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DETERMINATION OF HEATING REQUIREMENTS AND ENERGY CONSUMPTION OF GREENHOUSES IN ADANA REGION OF TURKEY

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Abstract

In this study, the heating loads of plastic greenhouses were determined based on long term meteorological data in Adana region of Turkey. Considering the air temperature requirements of warm season species, energy consumptions were calculated for heating periods. If the monthly average low temperatures are considered as the outside air temperature, when the air temperature in the greenhouse is considered as in 18 °C, the average greenhouse heating load is 64.4 W/m^2, during the October-May heating period. However, when the air temperature in the greenhouse is considered as in 15 °C, the average greenhouse heating load is 44.5 W/m^2 during the same period. The average energy consumption for 1 da greenhouse heating (T_g=15°C) is 176 MJ/h, during the October-May heating period.

***Key words**: greenhouse, cooling load, energy consumption, Adana.*

INTRODUCTION

The optimization of air temperature in greenhouses is of particular importance in relation to plant growth and development. In order to achieve optimum indoor conditions, it is necessary to heat the greenhouses, particularly during the cold seasons. Heating cost represents 30% of the overall operational cost of a greenhouse (Santamouris et al., 1994). Consequently, this cost has proved prohibitive in not permitting the use of heating systems in many applications. As a result, heating application has a significant impact on the cultivation time, quality, and quantity of the products, since the primary objective of greenhouses is to produce agricultural products, outside the cultivation season. To overcome these problems it is of primary importance to utilize alternative heating technologies, with low cost, and efficient and dependable operation, such as the use of advanced cover materials and night thermal screens.

Lack of greenhouse heating has an important effect on the yield as well as on the quality and the cultivation time of the products. Therefore, the availability of low cost, efficient, alternative to the conventional fuel systems, are of primary importance. Recent achievements regarding the energy conservation in the agricultural sector, has shown that the greenhouse sector has an exceptional potential in energy conservation.

Adana that is one of the centre places of greenhouse production in Turkey due to the very favourable ecological conditions for protected cultivation. According to 2015 statistics, 15 percent of the total protected cultivation area and 35 percent of plastic houses in Turkey located in Adana (TIS, 2015). The majority of the greenhouses in the Cukurova region are located in city of Adana. This climate zone allows unheated greenhouse production most of the time due to abundant solar radiation during the winter season. Greenhouse production makes a significant contribution to Adana's economy. It is not only provides income to growers but also employment opportunities.

In this study, the heating loads of plastic greenhouses were determined based on long term meteorological data in Adana region. Considering the air temperature requirements of warm season species, energy consumptions were calculated for heating periods.

MATERIALS AND METHODS

Based on the geographic features, two types of climate prevail in Adana: typical Mediterranean climate on the low lying plains and continental climate on high mountains. The Mediterranean climate is characterized with hot and dry summers, mild and wet winters. Summer months are very hot since high mountains surrounding the city on the north forms a barrier in front of the northern winds. Half of the precipitation occurs in winter, and the other half in spring and fall. There is almost no rain during two or three months in summer. According to the meteorological data recorded in Adana weather station, mean annual temperature is 19 °C, with an annual lowest of -6.4 °C in February and an annual highest of 43.8 °C in August. The change of air temperatures in Adana is given in Table 1.

Table 1. The Air Temperatures in Adana

Month	Air temperature (°C)				
	Max.	Min.	Average high	Average low	Mean
January	23.0	-2.8	15.2	5.6	9.8
February	24.4	-6.4	15.9	5.7	10.2
March	30.0	-3.6	19.0	8.2	13.1
April	36.8	-1.3	23.8	12.3	17.5
May	40.6	5.6	28.0	16.2	21.6
June	41.0	13.7	31.5	20.1	25.4
July	41.5	17.1	33.6	23.5	28.1
August	43.8	17.6	34.4	23.7	28.4
September	43.2	10.9	33.4	20.9	26.3
October	39.4	5.0	29.1	16.1	21.5
November	33.3	1.0	21.4	10.7	15.1
December	25.8	-1	16.6	7.2	11.1
Yearly	43.8	-6.4	25.2	14.2	19

The average monthly air temperatures (20 years' average) range between 9.8 and 28.4ºC. The minimum air temperatures are very important for protected cultivation. Frosts are rare. Expected 20-year lowest temperature is -6.4°C. Soil temperature never falls below zero centigrade. Weather is mostly clear. The number of cloudy days is only 49.2. Mean annual hours of sunshine is 8.6 hours in the plain and in the mountainous region, with the highest in July, and the lowest in December and January. Prevailing wind direction is southwest and the yearly average wind velocity is 1.45 m/s. While southern winds are dominant during summer months, northern winds prevail in October, November and February. Mean relative humidity is about 65%.

