Assessment of the Inside Greenhouse Temperature Heated by a Storage System

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Abstract: The ansys fluent R 14.5 computational fluid dynamics Code was used in this study to estimate the inside greenhouse temperature Heat transfer, radiation and temperature, all this parameters are treated in this study with differents Rayleigh number values .The external boundary conditions are introduced via User Defined Functions .Turbulence was modelled by the k- ε model and the solar radiation using the Discrete Ordinates model .The plants are not considered in this study .As a result this study make possible to improve design of greenhouses and its thermal needs as well as the positioning of heating and cooling systems w and geometrical configuration.

1 INTRODUCTION

As a complex biological forms and energetic system in which most heat exchange and mass modes are involved (Naijun Zhou et al 2017):Radiative, exchanges by conduction through the soil and walls, convective exchanges on the surface of the cover, plants and soil and air exchange due to the permeability of the greenhouse or ventilation.

The different modes of exchanges defined above do not have the same importance and some can be simplified or neglected according to the desired precision and the simulation objective Nessim Arfaoui et al, 2017).

The main greenhouse environmental factors, which are different from the outside, are temperature, light and humidity. Each of these factors is conditioned in the greenhouse by its level outside the enclosure, by the properties of the roofing material and by the characteristics specific to this greenhouse (F. Berroug et al, 2011).

Tunnel-type plastic greenhouses are widely used around the world, especially in the Saharan countries because of their low investment cost (M. Lazaar, 2004).

These are efficient in winter and spring, where solar energy is useful and sufficient for greenhouse production. On the other hand, these greenhouses lose their effectiveness in summer where, the climate is very hot, which causes excessive overheating and strong hygrometries inside (T. Boulard et al , 2000).

These extreme weather conditions affect the quality and quantity of the product and promote the development of certain diseases. On the physical plane, the greenhouse is a complex energy system in which all the different modes of thermal and mass exchange mentioned above (Reski Khelifi et al, 2018). If they are relatively simple and well known, their coupling causes difficulties in the modelling of the system.

In this system, natural convection is a particularly important mechanism for heat exchange between indoor air and all other solid surfaces (floor, walls, roof, culture, air conditioning and heating systems) (Erdem Cuce et al , 2016).The aim objective of this study consists to predict the storage system effect at the thermal behavior of an agricultural greenhouse in semi-arid climate . The study based on how to ameliorate the efficient of the production in this region using its date climate. The outline of this paper is: We started by an introduction, the Climatic condition like the solar radiation, outside temperature, relative humidity and the win speed are treated in the second parts. The third parts reserved to the description of the experimental greenhouse test facility and storage system. In fourth parts, a numerical simulation of the heated greenhouse was

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presented with interpretation of the obtained results and we finished by a conclusion and some perspectives

2 POTENTIAL SOLAR ENERGY OF AREA STUDY

In this study, experiments were carried out in two greenhouses at the Applied Research Unit on Renewable Energy at Ghardaïa from Algeria. Around of 77% of Algerian area presented arid and semi-arid regions. The characteristics of this region (Ghardaïa) are:

•Location 595Km south of the Mediterranean sea
• Latitude and 32°36 N
•Longitude3°80E
•Altitude of 469 m above the sea level
•Rate of sunny days per year: 77%
• Annual daily average of global solar irradiance about 7 kWh/m^{2}at horizontal surfaces.

Figs.1 shows the global solar radiation variation of January 2016.It can be seen that the global solar flux radiation has the same trend variation as the ambient temperature Fig.2.

It is observed also that the peak of average radiation is registered in the period of 10 h to 16h (800 W/m^2) with a highest ambient temperature surrounding 30°C. The least average radiation is 200W/m^2 with an ambient temperature around 5° C. It can be conclude that the heating period in this month is a largest than the storage period. The relative humidity is a counter variation like the temperature, it can be seen that high values observed in the morning and night periodic at the low temperature Fig.3. It can be conclude in this figure that the relative humidity can be passed the85 %. Fig.4 shows the average win speed in the same month. It can be seen that highest values does not break the 10m/s, it is the calm month (Lalmi Djemoui et al, 2016).

