GEOTHERMAL HEATING OF GREENHOUSES IN SOUTH ALGERIA

Omar Bellache, Mahmoud Hellel, El-Hadj Abdelmalik and Abdelkrim Chenak

Centre de Développement des Energies Renouvelables
B.P. 62 - Bouzaréah , Alger - Algeria.

ABSTRACT

In Algeria the average minimum air temperature is mostly lower than 5°C *during* the December-February period in the coastal belt regions, while in semi-desertic regions, it falls under 4°C. It is obvious from these data that to maintain the minimum air temperature of 14°C in the greenhouses we must heat them. Theoretical and experimental studies of the thermal behaviour of greenhouse have been achieved. Many experiences of heating greenhouses by means of g e o t h d water have been designed in the South of Algeria (semi-desertic region). A numerical simulation has led to the determination of heat capacity, delivery rate of g e o t h d heating water and heat exchange surface. The hourly ambient air temperatures and relative humidities inside heated and unheated greenhouses are presented. Precocity of three weeks is obtained, while the total production has increased in heated greenhouses.

KEYWORDS

Heating greenhouses, design procedure, measurements, Algeria.

1. INTRODUCTION

Eventhough the vegetables production period and the efficiencies have increased substantially by using greenhouses, this way of cultivating remains limited in covering the population needs in fruits and vegetables. The solution we propose in order to increase the agricultural production is to heat the greenhouses. Geothermal energy, for its availability is the indicated heating solution. The present study intend to show the short Algerian experience in using geothermally heated greenhouses.

2. AGRICULTURAL CALENDAR PRODUCTION OF ALGERIA

Related to the periods of production, two main zones can be distinguished :

- The coastal zones of the country, where the plantation starts in February and the production begins in May.
- The internal zones, where the plantation begins in May while the production occurs in July.

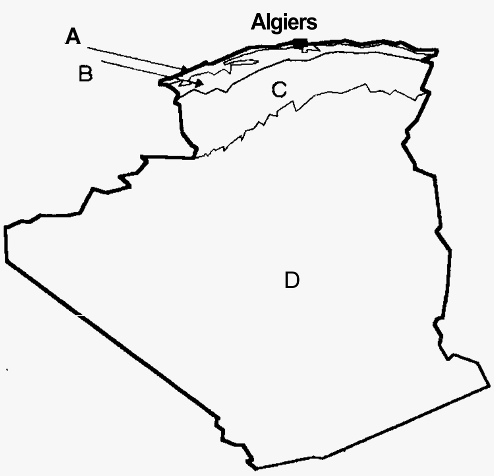
This leaves two periods where passive greenhouses are not used, i.e. from December to February in the coastal regions and from November to April in the interior of the country because of the severe climatic conditions.

3. CLIMATIC ZONES OF ALGERIA

The Algerian territory is divided into four climatic zones (Borel, 1960), which are as follows (see Fig. 1.):

- Zone A, which includes the northern part of the country i.e. the coast and a part of the northern mountain range.
- Zone B, including the regions between the northern mountain range and the tellian Atlas.
- Zone C, covering the region between the tellian Atlas and the Saharian Atlas.
- Zone D, which covers the Sahara.

From the *figure* 1, we can see that from December *to* February, the minimum ambient temperature is generally lower than 5 °C in the A and B zones and over 4°C in C and D zones. These data show clearly that heating the greenhouses is necessary to assure a good vegetable growth.



climatic data		coldest month characteristics		
zone	Altitude	daily minimum temperature	average daily temperature	external tasee temperature
A	above 500 m	5	12	6
	500 to 1000 m	4	a	4
C	500 to 1000 m	2	7	5
	above 1000 m	0	5	5
D	below 500 m	4	10	6
	500 to 1000 m	2	4	
	above 1000 m	0	5	

Figure 1: Climatic zones of Algeria.

