and the heat was also transferred to it by thermal radiation from the surface of the soil heated by the heat exchanger buried beneath it.

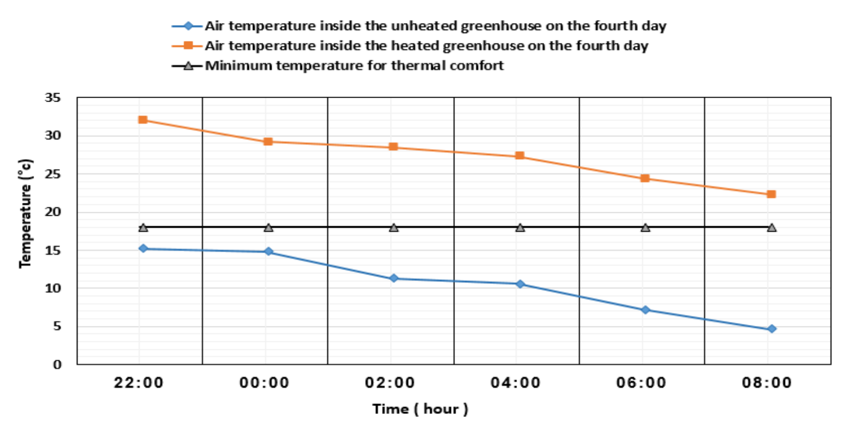

Figure.14: Comparison of indoor air temperatures between the heated greenhouse and the unheated greenhouse for the fourth day of the experiment

Figure 15Shows that the temperature of the soil inside the heated greenhouse is much higher than its counterpart in the traditional greenhouse, as the average temperature during the entire cold period reached 27.3°C, which is 14°C higher than the average temperature of the soil inside the traditional greenhouse. It also Shows that the soil temperature when heated was higher than the lower limit of the plant's thermal comfort range during the entire cold period, in contrast to the non-heating condition. This confirms that the geothermal water heating system using both surface and buried heat exchangers together is very effective in heating the soil. The physical explanation for the increase in soil temperature is that heat was transferred by thermal conduction from both heat exchangers in contact with the soil due to the temperature difference.

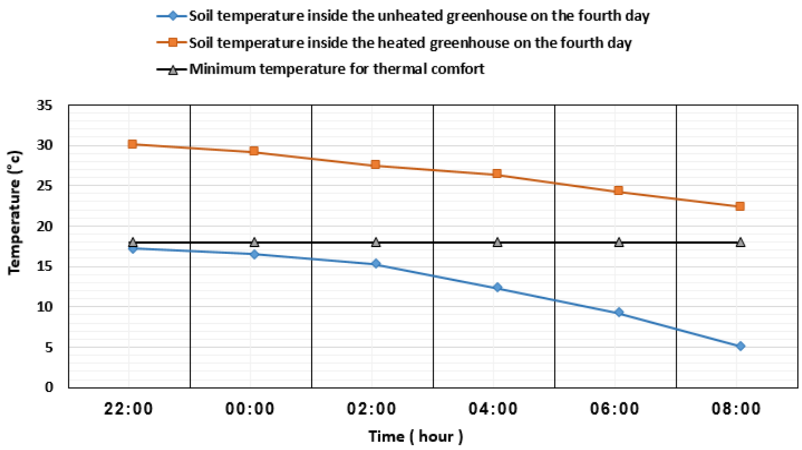

Figure.15: Comparison of soil temperatures between the heated greenhouse and the unheated greenhouse for the fourth day of the experiment

-4- Comparing the effectiveness of the three heating methods used.

Table 01 shows the limit and average values of the temperature range for both indoor air and soil in each experimental mode in order to evaluate each mode and also compare each mode with the normal mode, as well as compare the three modes of the heating system with each other.

			Temperature		
		Plastic greenhouse	mean	Maximum	Minimum
First position Surface exchanger (air-water) only	Indoor air	Unheated greenhouse	7.8	13.1	3.1
		Heated greenhouse	23.1	28.1	15.5
	the soil	Unheated greenhouse	11.6	16.3	5.6

		Heated greenhouse	18.5	22.2	14.6
The second position Buried exchanger (water-soil) only	Indoor air	Unheated greenhouse	7.9	14.1	3.3
		Heated greenhouse	18.1	23.3	13.3
	the soil	Unheated greenhouse	9.6	17.3	4.3
		Heated greenhouse	2.6	26.3	19
Third position The two heat exchangers together	Indoor air	Unheated greenhouse	10.6	15.2	4.7
		Heated greenhouse	27.3	32.1	22.3
	the soil	Unheated greenhouse	12.6	17.1	5.2
		Heated greenhouse	26.6	30.1	22.4

Table 01: Limit and average values of the temperature range for both indoor air and soil in each experimental position.

Figures 16 and 17: The two figures show the extent to which improvement has been noticed in the temperature of the air and soil inside the heated greenhouse in the three modes tested using the surface heat exchanger (water-air), the heat exchanger (water-soil), and both exchangers together. The two figures show that the best method for heating is to combine the two exchangers, as this ensures heating of the air and soil together for the entire cold period of the night.

