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THE DETERMINATION OF PROPERTIES OF HEATING AND COOLING SYSTEMS IN GREENHOUSE

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Abstract

In this study, the heating and cooling conditions of the greenhouses in Antalya were examined and suggestions were made for solutions of the problems that emerged. The Simple Random Sampling Method was used in determining the number of enterprises to be surveyed. The number of enterprises to be surveyed was determined as 246 with a 90 % confidence limit and 10 % error rate. It was determined that the greenhouses enterprises surveyed were heating at 96.34%. It has been determined that the most commonly preferred type of heater in the region is the stove and that the stove is heated only to protect the product from frost damage. In accordance with the data obtained from the research area, it was determined that one stove was used for 1000 m^2 greenhouse floor area. It has been determined that 92.68% of the surveyed greenhouse enterprises are trying to reduce the excess temperature inside greenhouse by natural ventilation. It was determined that both the sidewall and roof ventilation were made at 45.93% of the greenhouse enterprises where examined in the research area. It has been determined that the ratio of ventilation area to greenhouse floor area changes between 10 and 15 in 32.52% of greenhouse enterprises and this ratio changes between 15 and 20 in 41.46%. As a result, the heating and cooling properties and problems encountered of the greenhouse enterprises in the study area were determined and necessary precautions to be taken.

Key words: Antalya, Greenhouse, Heating, Cooling

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INTRODUCTION

Greenhouses are the structures in which it is possible to move, that enable growing cultivated plants economically during the periods when climatic conditions are not suitable for outdoor plant growing and that can provide development factors essential for plant production. Since greenhouse cultivation develops depending on climatic conditions, our greenhouse areas are widespread especially on the southern coasts of our country (Sevgican *et al*., 2000). When the developments in the last five years in Turkish greenhouses are examined, the annual average growth rate of greenhouse cultivation in Turkey is around 15%. This growth rate is higher when compared to many countries. The operating structure of the greenhouses in our country is in the form of family-owned enterprises, and they are small enterprises with average sizes ranging between 400-1500 m^2 (Canakci, 2013). Vegetable growers prefer double crop growing instead of single crop growing in order to minimize heating costs. In single crop growing, heating is performed only for protection from frost damage, and fruit set is especially achieved by the use of plant growth materials in vegetable species such as tomatoes and eggplant. In double crop growing, product space appears when product prices are high on the market. The fact that the planning in production cannot be realized, the price fluctuations faced by the producers and the low yield and fruit quality are the most important problems encountered in production. It will be easier to solve these problems if export is targeted in greenhouse cultivation in which inputs are high. The first requirement of this is to improve fruit quality and to be able to perform production planning. This can only be achieved by providing suitable climatic conditions according to the varieties grown in greenhouses (Sevgican et al., 2000). The most important advantage of production in greenhouses is keeping the environmental and climatic factors under control. The most important one of these factors is the controlling of the greenhouse temperature. The temperature increase is the most important problem in greenhouses because of the fact that there are not barriers that prevent the entrance of light and heat, instead, they are constructed from glass or plastic in the planning of greenhouses as in other structures (Oz, 2007). Harzadin (1986) states that appropriate environmental conditions should be established in greenhouses by cooling them with different measures during summer to perform plant production in greenhouses. It was also reported that the mentioned environmental conditions could be achieved by keeping the internal temperature and moisture of the greenhouse between certain limits, therefore greenhouses should be ventilated, cooled and shaded during the summer (Aydincioglu, 2004). The aim of this study was to determine the current status of the heating and cooling systems used in the greenhouse. For this purpose, the heating and cooling systems of the greenhouse enterprises are examined.

MATERIAL AND METHOD

The information obtained from Antalya Provincial Directorate of Agriculture has been used in determining the enterprise numbers to be examined in the research. The simple random sampling method was used for the selection of the enterprises to be surveyed as follows (Cicek and Erkan, 1996).

$$n = \frac{N * S^2 * t^2}{(N-1) * d^2 + S^2 * t^2} \quad (1)$$

Where; *n*: sample size; *N:* Number of enterprises in population,
S: Population variance; *d*: expresses deviation at a particular rate (%10) from average,
t: expresses t table value which is equivalent to 90% confidential limit. The distribution of the enterprises surveyed around Antalya province is shown in figure 1 and table 1.