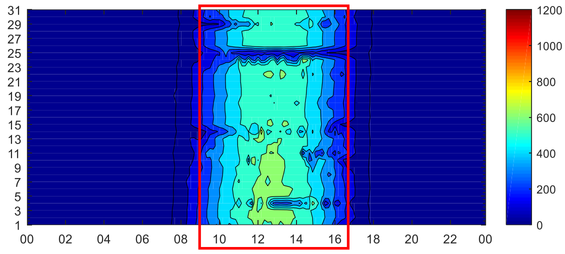

Figure 1: Global solar radiation variation, January 2016

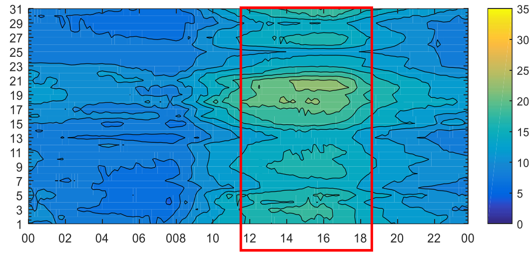

Figure 2: Temperature variation, January 2016

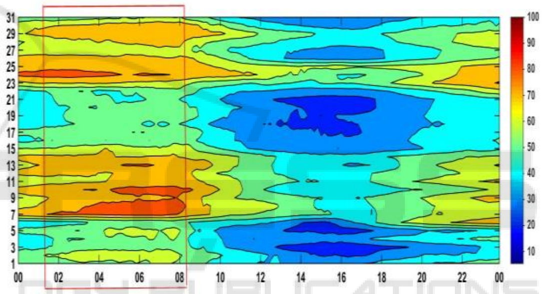

Figure 3: relative humidity variation ; January 2016

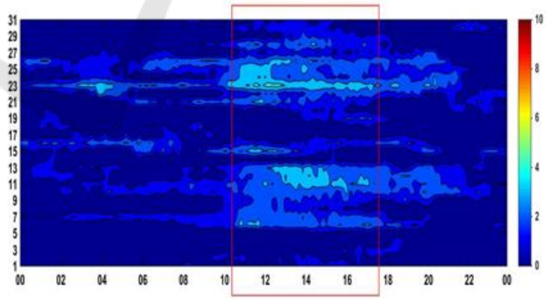

Figure 4: Average speed variation ; January 2016

2.1 Experimental Investigation

The two tunnel greenhouse test bench complete occupied and without storage system are shown in the Fig 5. It has a height of 3m, 25m of length and 8m of width, which leads to a volumetric of 528m3.The greenhouse has a north-south direction, with optimal deviation angle of 32° to the West. It has doors (opening) at the side walls create for ventilation (Efrén Fitz-Rodríguez et al, 2010).
The polyethylene covers the experimental greenhouse with a low density. The thermal proprieties of the cover material are presented in the Tab. 1(Serm J et al, 2011)

Figure 5: The two experimental greenhouses test facility in URAER

2.2 Experimentation and results

In the two greenhouses with and without storage system, courgettes plants are transplanted on the 27 th of December 2017 and the harvesting started on the 14 th of March 2018.
The major environmental factors that affect the growth and the precocity of the production of greenhouse plants are temperature, light and humidity.
The courgettes plants have two optimum temperatures, one during the day; which varied between 24 and 32 °C, and the other nocturnal temperature that is the most crucial temperature varied between 16 and 19 °C. A courgettes crop (local variety) was planted in both greenhouses and planted at 20 plants in the row and arranged in (8) eight rows with 30 cm between the rows and 20 cm between the plants.
Fig.6 shows the yearly inside and outside temperature evolution in 2016. It can be seen that the inside temperature is larger than the outside temperature. It is clear to see that in the hot months the inside temperature can reach 65°C hover in the cold months is taken the small values like 5°C. It is important to say that heating is necessary in the cold month and especially during the night. In the author hand the ventilation is necessary in the hot months like the august.

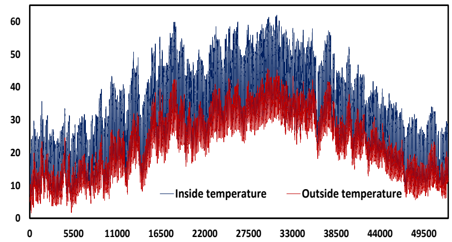

Figure 6: Yearly instantaneous temperature

Inside and outside the greenhouse

3. NUMERICAL STUDY

The flow inside the greenhouse is assumed to be two-dimensional (2d), incompressible and turbulent. Geometrical configuration with all boundaries condition considered in this study showed in the Fig.9
The airflow and the heat transfer are describe by the Navier stokes equations. The time average Navier stokes equation, for the mass, momentum and energy transport are solved using ansys Fluent 14.5.Physical properties of the air confined in the greenhouses are given in the Tab.1**.** Turbulence was treated via the re k- ε model, and the radiation modelling was simulated using the DISCRETE Ordinate model.

