Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. VI, 2017
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

# COMPARISON OF THE HEATING ENERGY REQUIREMENTS OF THE GREENHOUSES IN THE TIGRIS BASIN WITH ANTALYA

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***Abstract***

*The rapid growth of the world population also increases the amount of food needed for the human being's life. Therefore, applications that increase productivity and through which production can be made throughout the year in plant production come to the forefront in the world. In this context, one of the most important activities is greenhouse cultivation through which production can be made throughout the year by keeping climate conditions under control. Greenhouses are climate-controlled plant production structures in which indoor environment conditions can be controlled and can be kept in accordance with growing conditions. Heating must be performed during the winter period in greenhouses if it is desired to make production throughout the year. In Turkey, almost all of greenhouse production is performed in the Mediterranean region, and the production areas are situated in a relatively limited area in the Southeastern Anatolia Region. In this study, 10-year climate data (Maximum, Minimum and Average Temperature, Humidity, Sunshine Duration and Amounts) of 5 provinces (Diyarbakir, Mardin, Siirt, Batman and Sirnak) in the Tigris basin were achieved by considering the climatic conditions and production capacity of Antalya province, which has the most production areas in Turkey. According to the results obtained, the average minimum temperature for each month showed a statistically significant difference according to the provinces ($p<0.01$). Consequently, while the highest heating load was 1852.836 W/m$^2$ for a greenhouse of 576 m$^2$ for Antalya province in January during which heating requirement is the maximum, 3887.13 W/m$^2$ and 5615 W/m$^2$ heating load differences were obtained from Mardin and Diyarbakir provinces, respectively.*

**Key words:** *Antalya, climate parameters, heating loads, temperature analysis of variance, Tigris basin.*

## INTRODUCTION

Applications in which climate conditions are kept under control and production can be made throughout the year are called greenhouse cultivation. Greenhouses are plant production structures realized in different forms for the purposes of producing various cultivated plants and their seeds, seedlings and saplings and protecting and displaying the plants by coating them with light transmissive materials such as glass, plastics, etc. and by keeping the factors such as temperature, light and humidity under control without being wholly or partially dependent on climate-related environmental conditions (Ones, 1986; Yaganoglu and Orung, 1997; Yuksel, 2000).

The most extensive and effective environmentally controlled production takes place in greenhouses. New innovations and developments for greenhouse production go hand in hand with efforts for sustainability. The greenhouses must be heated to ensure high yields and high quality. However, a high heating cost (20-60%) adversely influences production. The costs of the sustainability of greenhouse production can only be maintained with an increase in energy efficiency. The use of renewable energy sources in place of fossil fuels is theonly means to increase energy efficiency (Baytorun, 2016).

Greenhouses provide a suitable environment for the intensive production of various crops. They are designed to control solar radiation, temperature, humidity and carbon dioxide levels in the aerial environment. The availability of solar radiation and its daily and yearly distribution have a tremendous influence on productivity and quality of plant growth and also on comfort living (Kania and Giacomelli, 2001).

The most important energy requirement in the air-conditioning of greenhouses is realised in heating applications during the winter months. The expenses required for heating that is

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

performed to increase the internal temperature of the greenhouse to the values appropriate for the plant requirements during cold seasons account for approximately 60% of all production expenses. Therefore, cultivators usually heat their greenhouses just to protect from frost, and the benefit expected from greenhouse cultivation is not fully achieved (Yagcioglu, 2005).

The greenhouse heating requirement depends on the amount of the heat lost from the greenhouse. The heat loss from a greenhouse results from conduction, convection and radiation, which are the three forms of heat transfer. Generally, heat changes occur at the same time. In the heat loss equation, the heat requirement of the greenhouse is calculated by combining the whole of the heat losses with a coefficient (Worley, 2005). In this study, climate parameters provinces of the Dicle Basin were compared with those of Antalya and the appropriate greenhouse areas in the Dicle Basin were tried to be determined statistically according to these parameters.

