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Research Article

Greenhouse Climatization in Different Climate Regions in Turkey

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ABSTRACT

For profitable production, greenhouses must be heated, particularly during the winter in all the zones in Turkey, and the high load of heating was calculated in zone III. Throughout all Turkey zones, ventilation plays a role in regulating the greenhouse climate for a part of the year. The cooling load (in hours) was calculated to be high in zone II compared to other zones, and the Fan&Pad system is more effective in this zone, however, in Zone III it is possible to control the temperature to the comfort levels by using a short-term fog cooling system.

Keywords: Greenhouse, Heating, Ventilation, Cooling

Türkiye'de Farklı İklim Bölgelerinde Sera Iklimlendirmesi

ÖZ

Kazançlı üretim için, Türkiye’nin tüm bölgelerinde kış aylarında seraların ısıtılması gereklidir, ayrıca III. Bölgede yüksek ısıtma yükü hesaplanmıştır. Tüm Türkiye bölgelerinde havalandırma, yılın bir dönemde sera ikliminin düzenlenmesinde rol oynamaktadır. II. Bölge’de soğutma yükünün (saat olarak) diğer bölgelere göre yüksek olduğu hesaplanmış ancak bu Bölge'de fan-ped sistemi daha etkilidir. III.Bölge'de kısa süreli sisleme soğutma sistemi kullanılarak sıcaklığın konfor seviyelerine kadar kontrol edilmesi mümkündür.

Anahtar Kelimeler: Sera, Isıtma, Havalandırma, Soğutma

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Introduction

Due to the overuse of agricultural land, rapid population growth, and subpar product quality, measures that will increase production must be implemented. These measures include providing and distributing the materials required for adopting modern agricultural technology, raising the production of fruits and vegetables, and significantly increasing the greenhouse area (Nasrollahi et al., 2021). The primary objective of a greenhouse is to enhance yields during the non-cultivation season, which can be achieved by maintaining the optimal temperature throughout the crop's life cycle understanding the microclimate and its characteristics is necessary to keep the greenhouse running at its best during the different stages of plant development. To create a practical physical model, it is imperative to have accurate calculations of solar radiation, mass transfer coefficients, and heat transfer coefficients because these factors have a significant impact on the greenhouse energy and mass balance (Su and Xu, 2017; López-Cruz et al., 2018).

Accurate knowledge about plant requirements at different growth stages, and under various light conditions, can contribute to the design of adaptive control strategies for more cost-effective and competitive production. The production's ability to succeed depends directly on the greenhouse's environment, which must have the ideal values of light, temperature, ventilation, and moisture, the temperature is one of these aspects that should be established within the greenhouse since it is one of the most crucial climatological factors (Nasrollahi et al., 2021). Greenhouse inside air temperature depends mainly on the outside climatic conditions (ambient temperature and solar radiation) and greenhouse design parameters (Choab et al., 2019). By operating at the ideal temperature for each stage of the crop, the greenhouse may merely produce a higher yield outside of the crop-growing season. To achieve this, the right heating or cooling technique must be used (Paksoy and Beyhan, 2015; Hassanien et al., 2016). Higher indoor air temperatures are required for optimal plant development in cold areas. By maintaining the greenhouse effect or by employing any suitable heating technique, these temperatures can be reached. The greenhouse effect, on the other hand, is only necessary for two to three months at a time in hotter places, with the remaining months necessitating the usage of more efficient cooling technology (Aljubury and Ridha, 2017; Zhou et al., 2017). The most significant cost that influences greenhouse farming's profitability is heating, because of this, it might not be economical for plants in some locations to use heating operations to satisfy their needs. To protect plants from potential frost hazards, the technique should only be utilized in specific locations (Canakci et al., 2013; Yagcıoglu, 2005). While ambient temperatures can reach 38°C, Ajwang and Tantau (2004) , Kittas et al., (2005) found that temperatures within a greenhouse without a climate controller maybe 20-30°C greater than those outside. Temperatures are slightly increased by 2 to 4°C in greenhouses compared to open spaces, according to data from the study by Shamshiri et al. (2018), daytime temperatures in greenhouses are noticeably higher than in open spaces. The temperature difference in a greenhouse that is not ventilated and heated to a certain temperature varies depending on the heat stored in the greenhouse. During the day, this difference is significant, while it is exceptionally low at night because of the lack of solar radiation.

The temperature, relative humidity, and CO_2 required for optimal plant growth are controlled through greenhouse ventilation. When the relative humidity of the outside air is lower than that in the greenhouse, the ventilation replaces the greenhouse air with outside air until the equilibrium point between the humid indoor and outdoor air in the greenhouse is established (H. Zhang et al., 2021). Therefore, natural or mechanical ventilation theoretically reduces the greenhouse temperature close to the outside temperature. For this reason, ventilation helps to provide the necessary comfortable environment for plants not only during hot periods but also during the production period (Shamshiri, 2013). When the average daily temperature is between 12 and 22 ℃, it is possible to provide suitable conditions with ventilation for the plants in the greenhouse, while the temperature difference reached in empty greenhouses with good ventilation is 2-3℃, it can be reduced to 1-2℃ in fully planted greenhouses (Baytorun ve ark., 2000, 2017; Zabeltitz, 2011).

Greenhouse cultivation in hot climates is characterized by the heat load caused by high solar radiation, which creates major problems in the greenhouse environment and restricts plant growth. Temperatures should not be below 12℃ or above 30℃ in the greenhouse for optimum growth of plants and quality crops (Costantino et al., 2021). In this context, it is necessary to remove the excessive heat load from the greenhouse during hot periods.

In regions where the temperature is not too high, natural ventilation is the most common and least expensive technique for creating a moderate greenhouse climate (Baytorun et al., 2019). However, natural ventilation is not sufficient to remove excessive heat load from the greenhouse during periods of high solar radiation. Cooling is required to keep the temperature and water budget at an optimum or near-optimal value in the greenhouse (Baytorun et al., 2019). In case the daily average temperature rises above 22℃ or the maximum temperature above 27℃, active cooling should be done in greenhouses (Kittas et al., 2013).