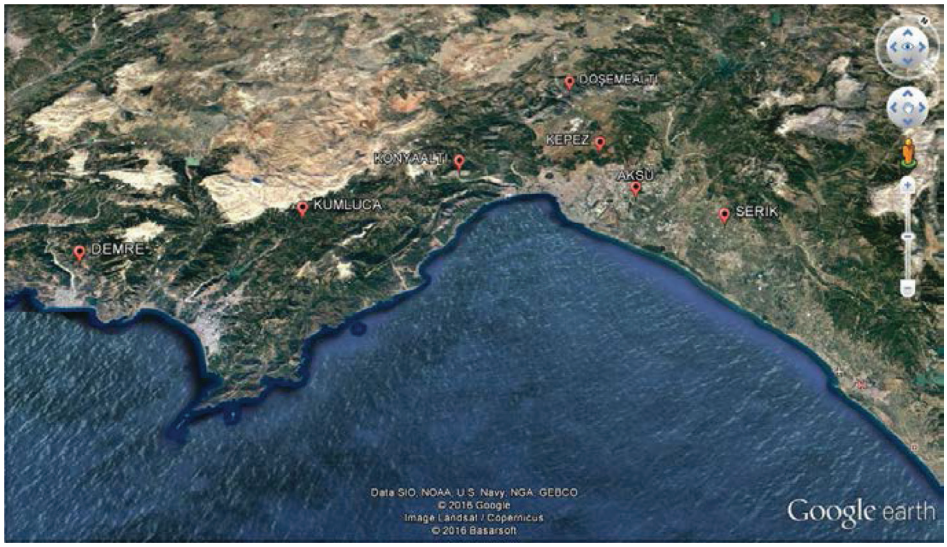

Figure 1. Satellite view of the study area (Anonymous, 2017)

It has been determined that a total of 246 enterprises must be surveyed with a 90% confidential limit and a 10% error margin as a result of the calculation using the equation one. The enterprises to be surveyed were randomly selected and the study was completed in 2016. Survey questions asked to the producer is as follows: Greenhouse properties (cover material and layout, size and direction of the greenhouse area), greenhouse production (grown crop, cultivated form), greenhouse heating status (heating purpose and application type, fuel source,

heating time and month, heating cost), greenhouse cooling status (purpose and type of ventilation, position of ventilation openings, ratio of ventilation area to greenhouse floor, used cooling method, cooling usage time, shading method) and producer information (educational status, time spent in production, whether technical support is available).

Table 1. Distribution of surveyed enterprises around Antalya province

Province	County	Village	Survey numbers	%
Antalya	Serik	Kayaburnu	14	5.70
		Cumali	11	4.47
	Aksu	Boztepe	18	7.32
		Topalli	11	4.47
		Kursunlu	15	6.09
	Kepez	Gaziler	25	10.16
		Zeytinlik	17	6.91
		Kizilli	12	4.88
	Demre	Koskerler	10	4.07
		Cevreli	7	2.85
	Kumluca	Mavikent	32	13.00
		Ortakoy	20	8.13
		Saricasu	12	4.88
	Konyaalti	Hisarcandir	15	6.09
		Karatepe	7	2.85
	Dosemealti	Karatas	8	3.25
		Komurculer	12	4.88
Sum			246	100

The questions asked to the enterprise owners who participated in the survey were turned into two-sided tables and the Chi-square independence test was applied. The chi-square test is based on whether the value between observed and expected frequencies is statistically significant. The chi-square test is preferred in the analysis of qualitatively stated data (Gungor and Bulut, 2008).