## MATERIALS AND METHODS

The Tigris basin is one of the largest basins not only in Turkey but also the Middle East. The basin has about 5500 $km^2$ catchment area within the borders of the country. Therefore, the Tigris Basin was selected as the study area. The Tigris Basin consists of Diyarbakir, Batman, Siirt, Sirnak and Mardin cities. The map showing the Tigris Basin is given in Figure 1 (Atilgan et al., 2016).

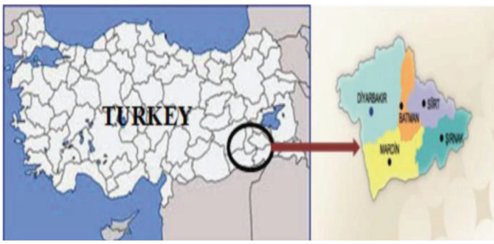


Figure 1. Map of Tigris Basin

Antalya province with the highest greenhouse production area and capacity in Turkey and 5 provinces (Diyarbakir, Mardin, Siirt, Batman and Sirnak) in the Tigris basin constituted the study area. The climatic data (Maximum, Minimum and Average Temperature, Sunshine Duration and Amounts) of long years (1990-2015) in the study area were used. The Global Radiation Values and Sunshine Durations of Antalya and the Tigris Basin between 2006-2015 were used to be able to examine the changes in the amount and duration of the sunshine (Anonymous, 2016).

In order for the comparison to be carried out in a healthy way, it was aimed to find the heating loads that would emerge if a greenhouse established in Antalya was established in the Tigris basin without changing its features. In this context, the dimensions of the single-span PE (polyethylene) covered greenhouse with a spring roof used for modelling are presented in Table 1.

Table 1. Dimensions and calculated values of the greenhouse used in modelling

| | |
|---|---|
| Greenhouse's Width (m) | 9.6 |
| Greenhouse's Length (m) | 60 |
| Greenhouse's Floor Area ($m^2$) | 576 |
| Greenhouse's Height (m) | 3 |
| Greenhouse's Ridge height (m) | 4 |
| Greenhouse's Cover Surface Area ($m^2$) | 980 |

In the study, the analyses were performed in 2 steps. In the first step, whether the difference between minimum temperatures for Antalya and the basin was statistically significant and whether the temperatures showed significant differences on the basis of months, days and years were determined by the one way and two way analysis of variance; then, based on this determination, the effective heat consumption was calculated according to the unit greenhouse area according to Zabeltitz (1988), and the results obtained were interpreted for Antalya and the Tigris basin. In the second step of the study, 10 years (2006-2015) daily minimum temperatures in Antalya, Siirt, Mardin, Diyarbakir, Sirnak and Batman provinces were analyzed with the two-way analysis of variance. The actual values of the outer environment temperature and total radiation were taken into account to determine the heat consumption accurately. The energy required to heat the greenhouse is provided by solar radiation and additional heating system. The Zabeltitz 1988 formula was used for the effective heat consumption (qh). In this formula, whether u, Ac, Ag, ti, τ and γ values changed, in other words, the change of the outer environment air temperature (°C) and solar radiation (W/m$^2$) by years and the differences that could be shown by the resulting heating load in Antalya province and the Tigris basin were examined. Accordingly:

$$qH = \frac{Ac}{Ag}.u.(t_i\text{-}t_{oeff}) - I.\tau.\gamma$$

where:
$q_H$ is the Heating Load (W/m$^2$);
u: total heat consumption coefficient (W/m$^2$ K) (Single-layered PE was taken as u: 7);
Ac: greenhouse cover surface area (m$^2$) (taken as 980 m$^2$);
Ag: greenhouse's floor area (m$^2$) (taken as 576 m$^2$);
$t_i$: Greenhouse's ambient temperature (°C) (Indoor temperature of 15°C was taken as a constant);
$t_{oeff}$: actual outer environment temperature (°C)
I: solar radiation (W/m$^2$);
τ: Radiation transmittance of the greenhouse (taken as 0.65 for the greenhouses covered with single-layered PE);
γ: the ratio of solar radiation entering into the greenhouse which is effective in the increased indoor temperature (taken as 0.6). The heat consumption qH (W/m$^2$) and the actual outer environment temperature of the greenhouse were calculated on a daily basis using the Excel program for Antalya and provinces in the Tigris basin between 2006 and 2015, and the differences between these values were analysed by the analysis of variance.