In this study, to answer the question of ventilation, heating, or cooling? In greenhouses, the required year-round acclimatization for model modern plastic greenhouses was determined by considering meteorological data for the different regions in Turkey.

Methodology

Temperature management and adaptation for day and night in greenhouses are necessary for optimal plant development, all environmental management systems strive to promote plant development and deliver a mature harvest promptly, with the desired quality that the producer's market requires. However, to react to daily variations in climatic conditions, micrometeorological parameters must be precisely monitored. Maintaining temperatures, relative humidity, light, and CO_2 as close as possible to the ideal point for crop development is known as climate control. A greater emphasis has been placed on precise environmental control of greenhouses because of the global energy crisis to avoid high energy usage and, as a result, economic losses. The distribution of solar radiation depending on the time of the year is of great importance for the selection and design of the appropriate systems in greenhouse air conditioning, for the determination of plant growth and water requirement. Another climate parameter that affects plant growth in greenhouses is air temperature. The temperature in a region varies depending on solar radiation, seasons, latitude, and altitude above sea level, distance to the sea, wind intensity, and cloudiness. For suitable plant growth in the greenhouse, the temperature values should be between 17-27℃ (Shamshiri et al., 2018). Throughout the entire year, a variety of greenhouses are in use for growing plants like tomatoes, cucumbers, lettuce, peppers, or even flowers.

In this study, different mathematical models have been used to predict the behavior of the environmental variables in high-tech greenhouses in diverse climatic areas of Turkey following TS 825 standards. Using the models, it was possible to determine how much air conditioning is required. Calculations were performed using meteorological data (solar radiation, ambient air temperature, humidity, and wind velocity), as well as technical/thermal characteristics of the greenhouses.

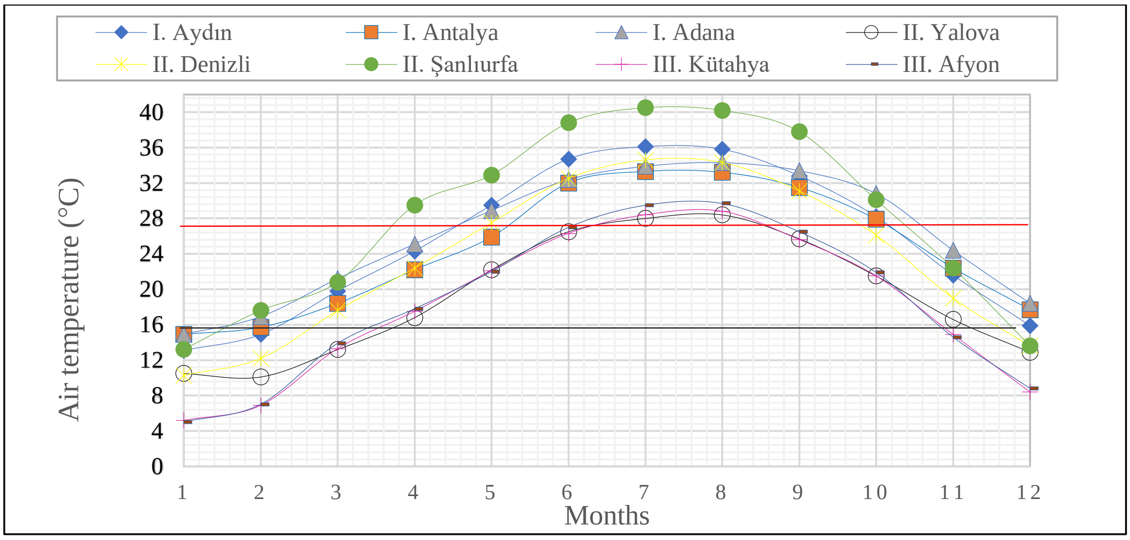

Figure 1. Monthly maximum temperature values of provinces in different climate zone

Figure 1 shows that ambient air temperatures may be extremely high, exceeding 27 °C in the summer times, and cooler months dip to below 16°C. In these conditions, to maintain the inside temperature at levels that are optimal for the crop, cooling and heating systems must be used, the most popular system is forced or natural ventilation. The efficient utilization of information is essential to the success of system assessments in greenhouse automation and control. Reducing the unnecessary energy needed for greenhouse heating and cooling, particularly in areas with unfavorable climatic conditions, is crucial for preserving market competitiveness. As expected during the summer months the heating loads are equal to zero, while the cooling loads are not eliminated during the winter.

Heating Calculations

Generally, heating demands have been calculated based on the outside temperature, which is different from the indoor temperature environment due to the greenhouse effect. In this study, in the greenhouse monthly and seasonal heating requirements were estimated in the different climatic regions based on the inside temperature. However, with the aid of the developed heating model (Equation 1), the heat stored in the greenhouse during the day was taken in the heating calculation.

$$q = \sum_{n=1}^{8760} \left(\frac{A_c}{A_G} * U_{cs} * \left(\theta_{i_n} - \theta_{i,oH_n} - \Delta\theta_{sp_n}\right) * \left(1 - EE_{ES_n}\right) \right) * t_{si} \tag{1}$$

q: Heat energy requirement [W.m^{-2}]

θ_{i_n}: The desired temperature in the greenhouse [°C]

θ_{i,oH_n}, the temperature in the greenhouse that is not heated and ventilated to a certain temperature [°C]

$\Delta\theta_{Sp}$: Temperature rise due to the characteristics of the greenhouse [°C]

U_{cs}: Heat requirement coefficient [W m^{-2} K^{-1}]

A_c: The cover surface area [m^{-2}]

A_G: The greenhouse ground area [m^{-2}]

EE_{ESN}: Heat saving provided by the night curtain

n: Hours of the year

t_{Si}: Time zone in simulation (1 h)

Ventilation Calculations

In the study, the ventilation model that was developed based on the energy balance (Equation 2) and the Bernoulli equation (Equation 3) was used to calculate the maximum inside temperature and the period (h) when the temperature is higher than 22°C in high-tech greenhouses at different ventilation opening ratios, in addition, to calculate the ventilation rate according to the size, location, and wind speed at the ventilation openings. To define the effectiveness of ventilation in controlling greenhouse temperature, the climate values of the climatic zone defined were used in the ventilation model that was developed based on the following equations, the data required for the calculations are defined which is such as the greenhouse size information, cover material information, ventilation system information, climate, and location information, and other data are defined.