4. POTENTIAL EVALUATION IN GEOTHERMAL WATER

The Algerian territory is rich in g e o t h d reservoirs and **springs** whose **temperatures** range fiom 22°C to **98** "C. In the northern part of Algeria, there are more than 240 thermal springs. These springs have been classified with respect to their temperature : **46 %** are in the range 22-37°C range, 22 **% are 37-45°C** range, and **33 %** have temperatures above **45°C.** The distribution of hot springs shows an important concentration in the north-eastern part of Algeria. It includes the largest concentration of springs where the hottest **spring (98°C)** is situated

The chemical analysis have shown **that** chloride, **sodium-**bicarbonate and **sodium** sulphate are **prevailing** (Table 1).

Table **1** : Chemical *analysis* of water of the main hot springs of Algeria.
(concentrations are in mg/l)

Spring	T (°C)	pH	Ca^{2+}	Mg^{2+}	K^+	Na^+	HCO_3^-	Cl^-	SO_4^{2-}	TDS
H.Ouled Ali	50	7	188	62	8	30	372	40	438	1140
H.Beni Guecha	50	7	46	547	10	960	598	7800	1360	17616
H. Ain Hammam	50	7	204	68	43	414	915	639	190	2012
H. Sidi Bou Abdellah	51	7	76	39	4	253	342	440	202	1194
H. Boutaleb	52	7	286	112	35	625	195	1175	815	3416
H. Hamoula	52	-	296	135	39	460	177	639	1100	2710
H. Salihine	55	7	64	352	12	33	415	195	863	2046
H. Sidi Mansour	55	7	76	336	24	225	183	360	1250	3332
H. Rass Djedar	57	-	304	125	47	414	189	568	1000	2810
H. Ibainan	60	7	496	112	81	96660	372	5800	1500	13482
H. Ksena	60	-	358	69	35	1465	239	2663	920	3520
H. Sidi Trad	63	8	28	18	8	93	292	43	30	542
H. Bouhanifia	67	7	172	49	10	253	884	355	110	1400
H. Bouhadjar	67	6	196	107	32	874	549	1469	68	3210
H. Righa	67	-	601	93	15	114	196	337	1074	2466
H. Guerfa	68	7	380	118	16	95	366	250	900	2206
H. Essalihine	70	8	106	43	29	565	274	775	300	2082
H. El Bilan	80	8	468	155	13	5000	250	8300	1000	16103
H. Meskhoutine	98	-	215	28	16	219	331	336	396	1600

To the South there is an important **nappe**. It is the Albian nappe which covers 600 **000 km²** (Dubost, **1983).** Its depth is variable fiom 80m at El Golea to **1500** m at Touggourt and containing g e o t h d water at **60°C** and **TDS** of **3** to **6 g/l** (see **Fig.** 2.).

The physico-chemical properties and the temperatures of the hot springs lead to consider the **following** geothermal **possibilities** :

- In the north-east of Algeria, where the temperatures of the **springs are high (40 - 98°C)** and the mineralisation is low **(1** to 2 g/l), The sources could be adequately used to heat **greenhouses as** well **as** for irrigation means.

- In the rest of the country, the mineralisation of the g e o t h d water **is high** (TDS> 6 **g/l)** and therefore the possible use of these **springs** is for heating only.