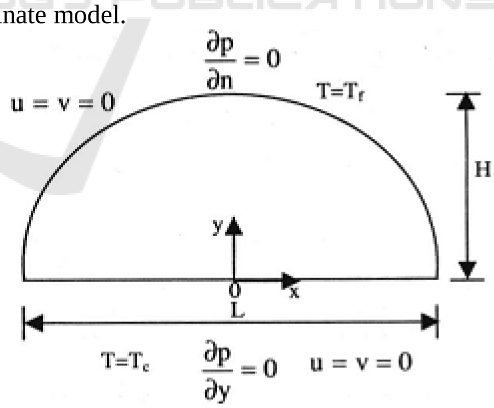

Figure7: Problem Position and boundary condition for tunnel greenhouse

3.1. Dynamical and thermical field

The Streamlines and isotherms of temperature are shown in Fig.8 for different Rayleigh numbers (Ra). The fluid flow intensifies and natural convection increases and predominates on conduction. The heated air particles at ground level rise along the wall then, the cooled particles in contact with the roof flow approximately the others wall.

The influence of the Rayleigh number on the streamline plots (right) and the isotherms (left) was illustrated. For the different Rayleigh numbers the flow characterized by two air circulation loops of the stream lines.

For low Rayleigh numbers ($Ra = 10^4$), the isotherms of temperature are parallel. This representation presented the domination of the conduction for heat transfer.

As Rayleigh number increases, isotherms become more and more wavy and heat transfer becomes more pronounced. As a result, fluid flow intensifies and natural convection increases and dominates. The heated air particles at ground level rise along the wall. Then, the cooled particles in contact with the roof flow approximately a median plane.

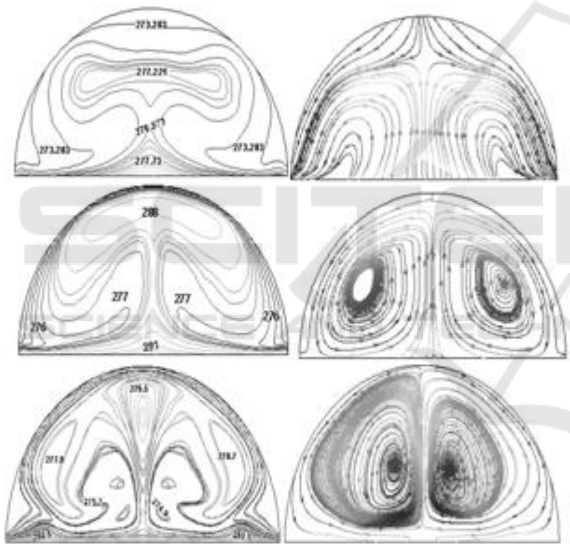

Figure8: left :isothermes right: isolines for Ra $=10^5$, $Ra=10^6$ $Ra=10^7$

Fig.9. shows the axial (right) and radial (left) velocities evolution. It can be seen that the large values of the radial velocity situate in the medium axis in the heated particles rise to the roof .However the large values of the axial velocity situate approximately at the wall.

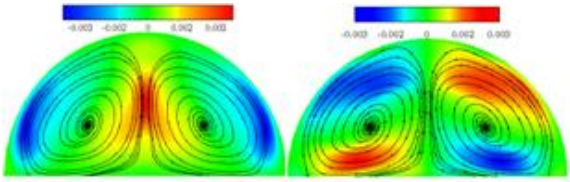

Figure9:Radial and axial velocity evolution

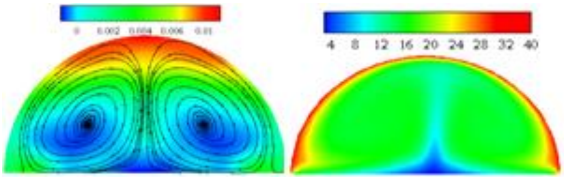

Figure10: saturation presuure and Relative humidity evolution

The saturation pressure and relative humidity are shown in Fig.10. We can see that there are same evolution of the pressure and temperature and there are counter evolution between the relative humidity and the temperature.