The air change created by the pressure difference in the greenhouses is expressed by Equation 2 according to the energy balance method when the heat flux to the soil and the heat energy used in photosynthesis (2%-3%) are neglected. The ventilation rate that occurs as a result of the wind effect and the dimensions of the ventilation flaps is calculated with the help of Equation 3. Equation 4 is created by equalizing the ventilation rate that is determined by the energy balance technique (Equation 2) with the number of air changes determined by the Bernoulli equation (Equation 3). In the study, using Equation 4, the temperature difference that can be reached depending on the ratio of the ventilation opening area of the greenhouse floor area was calculated

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$$\tau * \mathrm{I_o} = \mathrm{U} * \frac{\mathrm{A_C}}{\mathrm{A_G}} * \Delta\mathrm{T} + \mathrm{V_A} * \mathrm{c_p} * \rho * \Delta\mathrm{T} + \mathrm{E_V} * \mathrm{f} * \tau * \mathrm{I_o} \tag{2}$$

V_A: Ventilation rate
τ: Permeability of the cover material (-),
I_o: Solar radiation intensity ($W.m^{-2}$),
c_p: Specific heat of the air ($Wh.kg^{-1}K^{-1}$),
ρ: Density of air ($kg.m^{-3}$),
ΔT: Indoor-outdoor temperature difference (°C),
U: Heat transfer coefficient of the cover material ($W.m^{-2}K^{-1}$),
A_C: cover surface area (m^2),
E_V: Evaporation coefficient (-),
f: Vegetation factor (-).

$$\mathrm{V_A} = \frac{\mathrm{A_V}}{2 * \mathrm{A_G}} * \mathrm{C_d} * \mathrm{v_w}\sqrt{\mathrm{C_w}} * \left(\varepsilon * (2-\varepsilon)\right) \ (\mathrm{m^3/m^2 s}) \tag{3}$$

A_V: Ventilation opening area (m^2),
A_G: Ventilation opening area
ε: Porosity coefficient,
v_w: Wind speed ($m.s^{-1}$),
C_w: Wind effect coefficient (-),
C_d: Discharge coefficient (-).

$$\frac{A_V}{A_G} = \frac{2}{c_p * \rho * v_w * C_d\sqrt{C_w} * \left(\varepsilon * (2-\varepsilon)\right)} * \left[\frac{\tau * I_o(1 - E * f)}{\Delta T} - \frac{A_C}{A_G} * U\right] \tag{4}$$

Cooling Calculations

When the average daily temperature rises above 22°C and 27°C in naturally ventilated greenhouses, cooling measures must be taken to create desirable conditions for the plant. In evaporative cooling, the necessary parameters for the system could be determined by the model that has been developed according to the psychometric equations. In any climate zone, if a high-tech greenhouse is equipped with evaporative cooling, the data such as the external climatic conditions (the temperature, relative humidity) and greenhouse information, the size and effectiveness of pads used in the greenhouse could be used with the help of the developed program to evaluate the system efficiency.

Results and discussions

The climate of the relevant place should be examined to determine the suitability of the place where the greenhouse will be established in terms of climate and to determine the air-conditioning measures to be taken. The climate charts prepared for this purpose are compared with the monthly average daily air temperatures and the daily total solar radiation. From the graphs that could be obtained, it is possible to determine the heating, ventilation, shading, and cooling times for various plant species, as well as to determine the climate measures to be taken in greenhouses depending on the months. For this reason, climate data is a potentially useful tool in the primary assessment of suitability for greenhouse cultivation in greenhouses (S. Zhang et al., 2020).

Heating

It's crucial to maintain a comfortable greenhouse interior temperature during the growing season. Heating activities should be carried out at the time when the inside temperature is below 16°C (Fig.1), which is considered to be the ideal temperature for greenhouse vegetable production (Canakci et al., 2013). The grower occasionally can maintain an interior temperature above 16°C and due to economic concerns, it could be necessary to maintain this temperature below 16°C for a while because during the growing season the price of a harvested commodity may decrease, or energy prices could rise.

To figure out how the heating activities are important, the climatic data in different climatic zones of Turkey which are divided according to TS 825 standards was used in the modeling, the period of the temperature in hours when it is lower than 16℃ under outside conditions. Fig.2 shows that, the heating operation must be carried out between November and April in zone I, October and May in zone II, and September and May in zone III. The period required for the greenhouse's heating operation relies on both the temperature and the amount of solar energy received, zone III has the lowest night temperature values and needs heating operations more than the others. The model was used to predict the heating period based on the temperature inside greenhouses that are not heated and ventilated to a certain temperature in the months of the year. in zone I, During the year, the temperature in the outdoor environment (θ_o) is below 16 °C at 3686 hours in zone I, 4544 h in zone II, and 6060 h in zone III, due to the greenhouse effect ($\theta_{i,oH}$) These periods became 2691h, 3361 h, and 4522h in zone I, zone II and zone III respectively.