## RESULTS AND DISCUSSION

Our country is fortunate compared to many countries in terms of its potential for solar energy due to its geo Figureal location. It has been determined that Turkey's average annual sunshine duration is 2640 hours (daily total of 7.2 hours), average annual total solar radiation is 1311 kWh/m$^2$-year (daily total 3.6 kWh/m$^2$) according to a study conducted by EIE by taking advantages of the sunshine duration and the ray intensity data measured in the General Directorate of State Meteorology Affairs in the years 1966-1982. (Figure 2) (Anonymous, 2016).

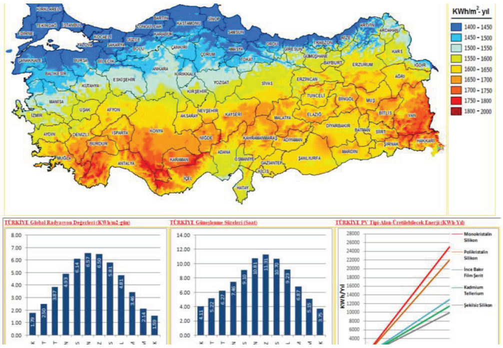

Figure 2. Turkey Sunshine Energy Potential

Greenhouse production can be performed in 2 different periods or in one period. With respect to planting during the autumn season, production is performed in October, November, December and January. In particular, December and January are the months during which the minimum temperatures affecting the yield in the greenhouse take place. Therefore, the minimum temperatures that may especially occur during these months were examined in our study. Descriptive statistics are presented for the 10 years (2006-2015) daily minimum temperatures in Antalya, Siirt, Mardin, Diyarbakir, Sirnak and Batman provinces (Table 2). While the average minimum temperature for Antalya province was 16.90°C in October, the closest value to it was determined to be 15.36°C in Mardin province. The minimum temperatures required for the growth and development of seedlings in the greenhouse cultivation in October are compatible for Antalya and the Tigris basin.
As the minimum temperature, there is a difference of 6.39°C between Antalya province with the highest value and Diyarbakir province with the lowest value.
Accordingly, the temperatures required for the growth of the seedling are suitable for Antalya and the Tigris basin (Figure 3).

Table 2. Some descriptive statistics of 10 years (2006-2015) daily minimum temperatures