RESULTS AND DISCUSSION

68.7% of the enterprises in the study area are vegetable production greenhouses, 22.36% of them are cut flower greenhouses and 8.94% of them are seedling production greenhouses. Greenhouse enterprises have various sizes in terms

of greenhouse area, and it was determined that the smallest greenhouse area was 1200 m^2 and the largest greenhouse area was 21600 m^2 in the surveyed enterprises (Figure 2).

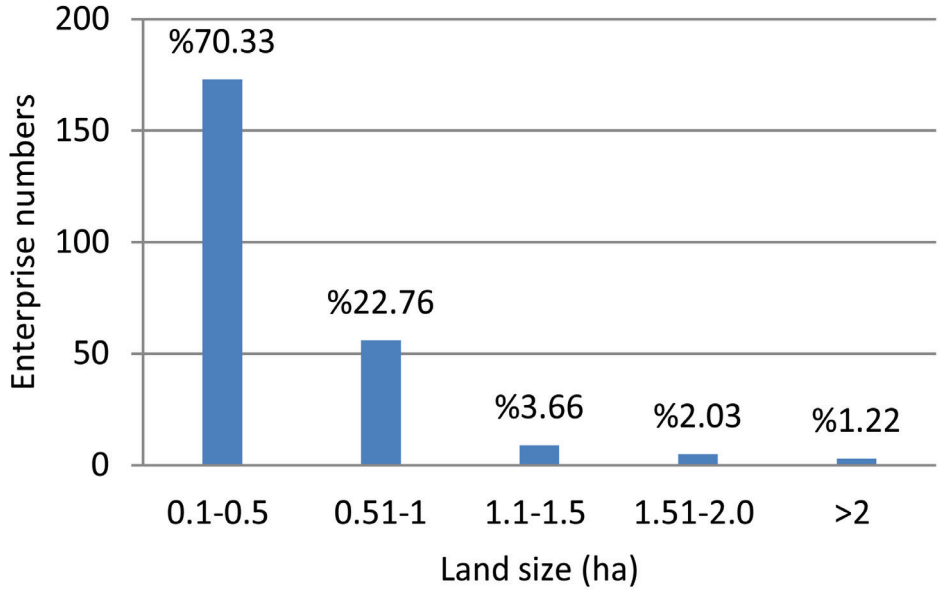

Figure 2. Land sizes of enterprises in the study area

215 of the enterprises in the study area are plastic greenhouses and 31 of them are glass greenhouses. Regarding the relevant plastic greenhouses, 31 of them are single greenhouses while 184 of them are block greenhouses. While 15 of the enterprises with glass greenhouses are constructed as single glass greenhouses, 16 of them are constructed as block glass greenhouses.

In the study area, 237 greenhouse enterprises (96.34%) perform heating while 9 greenhouse enterprises (3.66%) do not perform heating. It was determined that heating was performed in 211 enterprises (85.77%) to protect from freezing, in 26 enterprises (10.57%) to increase the yield and that there was no heating in 9 enterprises (3.66%). It was determined that heating was performed with the aim of protecting plants from frost hazard instead of providing the heat needed by plants in greenhouses in the study area. The chi-square independence test between the purpose of performing heating and the educational levels of producers was not found to be statistically significant. Sevgican *et al.* (2000), Buyuktas *et al.* (2016) stated that heating is performed only for protecting plants from freezing in regions with a temperate climate. Our findings are also consistent with the findings of Sevgican *et al.* (2000) and Buyuktas *et al.* (2016).

Sevgican *et al.* (2000) indicate that both yield and quality decrease and it becomes difficult to control diseases when heating is performed only for preventing from frost damages. It was determined that only stove heating was performed in 59.35% of the enterprises with heating in the study area (Figure 3).