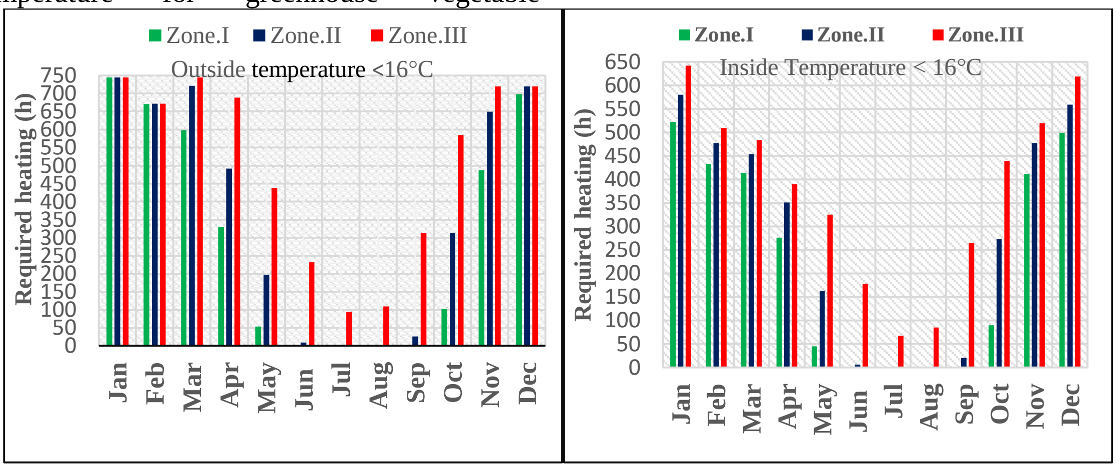

Figure 2. The average periods (in hours) when the outside temperature and the inside temperature are below 16 °C in different climate zone

To predict the effect of energy stored during the day at the inside temperature at night, the required heating periods are calculated based on the temperature inside greenhouses by taking into account the temperature rises ($\Delta\theta_{Sp}$) during the night. Fig.3 demonstrates that in Antalya climatic conditions, to keep the temperature in the greenhouse at a minimum of 16°C, the required for heating throughout the year will be 3491 h according to the outside temperature, however considering the greenhouse effect the heating load as time decreases to 2683 h. the heat energy that is stored in the greenhouse during the day causes the temperature of the greenhouse to rise, which is taken into consideration in the calculations done by the heating model, the calculated heating period was 2427 h which is different from the findings of Canakci et al, (2013) who indicated that as 321 h, the variations in the results might be attributable to the fact that in his study the calculation utilized the mean high daily temperature and ignored temperature rises throughout the night.

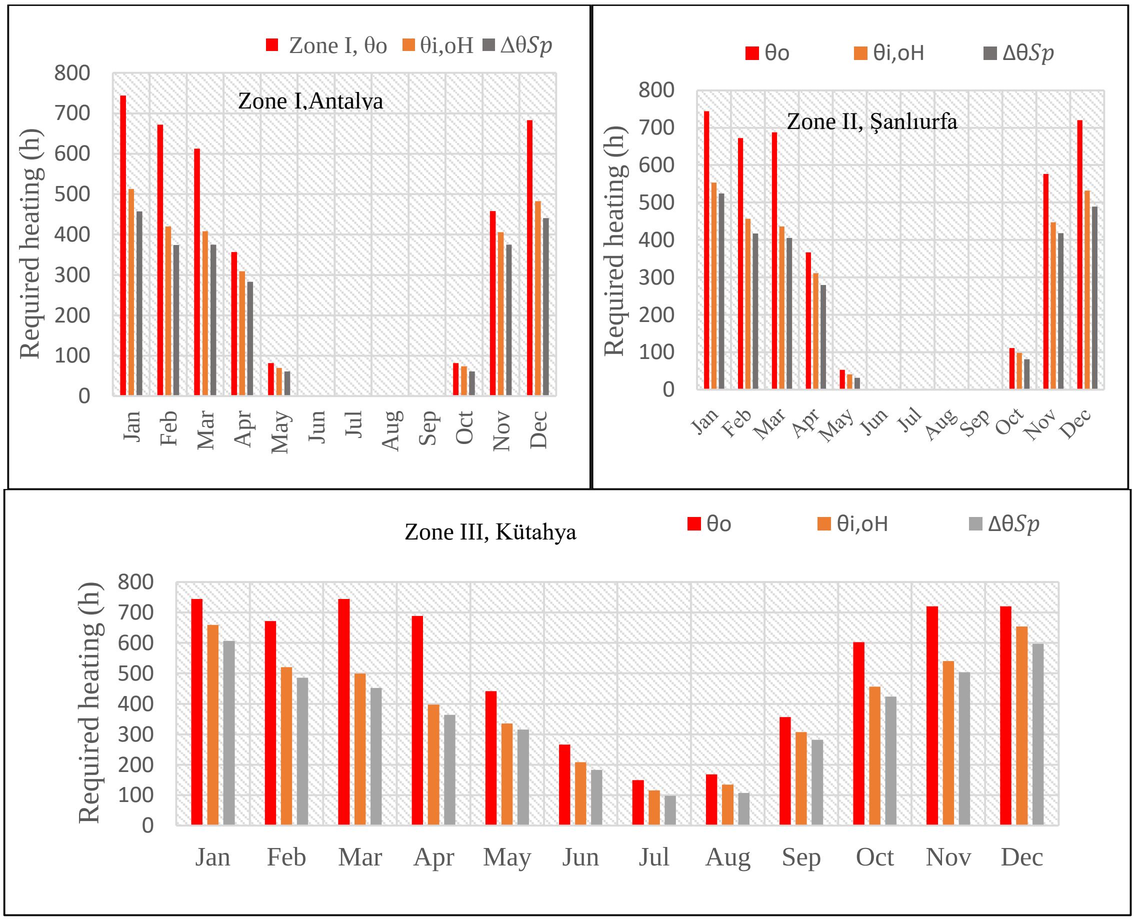

Figure 3. The required heating load (in hours) in different climate conditions

Under the climatic conditions of Şanlıurfa, the temperature drops below 16°C for 3931h throughout the year, this value becomes 2875h in the greenhouse covered with PE due to the greenhouse effect, however, considering the temperature rise in the greenhouse at night, this value decreases to 2646 h. In Kütahya climatic conditions, the outside air temperature drops below 16°C for 6273 h, while it stays below 16°C for 4827 hours in the greenhouse. However, considering the temperature rise in the greenhouse, the temperature in the greenhouse tends to be below 16°C at 4419h (Fig.3).