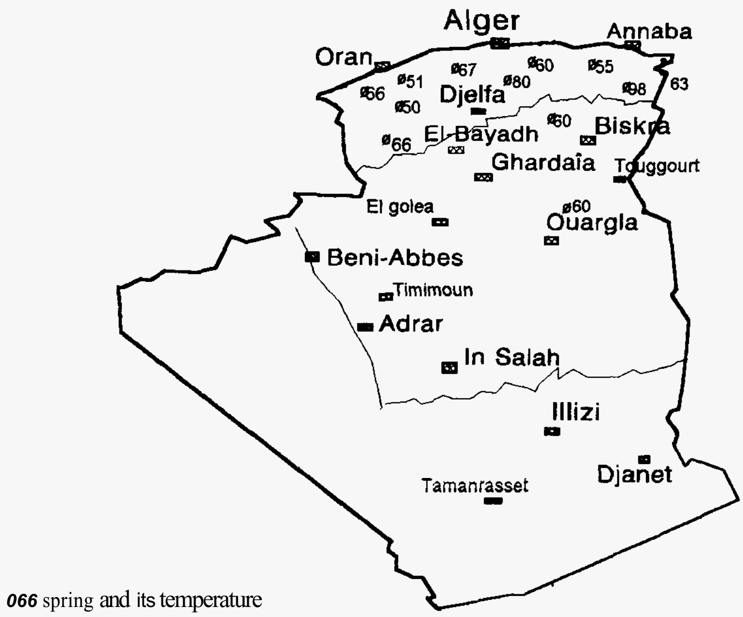


Figure 2 : Distribution of the main thermal **springs** of Algeria.

5. THE GEOTHERMAL POTENTIAL IN THE SOUTH OF ALGERIA

The geothermal potential in the South of Algeria is very important. As an example, an **artesian** well with a temperature of 60°C and a water mass flow rate of **150** l/s, when heating a greenhouse **14** h/day ***during* 120 days** would produce approximately 22.680.000 MCal. This is equivalent to burning **3.037.3701** of **fuel** in a boiler of an efficiency of **85 %** which corresponds to a saving of **18.224.220DA (1USD = 36 DA).** The geothermal potential in the regions of **Ouargla,** Biskra and **Touggourt** with a **mass** flow rate of about **3421l/s** can heat **9000** greenhouses saving **415.633 740 DA** per year. An important geothermal potential in the South of Algeria come from drilling at important **depths** for water irrigation. This also increase the possibility of heating greenhouses before using the water for irrigation.

6. ENERGY NEEDS IN GREENHOUSES

The method we developed in calculating the needs for heating a greenhouse uses the fact that the quantity of heat necessary to maintain the inner temperature of the greenhouse is function of temperature difference between the air inside the enclosure and the ambient **air.** The heat balance in a heated greenhouse is given by :

$$Q_G = K_G A_v (T_i - T_e) \quad (1)$$

A_v	: the greenhouse surface	[m²]
Q_G	: useful power	**[W]**
T_i	: temperature inside the greenhouse	[°C]
T_e	: ambient air temperature	[°C]
K_G	: the overall heat loss coefficient	[W/m²C]

K_G represents simultaneously the losses due to the flow of air entering and leaving the greenhouse and the heat transfer accuring in the plastic cover. In order to evaluate K_G, we need to determine the cover thermal losses and the losses due to air infiltration.

6.1 Plastic cover losses

Assuming :

- a uniform temperature distribution on the plastic cover and *on* the ground of the greenhouse,
- neglecting the evaporation and the condensation terms,

the energy balance on the plastic cover yields :

$$m_v Cp_v \frac{\partial T_v}{\partial t} = Q_r + Q_c \quad (2)$$

Q_r : radiative heat transfer
Q_c : convective heat transfer
T_v : cover temperature

<u>**Heat** exchange by radiation</u>

- On the interior surface of the plastic cover :

$$Q_{r,i} = \frac{\varepsilon_v A_v}{1-\varepsilon_v}(M_v - J_{v,i}) \quad (3)$$

- On the exterior surface of the plastic cover :

$$Q_{r,e} = \frac{\varepsilon_v A_v}{1-\varepsilon_v}(M_v - J_{v,e}) \quad (4)$$

Where :

ε_v : emissivity of the cover
M_v : emittance of the cover
$J_{v,i}$: radiosity of the interior surface cover
$J_{v,e}$: radiosity of the exterior surface cover

<u>Convection heat exchange</u>

The heat exchange at the interior of the **greenhouse** occurs by natural convection and is given by :

$$Q_{c,i} = h_{c,i} A_v (T_v - T_i) \quad (5)$$

where, $h_{c,i}$ is the convective heat transfer Coefficient occurring between the interior side of the plastic cover and the air inside the greenhouse.