In Turkey, a small proportion of the greenhouse owners use the auxiliary heating systems only during the coldest winter nights. On the other hand, Turkey has also great solar energy potential due to its location in the Mediterranean Region. The sunshine period of Adana is 3062 h/year with a maximum of 365 h/month in July and minimum of 103 h/month in December. The average yearly solar radiation intensity is about 1378.2 kWh/m²year.

Table 2. The Solar Radiation Energy and Sunshine Period in Adana

Solar radiation energy (kWh/m²)			Sunshine period (h/year)		
Yearly average	Max.	Min.	Yearly average	Max.	Min.
1378.2	180.0	44.2	3062	385	139

The heat requirement of the plastic greenhouse $\dot{Q}_g$ in W/m^2 was calculated from the following equation.

$$\dot{Q}_g(t) = \frac{A_c}{A_g} u\left[T_g - T_d(t)\right] - \dot{I}_t \tau\gamma \;\ldots\ldots\; (1)$$

where: A_c is the surface area of the greenhouse cover in m^2; A_g is the ground area of the greenhouse in m^2; u is the overall heat loss coefficient in W/m^2 °C; T_g is the air temperature in the greenhouse in °C; T_o is the outside air temperature in °C; $\dot{I}_t$ is the total solar radiation in W/m^2; τ is the transmittance of the greenhouse cover for solar radiation; and γ is the conversion factor of global radiation energy to thermal energy within the greenhouse. γ is the portion of the solar radiation entering the greenhouse which is used to increase the internal temperature.

The overall heat loss coefficient u represents the total energy loss in W per m^2 of external area of the greenhouse for a difference of 1 °C between the inside and outside temperatures. The value of the overall heat loss coefficient depends on especially external climatic conditions (principally on the wind speed but also on rain and snow), it is always given in relation to the wind speed. A number of relationships have been developed to predict the overall heat loss coefficient of different types of greenhouses.

In this experimental study, the following relationship that obtained by Ozturk (2005) for the plastic greenhouse (PE) in which the experiment will be carried out was used to calculate the overall heat loss coefficient:

$$u = 3.55 + 0.11\, v_w \;\ldots\ldots\ldots\ldots\ldots\ldots\; (2)$$

where: v_w is the wind velocity in m/s. In Eqn (1), the value of τ for single foil ranges from

0.6 to 0.7, for double foil greenhouses from 0.5 to 0.6.

During the day, a part or all of the energy may be supplied by solar radiation. During the night, the heat storage system will provide most of the energy. The value of γ depends on the proportion of the floor which is covered by plants, and generally lies in the range of 0.3-07. In this study, 0.6 and 0.5 as the values for τ and γ were used to calculate the heat requirement of the plastic greenhouse.

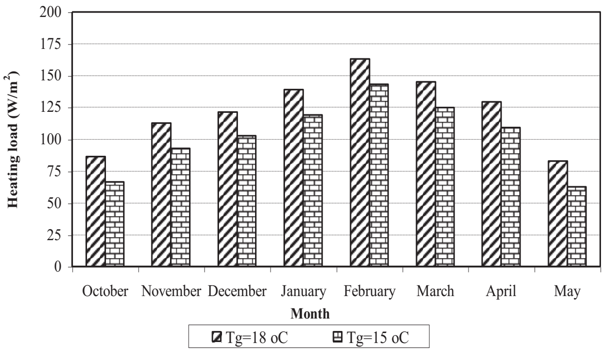
RESULTS AND DISCUSSIONS

The monthly changes of the greenhouse heating loads during the heating periods are shown in Figure 1 and Table 3.