| City | | | January | February | Mart | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Antalya | N | Valid | 277 | 275 | 307 | 299 | 306 | 296 | 309 | 309 | 299 | 309 | 298 | 296 |
| | | Missing | 33 | 35 | 3 | 11 | 4 | 14 | 1 | 1 | 11 | 1 | 12 | 14 |
| | Mean | | 7.09 | 7.87 | 9.59 | 12.57 | 16.49 | 21.10 | 24.23 | 25.03 | 21.24 | 16.90 | 12.03 | 8.66 |
| | St. Deviation | | 2.99 | 3.29 | 2.69 | 2.43 | 2.77 | 2.98 | 2.23 | 2.04 | 2.45 | 2.84 | 3.41 | 3.13 |
| | Minimum | | -.60 | -.90 | 1.80 | 5.40 | 9.50 | 14.90 | 18.10 | 19.20 | 14.60 | 9.30 | 1.00 | 1.20 |
| | Maximum | | 13.40 | 28.00 | 15.40 | 23.20 | 23.40 | 29.80 | 31.20 | 30.30 | 28.40 | 24.10 | 18.50 | 18.00 |
| | % 25 | | 4.90 | 6.00 | 7.80 | 10.90 | 14.40 | 18.83 | 22.80 | 23.50 | 19.70 | 15.10 | 9.78 | 6.60 |
| | % 50 | | 7.70 | 8.10 | 9.70 | 12.60 | 16.50 | 20.50 | 24.20 | 24.90 | 21.20 | 16.70 | 12.30 | 9.20 |
| | % 75 | | 9.65 | 10.10 | 11.50 | 14.00 | 18.70 | 23.30 | 25.80 | 26.30 | 23.00 | 19.10 | 14.53 | 10.70 |
| Batman | N | Valid | 308 | 282 | 303 | 297 | 307 | 297 | 308 | 306 | 300 | 305 | 296 | 308 |
| | | Missing | 2 | 28 | 7 | 13 | 3 | 13 | 2 | 4 | 10 | 5 | 14 | 2 |
| | Mean | | -2.46 | .23 | 3.27 | 7.07 | 10.52 | 15.52 | 20.03 | 19.91 | 15.03 | 10.74 | 3.50 | -1.05 |
| | St. Deviation | | 5.76 | 4.55 | 4.18 | 3.87 | 3.29 | 3.24 | 3.01 | 2.65 | 3.27 | 3.59 | 4.57 | 5.55 |
| | Minimum | | -24.0 | -10.6 | -8.50 | -4.60 | 3.60 | 8.00 | 12.50 | 12.80 | 4.60 | 1.50 | -7.60 | -23.0 |
| | Maximum | | 8.80 | 11.40 | 15.40 | 19.20 | 23 | 25.40 | 33.10 | 31.10 | 26.80 | 21.20 | 17.50 | 10.30 |
| | % 25 | | -6.48 | -2.85 | .50 | 4.60 | 8.20 | 13.20 | 18.30 | 18.20 | 12.80 | 8.50 | 0.40 | -4.70 |
| | % 50 | | -2.70 | .60 | 3.00 | 7.00 | 10.20 | 15.50 | 19.80 | 20.00 | 15.20 | 10.90 | 3.00 | -1.15 |
| | % 75 | | 1.80 | 3.60 | 6.20 | 9.55 | 12.50 | 17.70 | 21.58 | 21.63 | 17.00 | 13.05 | 6.48 | 3.00 |
| Diyarbakir | N | Valid | 300 | 282 | 310 | 300 | 307 | 296 | 310 | 309 | 289 | 301 | 298 | 310 |
| | | Missing | 10 | 28 | 0 | 10 | 3 | 14 | 0 | 1 | 21 | 9 | 12 | 0 |
| | Mean | | -3.10 | -.56 | 2.59 | 6.49 | 10.79 | 16.65 | 21.46 | 20.96 | 15.83 | 10.51 | 3.52 | -1.17 |
| | St. Deviation | | 5.21 | 3.97 | 3.50 | 3.39 | 2.85 | 3.16 | 2.44 | 2.46 | 3.01 | 2.83 | 3.95 | 5.27 |
| | Minimum | | -22.1 | -21.0 | -5.00 | -4.20 | 4.50 | 8.80 | 13.50 | 13.80 | 4.20 | 2.40 | -7.70 | -23.4 |
| | Maximum | | 8.20 | 7.30 | 11.80 | 19.00 | 19.70 | 25.90 | 29.40 | 27.00 | 25.10 | 18.50 | 13.00 | 9.20 |
| | % 25 | | -6.18 | -2.85 | -.10 | 4.30 | 8.90 | 14.40 | 19.90 | 19.40 | 13.95 | 8.75 | -0.98 | -4.10 |
| | % 50 | | -3.00 | -.05 | 2.45 | 6.40 | 10.80 | 16.45 | 21.50 | 21.00 | 15.80 | 10.40 | 3.45 | -1.00 |
| | % 75 | | .40 | 2.40 | 4.90 | 8.70 | 12.90 | 18.90 | 23.10 | 22.60 | 17.80 | 12.35 | 6.00 | 2.52 |