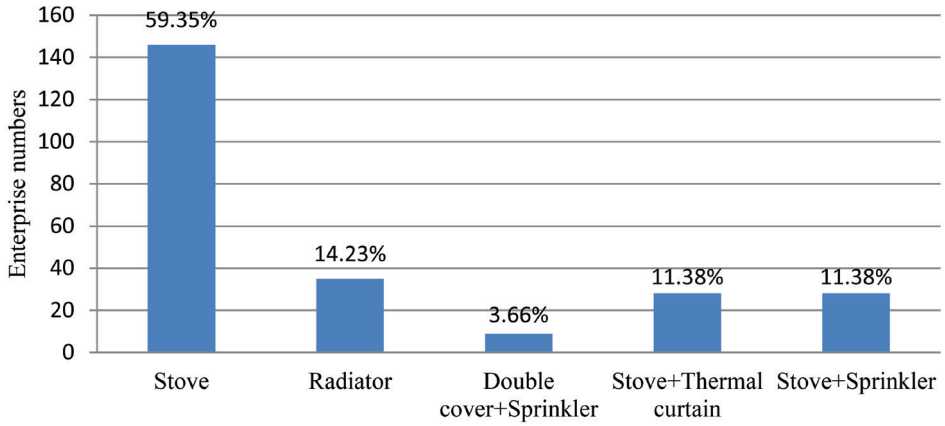

Figure 3. Heating applications in greenhouses in the study area

The most common type of heater in the region is the stove. Easy fuel availability and cost increase the use of stoves in the region. The types of stoves vary according to the enterprises. Since some stove types have 3 or 4 pipe outlets, producers prefer these types of stoves. Since there is less space loss in greenhouses when producers use stoves with multi-pipe outlets, they stated that they preferred these types of stoves. It was determined that the number of stoves used in each greenhouse in the study area varied between 2 and 6. In line with the data obtained in the study area, it was determined that one stove was used for a greenhouse floor area of 1000 m^2 (Figure 4). Yuksel (2004) reported that there is a need for a stove for each greenhouse floor area of 50-60 m^2 in our southern coastal regions in case of using the stove heating method in greenhouse heating, and this value should be decreased to 30-40 m^2 towards the northern regions. Therefore, it can be said that the number of stoves used in the greenhouses examined in the region is insufficient, so a suitable temperature balance cannot be ensured in such greenhouses.

Indeed, Baytorun (1994) reported that heating is necessary not only to control the internal temperature of the greenhouse but also to control the relative humidity and that all vegetable plants grown in the greenhouse need a certain temperature for fertilization. It was also found out that the sprinkler system was also used to protect the crops grown in the study area from freezing. 3.66% of the enterprises stated that they used the sprinkler system and double-cover, and

11.38% of them stated that they used the sprinkler system and stove. All of the greenhouses in enterprises where the sprinkler system is used consist of plastic greenhouses. In this system, a sprinkler system is placed on the roof of the greenhouse, and an attempt to protect the greenhouse temperature is made by using the sprinkler system at nights during which there is a frost hazard. Yuksel (2004) reported that the heat put out into the environment by the water while getting frozen could prevent frost damage by preventing the interior temperature of the greenhouse from decreasing too much in case of spraying water in the form of a thin surface to the two surfaces of the roof with the sprinkler nozzles laid on the roof of the greenhouse. 11.38% of the enterprises in the study area stated that they used a thermal curtain with the stove to protect the grown crops from frost hazards. It can be said that the use of the thermal curtain will enable minimizing the energy consumption by providing the heat protection necessary for the heating of the greenhouse rather than the yield obtained from the crop in the greenhouse.

Figure 4. A view of stove used in greenhouse heating

Onder and Baytorun (2016) stated that it would be possible to achieve heat savings at certain rates by means of the thermal curtain with different properties used in the heated greenhouses. In the surveys conducted in enterprises in the study area, the chi-square independence test between the application form of the heating and the intended purpose of heating was found to be statistically significant ($p<0.01$). In other words, it was determined that producers mainly performed heating for freezing protection regardless of the application form of heating. The ventilation preferences of enterprises are presented in Figure 5. 55.28% of the enterprises examined, 29.27% of them and 15.45% of them stated that ventilation was performed to throw out the excess heat inside the greenhouse, to adjust the moisture ratio and to adjust the gas concentration, respectively. It was determined that natural ventilation was mostly used as a ventilation method (92.68%) in the enterprises examined in the study area. It was determined that mechanical ventilation was performed only in 5.70% of the enterprises and that both mechanical and natural ventilation was performed only in 1.62% of them. The chi-square independence test between the ventilation method and the educational levels of producers was found to be statistically significant ($p<0.01$). It was determined that the number of enterprises using mechanical ventilation increased as the educational levels of producers increased.