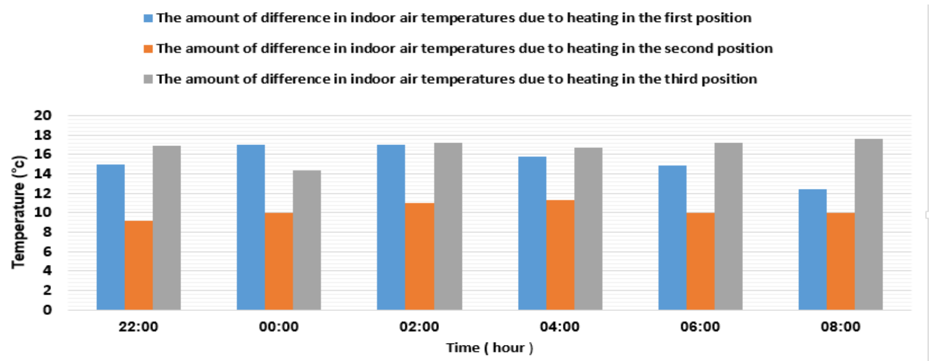

Figure 16: Amounts of thermal improvement of indoor air in the three modes.

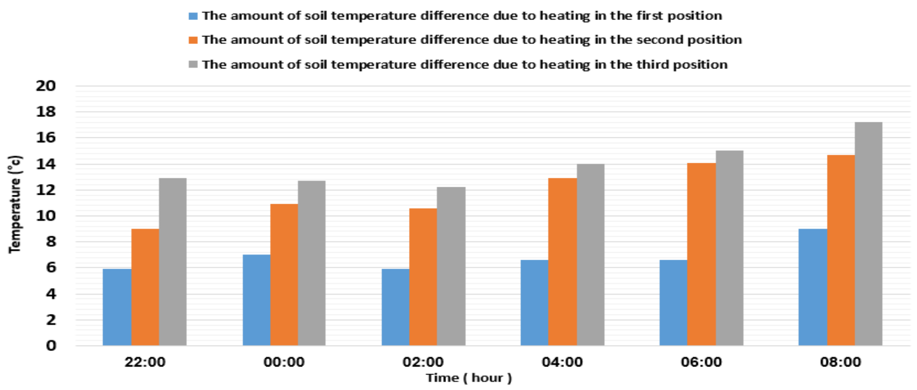

Figure 17: Amounts of soil thermal improvement in the three modes.

6-4- Limitations and suggestions for future research

In this experiment, hot geothermal water wells, which flow naturally without electric pumps and at a constant temperature of 65 °C, are exploited. They are widespread in agricultural surroundings in the study area. This makesthe costof the heating system,the installation and maintenance low. Therefore, in different circumstances, the economic feasibility of the system Suggested heating should be studied.

In this study, despite the positive effect of the heating system, the effect of construction factors on the efficiency of the system was not studied. Therefore, we suggest that future research work should consider the influence of water, volumetric flow, exchanger length, pipe diameter, pipe spacing, burial depth, orientation and other factors on the system performance.

5- Conclusion

In this study, a greenhouse heating system was proposed using geothermal energy using two heat exchangers operating with hot groundwater flowing from Albanian artesian wells available in the Ouargla region in southern Algeria, with the aim of improving the thermal performance of plastic greenhouses prepared for growing summer crops during the winter. The heating system aims to improve Air temperature and soil temperature inside the greenhouse. Through experimental data, we analyzed and evaluated the performance of the heating system and concluded some points mentioned below:

1- The heating effect of the heating system is clear, as the average air temperature and soil temperature inside the heated greenhouse when using the surface exchanger alone were 22.3 °C and 18.5 °C, and the unheated greenhouse one was 7.9 °C and 11.6 °C.When using the buried exchanger alone., the average air temperature and soil temperature inside the heated greenhouse were 18.1°C and 21.6°C and the unheated greenhouse one was 7.9°C and 9.6°C respectively. When the two exchangers were used together, the air and soil temperature in the heated greenhouse was 27.3°C and 26.6°C while the unheated greenhouse ones were 10.6 °C and 12.6 °C respectively.

2- There is a clear advantage in using both exchangers together, as there is a symmetrical improvement in the temperature of the air and soil at the same time. In contrast to using one of the exchangers alone, the air temperature improved better than the soil when using the surface exchanger, and the soil temperature improved better when using the buried exchanger alone.

3- In the same conditions of the study area, this system is considered effective and economically inexpensive due to its lack of reliance on electric pumps for pumping and the availability of naturally flowing hot ground-water.

4- The water coming out of the exchanger outlet can be used for irrigation operations.

5- The used materials are cheap and available in the market and have an acceptable expiration date.

6- The process of installing and maintaining the system is easy and can be carried out by farmers without a specialist.

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