To assess the relationship between the required heating in hours and climate zones, random locations are selected to calculate the heating requirement. Fig.4 shows that, the shortest heating periods are shown in zone I, and the longest happened in zone III. The heating energy consumption varies across different climate zones, which is more remarkable during the cold months. It was found that a significant difference occurs in January (Nasrollahi et al., 2021). Considering the climate data, the increase in heating operation is observed when the heating is applied at a high set point which leads to an increase in the cost. However, measures including heat conservation in the greenhouses can be taken to reduce heating requirements and lower costs. Generally, Heating is not carried out in the daytime due to the sufficient intensity of solar radiation.

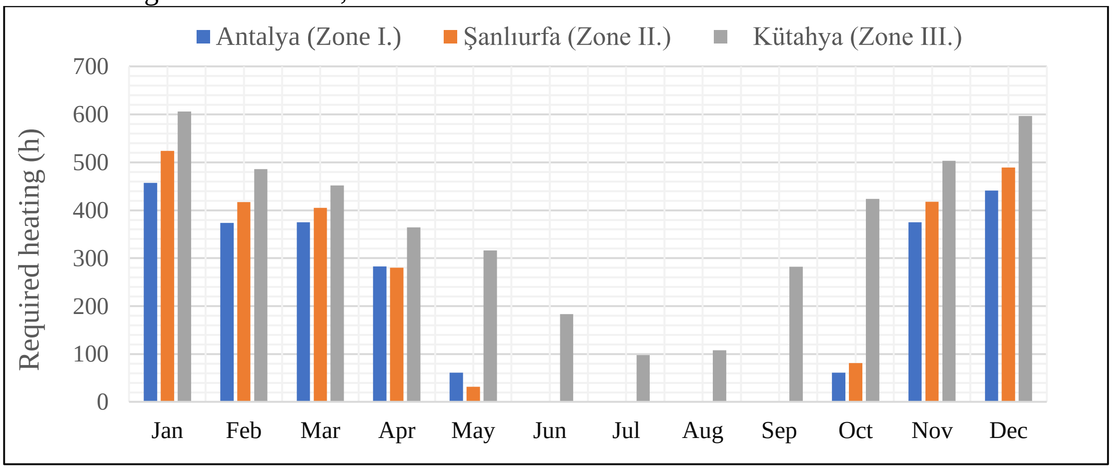

Figure 4. The heating periods (in hours) at different climate zone according to $\Delta\theta_{Sp}$

Ventilation efficiency

Over the last few decades, greenhouse technologies have improved in terms of environmental regulation (e.g., indoor temperature, relative humidity, and CO_2 concentration). One efficient technique to change the indoor climate is through ventilation, recent years have seen a substantial increase in research interest in natural ventilation due to its low energy needs. When the average daily temperature is between 12 and 22 °C, it is possible to provide suitable conditions with ventilation for the plants in the greenhouse (Soussi et al., 2022). This section summarizes the modeling results related to greenhouse ventilation, the temperature periods when it is higher than 22°C depending on the months of the year, and the maximum temperature through this period are considered the factors to evaluate the ventilation effectiveness under different climate conditions.

Figure 5 shows that, in Antalya, the months of the year affect both the highest temperature values that occur and the temperature periods when it is higher than 22°C, while the outdoor temperature is greater than 22°C in 264 hours in May, the highest temperature occurred during this period is 25.9°C, at the ventilated greenhouse with vent opening of 0.4 which is equipped with a mesh insect net, the temperature inside the greenhouse tends to be higher than

2°C in 295h, and the maximum temperature during this period is 26. 5°C.

To minimize crop mineral depletion and fungal infections, efficient greenhouse ventilation is essential for the Mediterranean region, the design of the ventilation opening as 40% of the greenhouse floor area means good conditions for the plant could be provided in the greenhouse in October, November, March, April, and May. These results are in line with the findings of Baytorun & Abass, (2022).

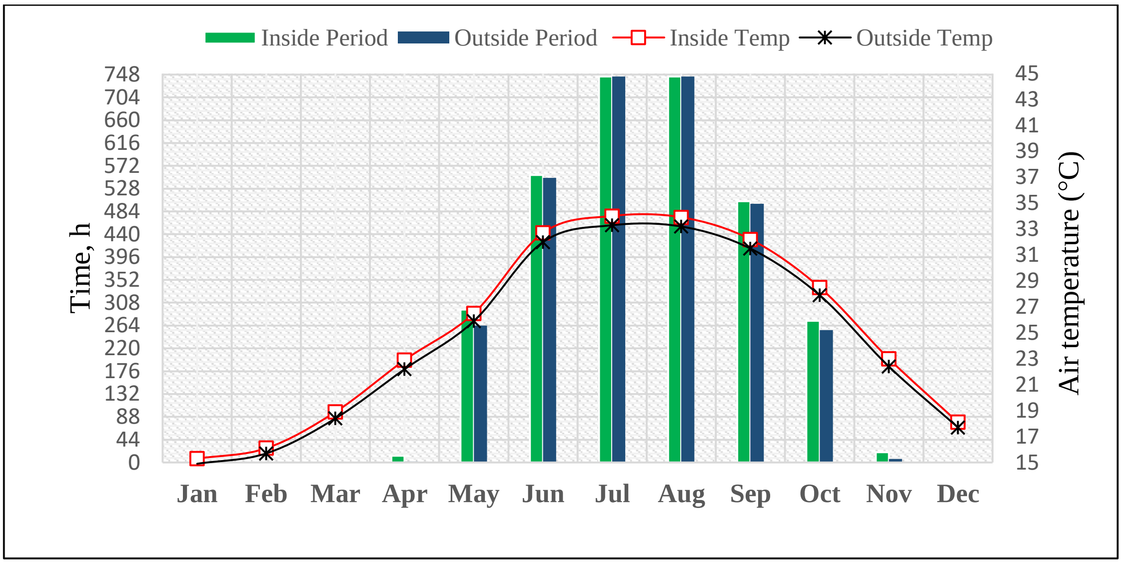

Figure 5. The period (in hours) when the temperature is higher than 22°C and the maximum temperature in Antalya climate conditions