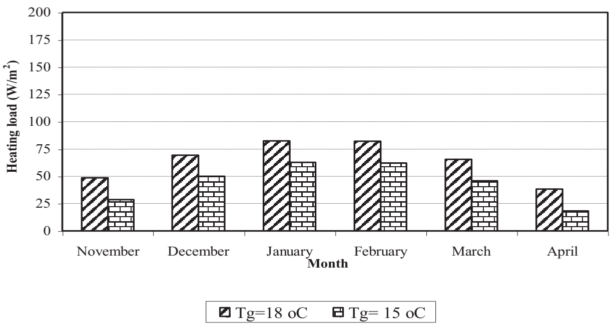
During the October-May heating period (Figure 1a), when the air temperature in the greenhouse is considered as in 18°C (T_g=18°C) the greenhouse heating load range from 63.8 W/m^2 to 163.2 W/m^2, while the greenhouse heating load is in the range of 62.8-143.1 W/m^2 when the air temperature is considered as in 15°C (T_g=15°C).

Table 3. Greenhouse Heating Loads

Month	Wind speed (m/s)	u (W/m^{2}K)	Q_g (W/m^2) T_o= Minimum		Q_g (W/m^2) T_o= Average Low	
			T_g=18 °C	T_g=15 °C	T_g=18°C	T_g=15 °C
January	1.48	3.7128	139	119	82.6	62.8
February	1.51	3.7161	163.2	143.1	82.3	62.2
March	1.59	3.7249	144.8	124.7	65.7	45.6
April	1.54	3.7194	129.2	109.1	38.2	18.1
May	1.49	3.7139	82.9	62.8		
June	1.64	3.7304				
July	1.55	3.7205				
August	1.45	3.7095				
September	1.46	3.7106				
October	1.31	3.6941	86.4	66.5		
November	1.24	3.6864	112.8	92.9	48.4	28.5
December	1.20	3.5645	121.2	102.7	69.3	50.0
Average	*1.45*	*3.7003*	*122.4*	*102.6*	*64.4*	*44.5*



a) During the period of October-May



b) During the period of November-April

Figure 1. Change of Greenhouse Heating Loads

If the monthly average low temperatures are considered as the outside air temperature when the greenhouse heating load is calculating (Fig. 1b), the greenhouse heating load range from 18.1 W/m^2 (T_g=15°C) to 82.6 W/m^2 (T_g=18°C) depending on desired temperature.

If the fuel is burnt in a heater, sited within the greenhouse, η is the combustion efficiency of the heater, but if the heat is produced remote from the house, the loss of energy from the transport pipes must be included which reduces the efficiency by 5-10%. When the greenhouse energy consumption is calculating for greenhouse heating and cooling, the greenhouse heating/cooling loads per square meter of ground surface in the plastic greenhouse and efficiency factor (10%) were considered. The monthly changes of the energy consumption for greenhouse heating during the heating periods are given in Table 4. The greenhouse heating loads and the overall heat loss coefficients during the heating periods are given in Table 3.

Table 4. Energy Consumption for Greenhouse Heating

Month	E_g (W/m^2) T_o= Minimum		E_g (W/m^2) T_o= Average Low	
	T_g=18 °C	T_g=15 °C	T_g=18 °C	T_g=15 °C
January	152.90	130.90	90.86	69.08
February	179.52	157.41	90.53	68.42
March	159.28	137.17	72.27	50.16
April	142.12	120.01	42.02	19.91
May	91.19	69.08		
June				
July				
August				
September				
October	95.15	73.15		
November	124.08	102.19	53.24	31.35
December	133.32	112.97	76.23	55.00
Average	*134.7*	*112.7*	*70.9*	*48.9*

If the monthly average low temperatures are considered as the outside air temperature, when the air temperature in the greenhouse is considered as in 18°C, the average energy consumption for greenhouse heating is 70.9 W/m^2, during the October-May heating period. However, when the air temperature in the greenhouse is considered as in 15°C, the average energy consumption is 48.9 W/m^2 during the same period. The average energy consumption for 1 da greenhouse heating (T_g= 15°C) is 176 MJ/h, during the October-May heating period.

CONCLUSIONS

Greenhouses may utilize central heating systems or localized heating systems. Central heating systems generate heat, most often using a large boiler, in one location, and distribute that heat to many locations. Localized heating systems are located in the greenhouse or greenhouse section that they are responsible for heating. For large operations, a central heating system may be more efficient than a localized system. However, the cost of installation and maintenance of a centralized heating system can be high. For smaller operations, this expense may be hard to justify. However, the size of the boiler unit, the fuel source, size of the operation, and maintenance costs all must be considered when deciding whether to use a centralized or localized heating system.

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