- On the exterior side of the plastic cover, the heat exchange occurs by forced convection and is given by :

$$Q_{c,e} = h_{c,e} A_v (T_v - T_e) \quad (6)$$

6.2 Losses due to the air renew

The quantity of heat lost by static ventilation and different leaks is evaluated by :

$$Q_r = RE[Cp_a(T_i - T_e) + h_w(H_e - H_i) + Cp_w(T_i H_i - T_e H_e)] \quad (7)$$

where :

RE : air renew rate
H_i : humidity of air in the greenhouse
H_e : humidity of ambient air
h_w : water vapour enthalpy
Cp_i and Cp_w are respectively the heat capacity of dry air and water vapour.

6.3 Total heat loss of the greenhouse

The total quantity of heat lost ***trough*** the plastic cover is then ***given* by :**

$$Q_G = U.A_V(T_i - T_e) + Q_r \quad (8)$$

The overall heat transfer coefficient is given by :

$$U = \frac{1}{R_e + R_i} \quad (9)$$

An electrical **analogy** of the heat exchange *on* the cover is **shown** in Fig 3. The thermal resistance *on* the exterior surface area is ***given*** by :

$$R_e = \frac{1}{\frac{Q_{r,e}}{A_v(T_v - T_e)} + h_{c,e}} \quad (10)$$

On the interior surface area,

$$R_i = \frac{1}{\frac{Q_{r,i}}{A_v(T_i - T_v)} + h_{c,i}} \quad (11)$$

If we assume that the thermal inertia of the plastic cover is negligible, we can see that the heat exchange between the cover and the external climatic conditions is equal to the heat exchange between the cover and the interior of the greenhouse. We *may* write then that :

$$T_v = T_i - R_i U (T_i - T_e) \quad (12)$$

From equations **(1)** and **(8)**, we obtain :

$$K_G = U + \frac{RE}{A_V(T_i - T_e)}(Cp_a + Cp_w H_i) \quad (13)$$

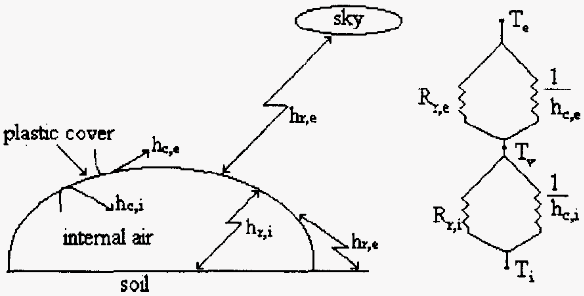


Figure 3 : Heat flows in the plastic cover.

In calculating the heat loss coefficient U, we proceed by iteration. First, we define a given value for T_V and we calculate from the equations (10) and (11) the thermal resistances, then the results are plugged in equation (9) and the value of U is obtained. From equation (12), we obtain an estimated value of T_V . This procedure is repeated until the value T_V remains approximately constant between two iterations.

A computer programme was developed :
- to evaluate the heating needs of the greenhouses.
- to determine, for different tube diameters, the heat exchange surface area
- to evaluate the mass flow rate of hot water to heat the greenhouse.
- to determine the pressure drop in the heating circuit.

7. RESULTS

Table 2 gives the values of the heat losses by radiation, conduction-convection and air infiltration as well as the heating monthly needs for the region of Ouargla.

Table 2 : Monthly heating needs for greenhouses in Ouargla.