Figure 6 shows that in the climatic conditions of Şanlıurfa the months of the year affect both the highest temperature values that occur and the temperature periods when it is higher than 22°C, while the outdoor temperature is greater than 22°C in 430 hours in May, the greatest temperature that happened during this time was 32.9°C, at the ventilated greenhouse with vent opening of 0.4 which is equipped with a mesh insect net, the temperature inside the greenhouse tends to be higher than 22°C in 434h, and the maximum temperature during this period is 34.3°C, in this case, it is possible to provide the necessary comfortable environment for plants in the greenhouse with ventilation even plus shading, especially during March, April, and November, however, active cooling should be operated to control the greenhouse temperature at hot months. These results are in line with the findings of Magrini et al. (2022).

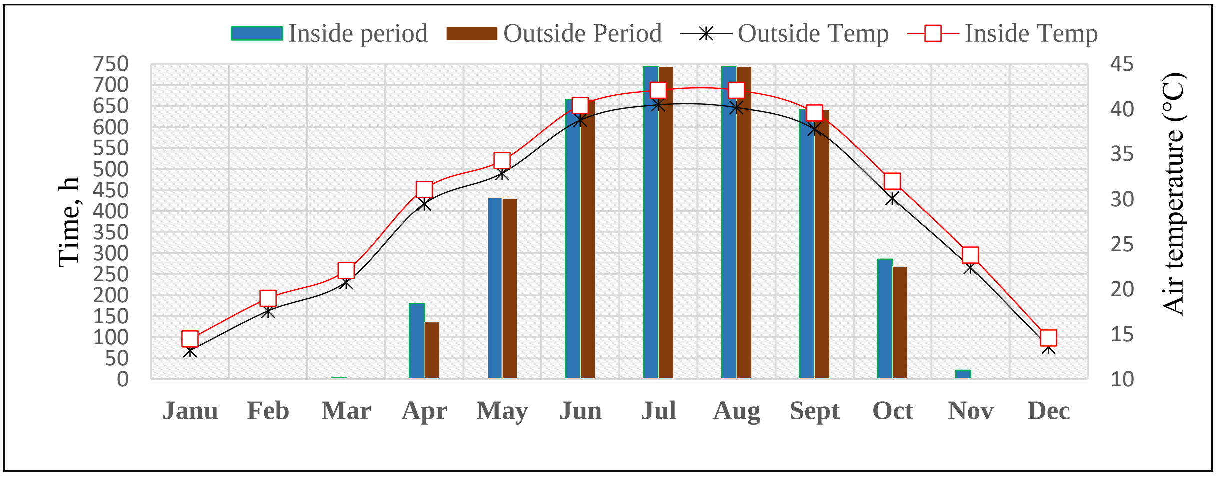

Figure 6. The period (in hours) when the temperature is higher than 22°C and the maximum temperature in Şanlıurfa climate conditions

Figure 7 shows that in Kütahya the ventilation effect in the greenhouse changes depending on the greenhouse location and as well as on the months of the year. In July, while the outdoor temperature is greater than 22°C in 304 hours, the greatest temperature that happened during this time was 28.4°C. , at the ventilated greenhouse with a vent opening of 0.4% which is equipped with a mesh insect net, the temperature inside the greenhouse tends to be higher than 22°C in 324 h, and the maximum during this period is 29.4°C which is in line with the optimum temperature of plant production according to Jones (2013), these results indicate that the ventilation efficiency of a greenhouse not only depends on its design characteristics but also is influenced by the weather conditions at its location.

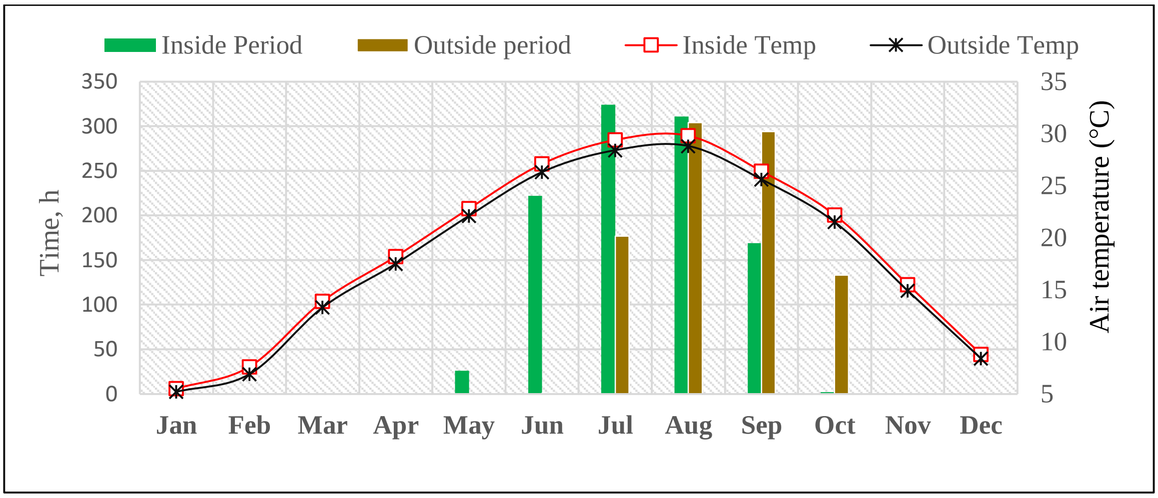

Figure 7. The period (in hours) when the temperature is higher than 22°C and the maximum temperature in Kütahya climate conditions

Cooling effect

Increasing yearly yield per unit area, profitability, export season, and production season are some of the most important concerns facing modern greenhouse farming. However, in many locations, the cooling method used (ventilation and shading) do not produce the ideal conditions, particularly during the hot summer months (Ventilation section), Evaporative systems for cooling greenhouses have been developed to provide the desired growing conditions in the greenhouse during the hot period of the year.