| Siirt | N | Valid | 309 | 282 | 302 | 300 | 310 | 299 | 310 | 308 | 297 | 306 | 298 | 308 |
| | | Missing | 1 | 28 | 8 | 10 | 0 | 11 | 0 | 2 | 13 | 4 | 12 | 2 |
| | Mean | | .34 | 2.03 | 5.82 | 9.95 | 14.74 | 20.56 | 24.20 | 24.46 | 19.75 | 13.69 | 6.78 | 2.09 |
| | St. Deviation | | 3.60 | 3.31 | 3.61 | 3.43 | 2.99 | 2.51 | 1.95 | 1.87 | 3.00 | 2.99 | 3.05 | 3.62 |
| | Minimum | | -11.0 | -7.20 | -3.60 | .70 | 8.00 | 11.80 | 17.70 | 19.40 | 8.50 | 6.30 | -1.50 | -11.1 |
| | Maximum | | 9.20 | 10.10 | 17.00 | 22.40 | 25.00 | 27.50 | 31.00 | 29.40 | 26.10 | 22.00 | 15.80 | 11 |
| | % 25 | | -2.00 | -0.03 | 3.48 | 7.70 | 12.60 | 18.90 | 22.90 | 23.20 | 18.20 | 11.50 | 4.68 | -0.10 |
| | % 50 | | 0.70 | 2.15 | 5.70 | 9.90 | 14.70 | 20.60 | 24.20 | 24.70 | 20.00 | 13.65 | 7.10 | 2.30 |
| | % 75 | | 2.90 | 4.30 | 8.03 | 12.00 | 16.80 | 22.40 | 25.40 | 25.70 | 21.70 | 15.73 | 9.00 | 4.48 |
| Mardin | N | Valid | 305 | 281 | 299 | 297 | 308 | 297 | 309 | 306 | 301 | 301 | 297 | 308 |
| | | Missing | 5 | 29 | 11 | 13 | 2 | 13 | 1 | 4 | 9 | 9 | 13 | 2 |
| | Mean | | 1.58 | 2.68 | 6.22 | 10.73 | 15.83 | 21.44 | 25.34 | 26.18 | 21.43 | 15.36 | 8.18 | 3.67 |
| | St. Deviation | | 3.34 | 3.56 | 4.12 | 4.39 | 3.65 | 3.05 | 3.06 | 2.69 | 3.83 | 3.89 | 3.57 | 3.45 |
| | Minimum | | -7.80 | -7.60 | -3.70 | -0.10 | 7.30 | 13.30 | 16.60 | 17.90 | 8.10 | 5.10 | -1.70 | -7.80 |
| | Maximum | | 8.10 | 11.40 | 18.70 | 25.00 | 25.60 | 29.60 | 33.30 | 32.10 | 29.60 | 26.40 | 16.50 | 15.10 |
| | % 25 | | -0.35 | 0.70 | 3.60 | 7.75 | 13.40 | 19.40 | 23.45 | 24.20 | 19.00 | 12.95 | 5.55 | 1.80 |
| | % 50 | | 2.00 | 2.70 | 5.80 | 10.30 | 15.80 | 21.30 | 25.60 | 26.35 | 22.00 | 15.50 | 8.80 | 4.00 |
| | % 75 | | 4.00 | 5.00 | 9.00 | 13.45 | 18.30 | 23.50 | 27.30 | 28.03 | 24.00 | 18.35 | 10.65 | 5.80 |
| Sirnak | N | Valid | 309 | 266 | 306 | 299 | 310 | 297 | 306 | 308 | 300 | 305 | 277 | 310 |
| | | Missing | 1 | 44 | 4 | 11 | 0 | 13 | 4 | 2 | 10 | 5 | 33 | 0 |
| | Mean | | -0.58 | 0.39 | 4.05 | 8.44 | 13.87 | 19.99 | 23.79 | 23.97 | 19.01 | 12.64 | 5.36 | 1.36 |
| | St. Deviation | | 3.96 | 3.94 | 4.23 | 4.52 | 3.91 | 3.37 | 2.99 | 3.10 | 4.22 | 3.75 | 4.10 | 4.06 |
| | Minimum | | -14.5 | -9.60 | -7.20 | -2.60 | 1.80 | 10.00 | 15.00 | 15.00 | 3.20 | 2.00 | -3.00 | -9.80 |
| | Maximum | | 11.50 | 11.00 | 16.10 | 19.00 | 21.30 | 28.00 | 31.50 | 29.50 | 27.10 | 22.60 | 15.30 | 15.10 |
| | % 25 | | -3.10 | -2.03 | 1.10 | 5.20 | 11.48 | 17.60 | 21.50 | 22.20 | 16.60 | 10.05 | 2.50 | -1.80 |
| | % 50 | | -0.20 | 0.40 | 3.90 | 8.40 | 14.10 | 20.30 | 24.20 | 24.80 | 19.65 | 12.40 | 5.00 | 1.80 |
| | % 75 | | 2.30 | 2.73 | 7.00 | 12.00 | 16.73 | 22.50 | 26.00 | 26.00 | 21.98 | 15.40 | 8.15 | 3.83 |