Month	Degree-day	Night		Needs		
		leaks (MJ)	conduction (MJ)	day (MJ)	total (MJ)	power (W)
January	121	30183	84163	22869	137216	51230
February	105	17368	66029	16679	100077	41367
March	67	10971	44014	10997	65982	24634
April	38	4553	22826	5475	32855	12675
May	2	213	1327	308	1849	690
June, July, Aug., Sep.	0	0	0	0	0	0
October	5	450	3025	695	4171	1557
November	60	10461	37785	9649	57896	22336
December	113	25321	78481	20760	124563	46506

8. EXPERIMENTAL DESCRIPTION

Many experimental works on heating greenhouses have been conducted in Touggourt and Ouargla and are reported hereafter :

8.1 Distribution of the heating lines

In all tests, the exchangers are looped on the ground around lines of plants. We adopted a parallel configuration, where the greenhouses are heated separately. The heating water mass flow rate was taken between 0.34 l/s and 0.4 l/s to maintain the temperature around 14°C. The outlet water gets colder and is used for irrigation.

8.2 Thermal regulation

Manual regulation was chosen fust. The different flow rates values were manually adjusted with respect to the meteorological data. This causes some difficulties in regulating correctly the greenhouses. To perform our experimental set-up, we reinstalled automatic valves where the mass flowrate of hot water was controlled by the value of the ambient air temperature.

9. THERMAL RESULTS

Figure 4 shows that the temperature and the humidity profiles in a heated and in an unheated greenhouse. The theoretical model used agrees well with experimental data. This figure shows also that the temperature inside the heated greenhouse is maintained at 12°C, when the ambient temperature is at its lowest value (less than 0°C).
On one hand, the temperature in the unheated greenhouse reaches a very low temperature value (less than 0°C), which is very unpleasant to the vegetation and may simply stop its growth.
On the other hand, for a certain day period, the temperature inside the greenhouse could reach an undesirable value and this also causes serious problems to the growth of the vegetation. Therefore, renewing the air inside the greenhouse becomes necessary. We note that the heating of the greenhouse has a positive influence on its internal humidity.