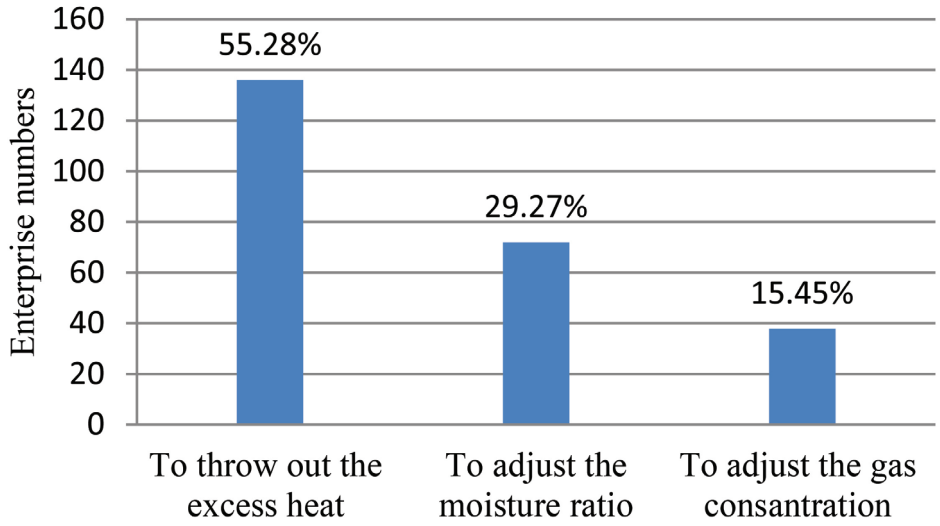

Figure 5. Purpose of ventilation in greenhouses in the study area

In line with the obtained information on ventilation, it was stated that 45.93% of the enterprises made side wall and roof ventilation (Figure 6). In other words, we can say that the proposed application form of ventilation is in-

adequate due to the fact that the ratio of enterprises with wall and roof ventilation is around 46%. Baytorun et al. (2000) reported that the most efficient natural ventilation in the greenhouse can be achieved when it is performed with roof and side wall ventilation.