The effect of the solar radiation at the air behavior inside the greenhouse was presented in Fig.11. The temperature evolution in three hours of day at morning, midi and at night was presented in. It can be seen that in the day the temperature can be reach the 38°C but in the night decrease to 14°C.

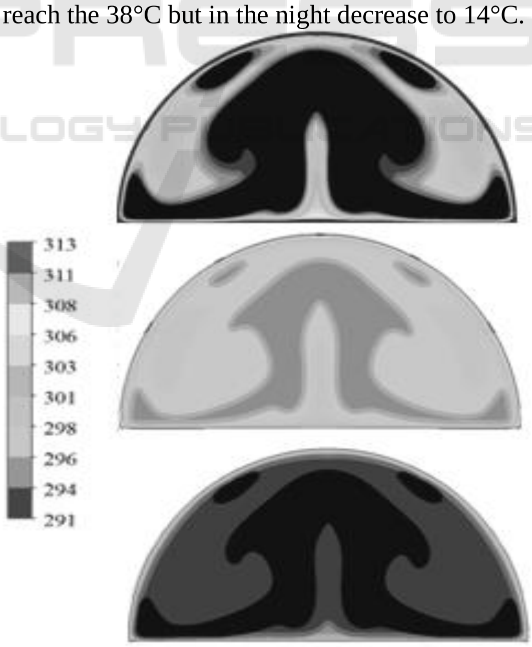

Figure11:Temperature of radiation evolution at morning, midi and night

3. 2 Heat Transfer Exchange Evolution

The heat transfer evolutions inside the greenhouse for different Rayleigh numbers are represented by the local Nusselt number have been given in Fig.12 and Fig.13.

Therefore, the logic is respected as long as there is a concentration of isotherms at the corners (ground), which explains a large number of Nusselt.

It is found that for a small Rayleigh number varying between 10^4 to 10^5 the Nusselt number is small, the conduction that dominates. With Rayleigh number increase, the exchange rate increases and the local Nusselt number becomes important. The rate transfer can be given according to the mean Nusselt number Fig.13.From these results; we can observe the good according between the literature and the present work for different Rayleigh numbers.

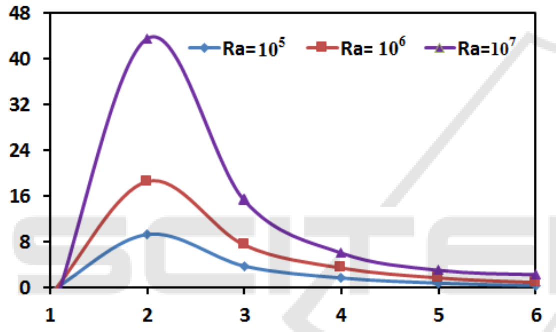

Figure12: Local Nusselt Number evolution
Ra $=10^5$, Ra $=10^6$ Ra $=10^7$

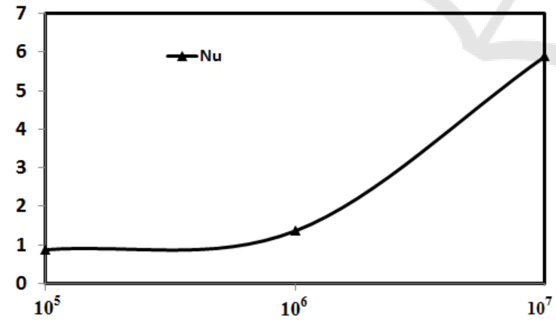

Figure13: Mean Nusselt number evolution
Ra $=10^5$, Ra $=10^6$ Ra $=10^7$

4. CONCLUSIONS

The study has an objective to estimate the temperature inside a greenhouse doted with a storage system .The study was focused on the use of the environmental data climate to ameliorate the thermal performances of the greenhouse during the in the winter season. The obtained results have been validate with the last work and the literature .We have also shown that for the our imposed conditions for low differences temperature between floor and roof, the air circulation is characterized by two recirculation cells rotating in the opposite direction. Therefore, this study should make it possible to improve the thermal design of greenhouse as well as the positioning of heating systems with thermal storage and geometrical configuration.

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Material	*Density [kg/m3]*	*Specific heat capacity Cp[J/kg.K]*	*Thermal conductivity [W/m.k]*	*Emissivity ,ε[-]*
Air	1.225	0.042	1006.43	0.90
Cover (polyethylene)	923.00	0.380	2300.00	0.70
Soil	1300.00	1.000	800.00	0.92

Table 1: Thermal proprities of materials