Table 1 displays the temperature periods that occur over 27°C depending on the months of the year in naturally ventilated greenhouses that are shaded by 50% in various climate zones. The data shows that the cooling loads in the region (I) of the greenhouse are needed for a maximum of 1734h in Adana. However, the maximum in the region (II) was estimated to be 2560 h in Şanlıurfa. Additionally, region III had the lowest cooling load determined.

Table 1. The period (in an hour) when the temperature is higher than 27°C at various climatic zones in naturally ventilated greenhouses

Zone/	Province	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
I.	Aydın	0	0	0	0	109	314	404	374	226	35	0	0	1462
	Antalya	0	0	0	0	0	272	436	416	271	36	0	0	1431
	Adana	0	0	0	0	112	307	424	442	304	145	0	0	1734
II.	Yalova	0	0	0	0	0	8	165	165	0	0	0	0	338
	Denizli	0	0	0	0	39	269	377	356	178	1	0	0	1220
	Şanlıurfa	0	0	0	37	223	457	685	650	394	114	0	0	2560
III.	Kütahya	0	0	0	0	0	4	116	137	0	0	0	0	257
	Afyon	0	0	0	0	0	0	143	154	0	0	0	0	297
	Nevşehir	0	0	0	0	0	0	121	123	0	0	0	0	244

Figure 8 shows that, under the conditions of Adana, with pad efficiency of 90%, the interior temperature tends to be above 27°C (set point) in 510 h (G+ cooling) as opposed to 1734 h in a naturally ventilated greenhouse (G-cooling), the results showed that the cooling system was able to keep the greenhouse temperature below outside air temperature for the specific ventilation rate (0.05 m3 s^{-1} m^{-2}). Although in addition, temperatures in the greenhouse can reach 30°C, and 31.2°C in July and August respectively. This situation shows that evaporative cooling is insufficient to provide the necessary comfortable environment for plants in some parts of June, July, and August, These results are also in line with those presented by Baytorun et al., (2019).

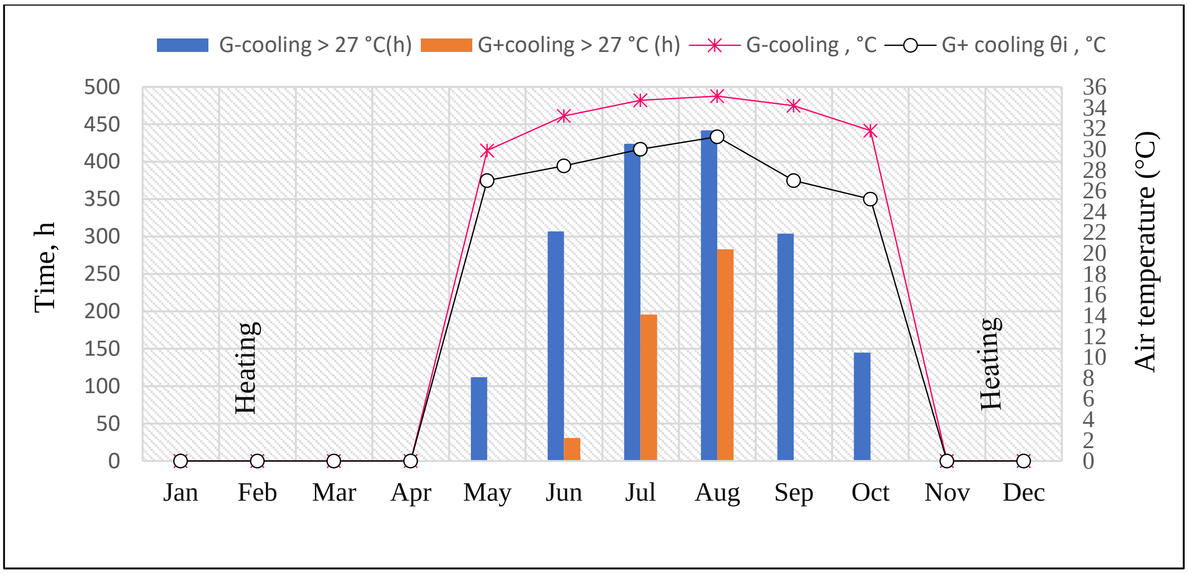

Figure 8. The period (in hours) when the temperature is higher than 27°C and the maximum temperature in ventilated, cooled greenhouse under Adana climate conditions

Figure 9 shows that, in Şanlıurfa, the cooling of the greenhouse is necessary for the period from the end of May until the first week of October, at pad efficiency of 90%, it is possible to keep the inside temperature below 27°C except in 11 h compared to 2560 h in just ventilated greenhouse, it could be noticed that evaporative cooling is most effective in Şanlıurfa climate condition and that because outdoor relative humidity (RH) is less than in other climate zones.