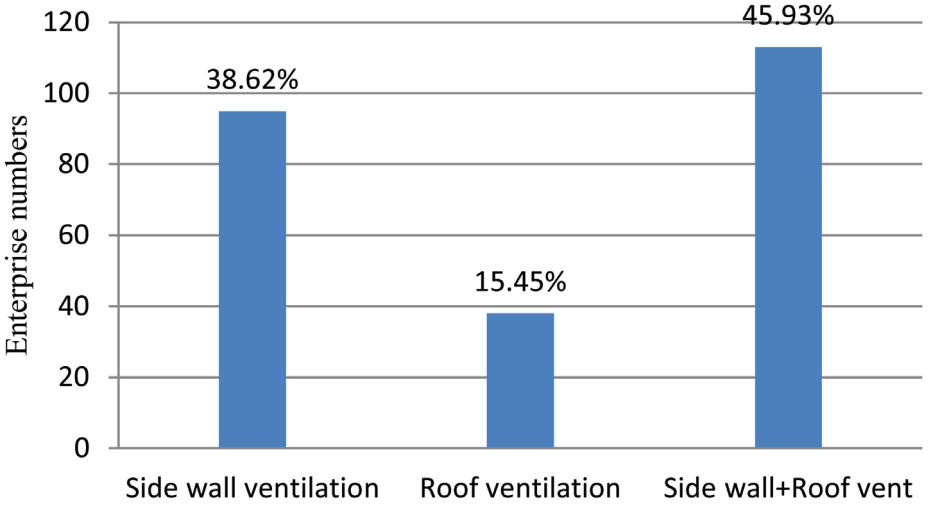

Figure 6. Position of ventilation openings

Demir *et al.* (1998) stated that roof ventilation in greenhouses should definitely be considered together with side wall ventilation, thus high moisture, which is an important problem in greenhouses, can be reduced, and so plants can stay longer and healthier. Coelho *et al.* (2006) stated that the difference between the internal and external temperature is less when roof and side wall ventilation are performed together. It was determined that 45.93% of the enterprises were compatible with the most ideal ventilation form specified in the literature (Demir *et al*., 1998; Baytorun *et al.,* 2000; Coelho *et al.,* 2006). Tuzel *et al.* (2005) stated that the relative humidity in the greenhouses increases in cases when there is not enough ventilation in greenhouses, and this situation will prevent pollination, which is the first condition of fruit set. The values regarding the ratio of ventilation openings to greenhouse floor areas in the enterprises examined are presented in Figure 7.

In the practice direction on the minimum requirements to be sought in modern greenhouses, greenhouses should necessarily be designed so that there will be a ventilation of at least 15% of the greenhouse floor area in greenhouses up to 3 decares and there will be a ventilation of at least 25% of the greenhouse floor area in greenhouses that are bigger than 3 decares, for an ideal ventilation in a greenhouse enterprise (Anonymous, 2012). Zabeltitz (1990) reported that

the ratio of the ventilation opening area to the greenhouse floor area should be between 18-25% in greenhouses in the regions where the Mediterranean climate is dominant, and Hakgoren and Kurklu (2007) reported that the ratio of the total window space to the greenhouse floor area should be 30%. The chi-square independence test between the ratio of ventilation area to the floor area and the educational levels of producers was found to be statistically significant ($p<0.01$). It was determined that the ratios of ventilation openings to the floor area increased as the educational levels of producers increased. The chi-square independence test between the selected ventilation method and the ratio of the ventilation area to the greenhouse floor area was also found to be statistically significant ($p<0.01$). According to the findings obtained in the study area, it was determined that the ratio of the ventilation area to the greenhouse floor area of 54.48% of the greenhouses in existing enterprises was not compatible with the values stated by Zabeltitz (1990), Hakgoren and Kurklu (2007) and with the standards related to greenhouse ventilation in Anonymous (2012). Therefore, it can be said that a significant part of the enterprises in the region do not have the appropriate ventilation area, and so the environmental conditions within the greenhouse cannot be achieved at the desired level.