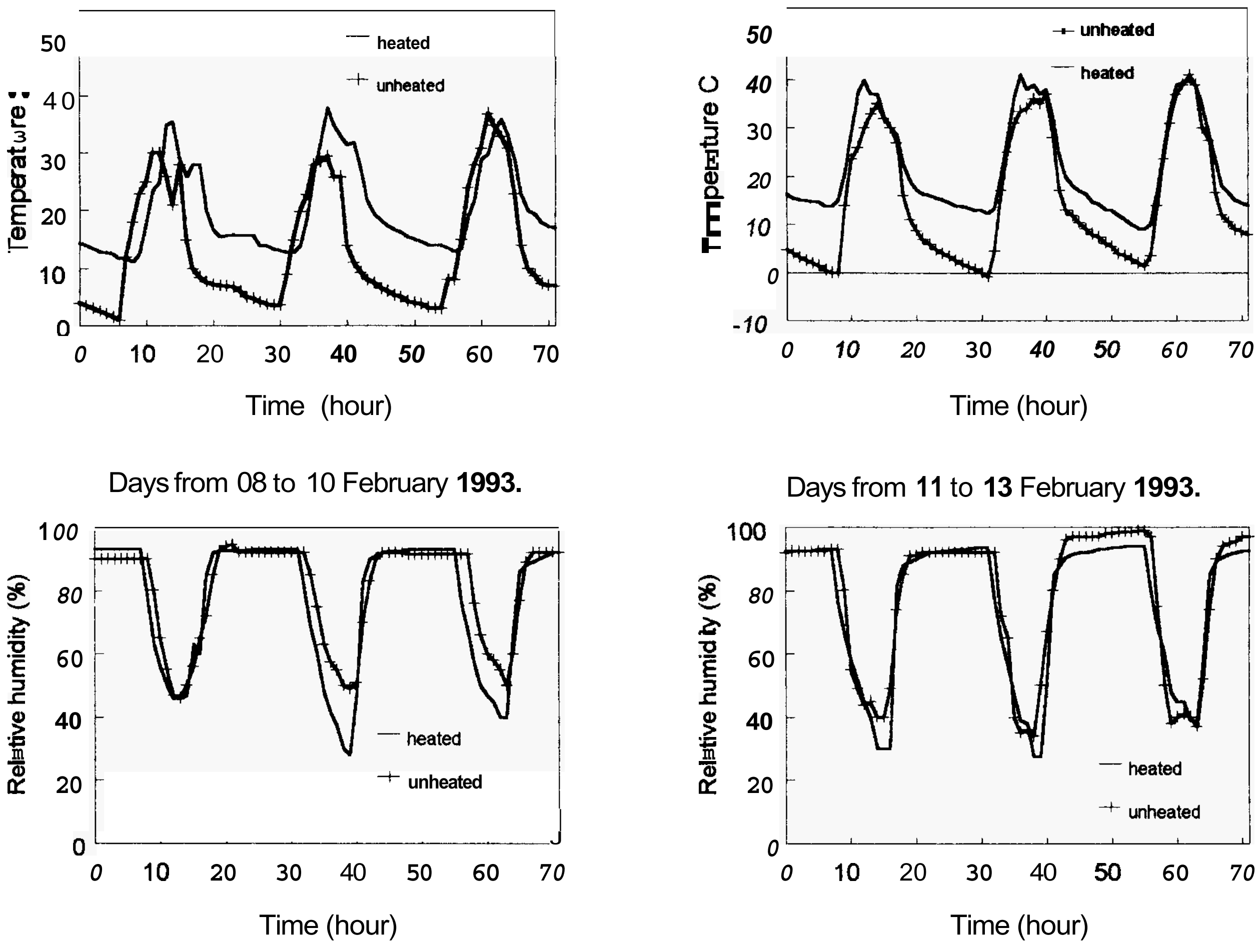


Figure 4 : Temperature and relative humidity evolution in heated and unheated greenhouses.

10. Agronomic results

10.1 For melon

The germination time on heated greenhouse for melon is reduced. It could be reduced by four to five day. 90 days are needed for melon to mature in a heated greenhouse against 110 days in a unheated one.

10.2 For tomato

A saving of 30 days is observed when using a heated greenhouse for the culture of fruit. The flowering and the maturation period goes from 120 days to 90 days. We observe also an increase of 50 % of the production rate and a better quality when the greenhouse is heated.

11. CONCLUSION

The experimental results of the geothermally heated greenhouses set-up in the south of the country are encouraging. We have obtained a better production and an appreciable precocity and quality of the vegetables.

The thermal potential of geothermal energy in Algeria is very important and its possible use in heating greenhouses is highly promoting. Generalising its use would have an important impact on social and economical welfare for the population.

12. REFERENCES

Amiensituru, M. (1986). *Optimisation technico-économique d'un bassin solaire en vue de son utilisation pour le chauffage d'une serre agricole ou d'une résidence.* Thbse de Docteur-ingenieur, Perpignan, pp. 90-96.

Borel, J. (1960). *Appbcabon du reglement de la construction des zones climatiques.* Ch. C.S.T.B., n°57, Paris. 23pp.

Dubost D. (1983). Bulletin D'agronomie saharienne, n°5, Alger. 142 pp.

Kedaid F, Rezig. M., Abouriche. M and Fekraoui. A. (1988). *Carte géothermique preliminaire du nord de l'Algérie.* Alger. 58 pp.

Kittas, C. (1980). *Contribution théorique et experimentale a l'étude du bilan d'energie des serres.* these de Docteur-Ingenieur, Perpigan.

Pruvot, J.M (1983). *Possibilités et limites de l'aspersion dans la climatisation des serres agricoles.* These de Docteur-Ingenieur, Perpignan.

Cormay Y. and Nicolas C. (1985). La *thermique des serres.* Eyrolles, Paris. 357pp.

Popovski K. (1993). *Heating greenhouses with geothermal energy.* Engineering Handbook, Skopje. 300pp.