The average minimum temperature in November was 12.03°C for Antalya, and the lowest average in the Tigris Basin was 3.52°C in Diyarbakir province.

Accordingly, heating must be performed in Diyarbakir and Batman provinces as the average of the Tigris Basin was below 5°C although heating is not performed in Antalya during this month (Figure 4).

Heating must be performed for 15 days in Diyarbakir province as half the month of November was between -0.98°C and 6.0°C compared to Antalya.

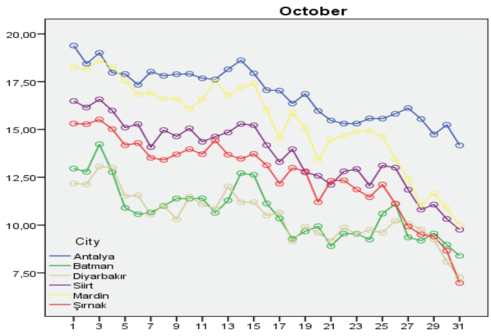


Figure 3. Average minimum temperature for study area in October

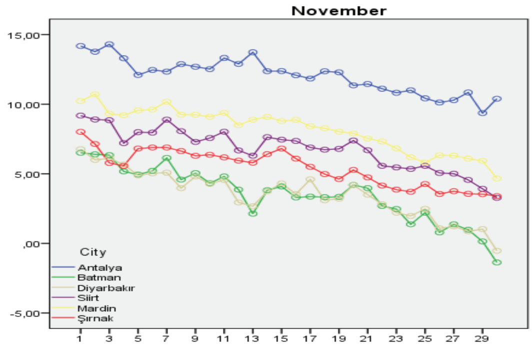


Figure 4. Average minimum temperature for study area in November

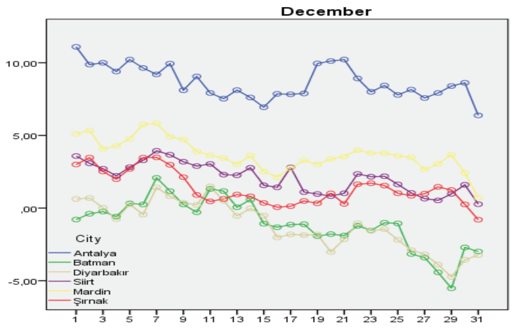


Figure 5. Average minimum temperature for study area in December

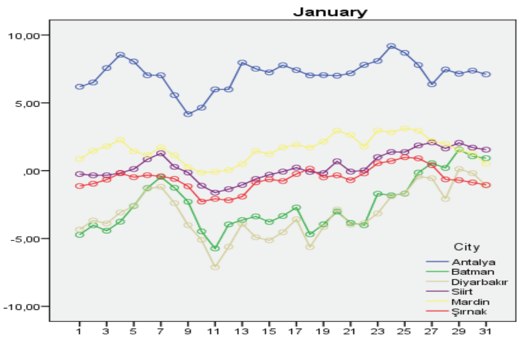


Figure 6. Average minimum temperature for study area in January

The fact that Diyarbakir province has continental climate especially leads to the increase in temperature difference between night and day, and this also reveals the need for heating in the greenhouse.