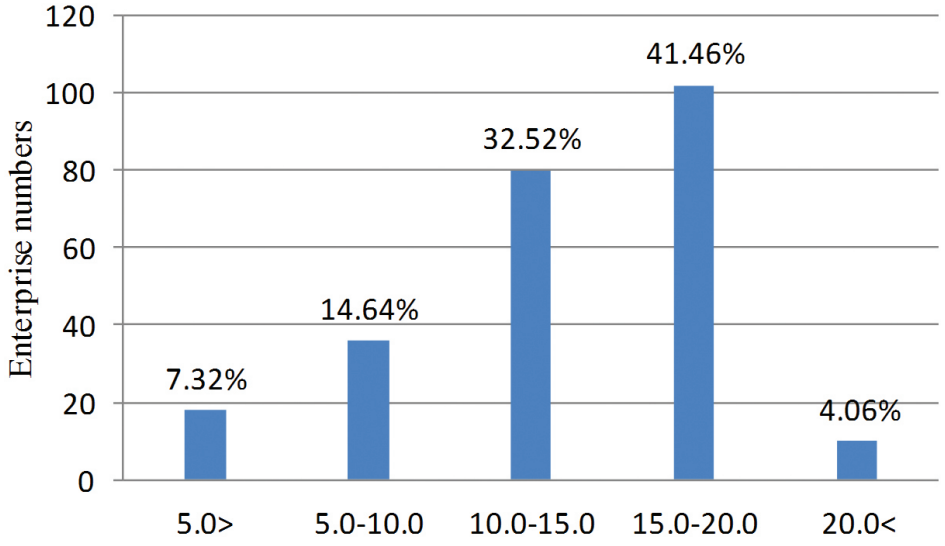

Figure 7. Ratio of ventilation opening to floor area

It was observed that cooling was performed in 173 greenhouses (70.33%) in the study area while cooling was not performed in 73 greenhouses (29.67%). Regarding the enterprises where cooling was performed, it was determined that the fogging method was used in 169 greenhouses (68.70%) and the fan-pad method

was used in 4 greenhouses (1.63%). The chi-square independence test between the cooling method and the educational levels of producers was found to be statistically significant ($p<0.01$). It was determined that the number of enterprises with a cooling system increased along with the increase in the educational levels of enterprise owners. None of the producers filters the water before the use in the fogging method. Indeed, Worley (2005) indicated that the most important aspect of the method is the filtration of the given water and that attention should be paid to the accumulation of minerals contained in the water used without filtration in plant leaves, the slowing down of photosynthesis, the salinity problem in the leaves, and fungal diseases due to the moistness of the wet leaves. In line with the findings related to the greenhouse area and the numbers of fogging nozzles of the enterprises using the fogging method in the study area, the number of fogging nozzles used for 1000 m^2 greenhouse area was determined to be 52 (Figure 8).

Figure 8. A view of fogging system in greenhouses in the study area

Atilgan and Oz (2007) stated that temperature could easily rise above 38 ^oC in the absence of a cooling system in greenhouses in hot regions, that a high temperature would decrease the plant quality and yield, and that production could also be maintained in greenhouses during summer by cooling greenhouses up to 10-12 ^oC with the fan pad system. The number of cultivators using fan-pad in greenhouses in the study area was found to be very low (1.63%) (Figure 9).

Among the enterprises in the study area, it was found out that the cooling system was most intensively used in 113 greenhouses (45.93%) using the cooling system in July and in 60 greenhouses (24.40%) in August. It is stated that the average temperature values of Antalya province according to long-term months for July and August are 28.4 and 28.2 ^oC, respectively (Anonymous, 2015).

Figure 9. A view of fan-pad system in greenhouses in the study area

Tomato growing is performed in approximately 80% of the study area. In the study area, tomato growing is performed in the form of autumn and spring growing. In a study carried out by Yucel *et al.* (2014) on tomato greenhouses in Antalya province, they found the cooling day values for the spring to be higher compared to the autumn. Since the spring production period has higher temperature values compared to other months in greenhouses in the study area, it has been concluded that to perform cooling applications in these months under proper conditions will contribute to cultivation. Among the enterprises performing cooling in the study area, it was determined that cooling was performed by using shading dust in 173 greenhouses (70.33%), that an attempt to prevent high sunlight from entering the greenhouse using shading nets was made in 65 greenhouses (26.42%) where there was no cooling, and that no shading was performed to prevent high sunlight in 8 greenhouses (3.25%). The chi-square independence test between the applied cooling method and the intended purpose of ventilation was also examined and was not found to be statistically significant. Baytorun et al. (1994) reported that the indoor temperature could be lowered to the outdoor temperature if the shading and ventilation measures were taken together in the greenhouses.

CONCLUSIONS

In conclusion, the heating and cooling characteristics of the greenhouses in the region and the problems encountered were determined in this study. The heating encountered in greenhouses in the region is not performed adequately and efficiently. The facts that detailed heating is not performed and that the fact that only a large part of heating is performed for protection from freezing reveal producers' sensitivity on costs. The wrong planning and wrong ventilation practices in greenhouses also show that there are deficiencies in cooling. It has been

concluded that the elimination of these and similar mistakes in the regions where greenhouse cultivation is most intensively performed will contribute to both the income of producers and the income of our country.

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