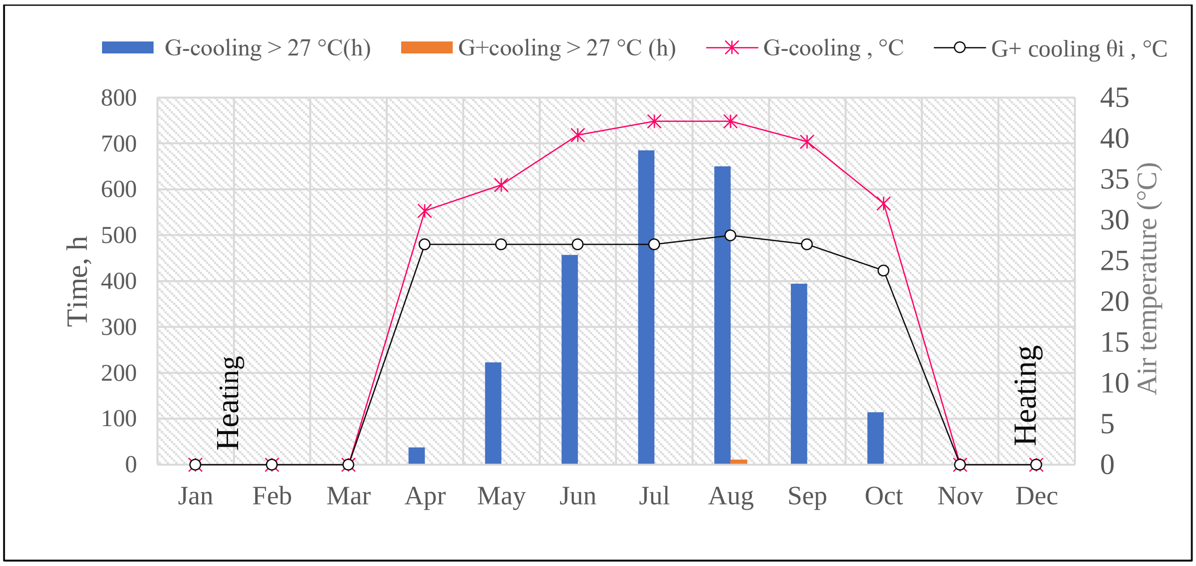

Figure 9. The period (in hours) when the temperature is higher than 27°C and the maximum temperature in ventilated, cooled greenhouse under Şanlıurfa climate conditions

Figure 10 shows that, in Kütahya, the cooling of the greenhouse is necessary for July and August, at pad efficiency of 90% it is possible to keep the inside temperature below 27°C., However, the maximum temperature values that occur in greenhouses that are shaded and naturally ventilated during hot periods reach 30°C, which is consistent with the fact that it will be possible to control the temperature to the comfort levels desired by the plants by using short-term fog cooling system in the greenhouse because with these systems it is possible to reduce the inner greenhouse temperature to around 6.6°C from the ambient air temperature (Öztürk, 2003).

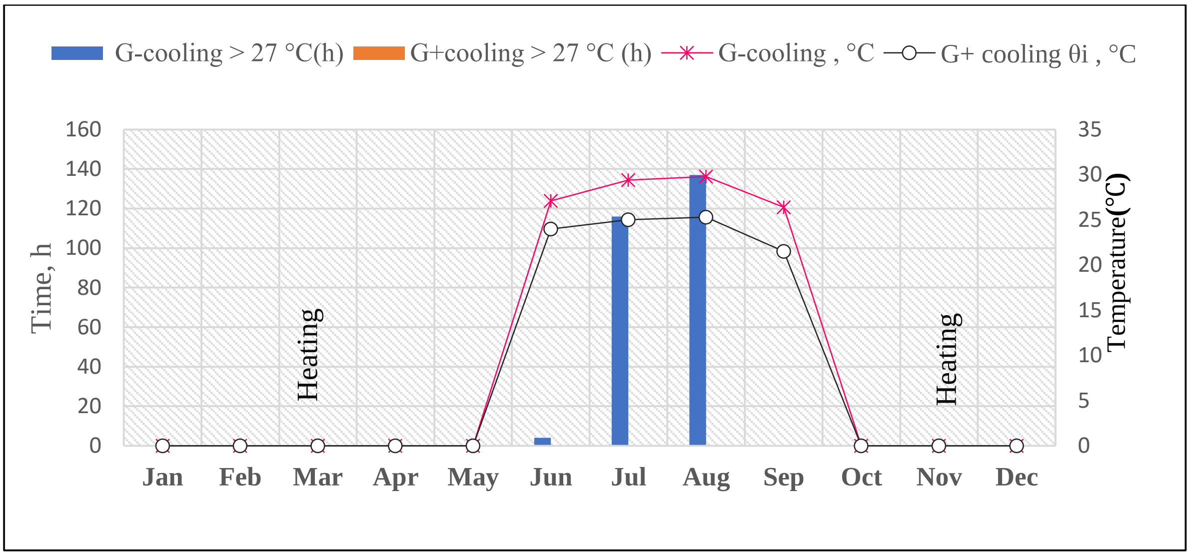

Figure 10. The period (in hours) when the temperature is higher than 27℃ and the maximum temperature in ventilated, cooled greenhouse under Kütahya climate conditions

Conclusion

To choose the size, style, and configuration of the heater and heat distribution systems inside the greenhouse, the design heat load of the structure must be calculated. The heat load is a function of the temperature difference between inside and outside the greenhouse and other factors. A crucial point to concern in natural ventilation is that the inside air temperature of the greenhouse can never be less than the outside air temperature, and unless the winds are very consistent and the greenhouse is oriented properly, the inside air temperature will always be greater than the outside temperature. This can become a major problem during the warm season when maximum cooling is required.

In Antalya's climate conditions, it is possible to provide optimum conditions for plants in greenhouses with ventilation in October, November, March, April, and May. Since the average temperature rises above 27℃ in July and August, it is not possible to continue plant production without active cooling in greenhouses. However, due to the high humidity in the Mediterranean region, the high operating cost of evaporative cooling, and the growth of the products produced in the greenhouse under external climatic conditions, cooling is not preferred in the greenhouses and the greenhouses are left empty.

Şanlıurfa is more disadvantageous than Antalya in terms of heating. In Antalya conditions, greenhouses need to be heated only at night, while in Şanlıurfa, greenhouses need to be heated all day in January. In addition, evaporative cooling is mandatory in greenhouses due to high temperatures from May to early October.

Kütahya, which has a continental climate, greenhouses need to be heated all day in December, January, and February, partially all day in November and March, and only at night in October and April. On the other hand, since the temperature in the ventilated greenhouse is 30°C, it will be possible to carry out production all year with ventilation, shading, and fogging cooling

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