As a continuation of this study, the energy costs resulting from heating can be considered as another research subject. In December, the minimum temperature average of the Tigris Basin was found to be 0.98°C. Accordingly, while heating is not performed in Antalya province in December, the heating load was calculated to be 20543.28 W/m$^2$ according to the minimum temperature averages of the Tigris Basin, and 15.2%, 18%, 19.32%, 23.65% and 28.83% of it were calculated to be the heating load required in Mardin, Siirt, Sirnak, Batman and Diyarbakir provinces, respectively, for the greenhouse with a floor area of 576 m$^2$ (Figure 5).

While the average minimum temperature for Antalya province was 7.09°C in January, the closest value to it was determined to be 1.58°C in Mardin province. Accordingly, it was found out that there was a difference of 1968.67 W/m$^2$ per month between Antalya and Mardin depending on the heating loads (Figure 6).

In the other provinces, 2463.70 W/m$^2$, 2803 W/m$^2$, 3126 W/m$^2$ and 3221.82 W/m$^2$ monthly heating load differences took place in Siirt, Sirnak, Batman and Diyarbakir, where the highest temperature difference was experienced, respectively. It can be seen from here that Antalya uses the heating load input, which is an important criterion for vegetable growing in the greenhouse, at the lowest level.

In the second step of the study, 10 years (2006-2015) daily minimum temperatures in Antalya, Siirt, Mardin, Diyarbakir, Sirnak and Batman provinces were analysed by the two-way analysis of variance method. According to the results obtained, the average minimum temperature for each month showed a statistically significant difference according to the provinces ($p < 0.01$). The Duncan multiple comparison test was applied to the temperature averages at $\alpha = 0.05$ significance level according to the provinces. The result of the the Duncan test is presented in (Table 3).

Table 3. Duncan Multiple Comparison test results

| City | January ($\bar{x} \pm ss$) | October ($\bar{x} \pm ss$) | November ($\bar{x} \pm ss$) | December ($\bar{x} \pm ss$) |
|---|---|---|---|---|
| Antalya | 7.1±3.0 a | 16.9±2.8 a | 12.0±3.4 a | 8.7±3.1 a |
| Batman | -2.5±5.8e | 10.7±3.6 e | 3.5±4.6 e | -1.0±5.6 e |
| Diyarbakir | -3.1±5.2 e | 10.5±2.8 e | 3.5±3.9 e | -1.2±5.3 e |
| Mardin | 1.6±3.3 b | 15.4±3.9 b | 8.2±3.6 b | 3.7±3.5 b |
| Siirt | 0.3±3.6 c | 13.7±3.0 c | 6.8±3.0 c | 2.1±3.6 c |
| Sirnak | -0.6±4.0 d | 12.6±3.7 d | 5.4±4.1 d | 1.4±4.1 d |

As can be seen from Table 3, the province of Antalya has a statistically significant difference from the other provinces with a minimum temperature of four months. In terms of minimum temperature, the province of Antalya is followed by Mardin, Siirt and Sirnak. There is no statistically significant difference between Batman and Diyarbakir in terms of this feature and they are at the end of the order. It is aimed to determine the difference between the Duncan test and sample averages. Accordingly, Mardin, which provides the closest value to the province of Antalya, has been identified as the most suitable location in the area of research.

## CONCLUSION

It was determined that the minimum temperatures of January of Antalya were between 9.65°C and 4.90°C for 15 days and that it was not different from the minimum value of 5°C suitable for greenhouse cultivation. However, minimum 5°C did not take place for the Tigris basin, the minimum temperature was between -6.48 and 1.80°C for Batman province, between -6.18 and 0.40°C for Diyarbakir province, between -0.35 and 4.0°C for Mardin province, between -2.0 and 2.90°C for Siirt province and between -3.0 and 2.30°C for Sirnak province. While there is not too much need to perform heating in the greenhouse in the mid-January in Antalya province, it is necessary to perform heating in the provinces in the Tigris basin.

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