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Structural characteristics and heat requirements of modern greenhouses in southern of Turkey

Türkiye'nin güneyindeki modern seraların yapısal özellikleri ve ısı gereksinimleri

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ABSTRACT

This study was carried out to evaluate the structural properties of modern greenhouses and the heat requirements of the modern greenhouse farms calculated using multi-years climate data in the Mediterranean region of Turkey. Greenhouse farms in Turkey spread mostly along Mediterranean costal areas, Marmara and Aegean regions. The most important region within Turkey for greenhouse cultivation is the Mediterranean region, covering almost 85% of total production with plastic and glass greenhouses. In recent years, the number and production area of modern greenhouses have increased in Turkey. Also, these greenhouses are located mostly in the province of Antalya, the reason why the region was selected as study area. As a result, 74, 16 and 10% of modern greenhouse enterprises in the region were the vegetable, seed and seedling production greenhouses, respectively. Soilless culture systems are usually applied in the vegetable production greenhouses. The technological and productivity levels of vegetable, seed and seedling production greenhouses are very high and their average size varies between 0.5 and 2.1 ha. The results indicate that the heating systems should be intensively operated in the period from November to April. The highest and lowest heat requirements were determined from PE and PC+(PE(DL**)+TS*) covered greenhouses, respectively.

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ÖZ

Bu araştırma, Türkiye’nin Akdeniz bölgesindeki modern sera işletmelerinin yapısal özelliklerini belirlemek ve incelenen modern sera işletmelerinin ısı gereksinimlerini uzun yıllık iklim verilerine göre hesaplamak amacıyla yürütülmüştür. Türkiye’de sera işletmeleri Akdeniz kıyı şeridi, Marmara ve Ege bölgelerinde yaygın biçimdedir. Türkiye’de sera yetiştiriciliğinde en önemli bölge, plastik ve cam kaplı seralarda toplam üretimin % 85’ini kapsayan Akdeniz Bölgesidir. Son yıllarda Türkiye’de modern sera işletmelerinin sayısında ve üretim alanında önemli artışlar gözlenmektedir. Anılan seralar genellikle Antalya ilinde bulunmaktadır bu nedenle Antalya ili çalışma alanı olarak seçildi. Araştırma seralarda yapılan bitkisel üretim, seraların yapısal özellikleri, boyutlandırma ve planlama kriterleri, sera içi çevre koşullarının yeterliliğini içeren anket uygulanması biçiminde yürütüldü. Sonuç olarak, bölgedeki modern sera işletmelerinin %74’ünü sebze seraları, % 16’ını tohum seraları ve % 10’unu fide üretim seraları oluşturmaktadır. Sebze üretim seralarında genellikle topraksız kültürde üretim yapılmaktadır. Yöredeki sebze, tohum ve fide üretim seralarında teknoloji kullanımı ve verimlilik düzeyinin yüksek olduğu ve anılan seraların ortalama taban alanı büyüklüğünün 0,5 ile 2,1 ha arasında değiştiği söylenebilir. Araştırma sonuçlarına göre, modern seralardaki ısıtma sistemlerinin Kasım ve Nisan ayları arasında çalıştırılması gerektiği belirlenmiştir. En fazla ve en az ısı gereksinimleri sırası ile PE ve PC+(PE(DL**)+TS*) örtülü seralarda belirlendi.

1. Introduction

Turkey is located between 36- 42° North latitude and 26-45° East meridians. That’s why it has advantages for greenhouse cultivation. In 1960, the total greenhouse area was 1,003 ha in Turkey and it increased up to 20,481 ha in 2000. According to statistics of 2009, the total greenhouse area is 30,312 ha of which 8,293 ha is covered glass and 22,019 ha covered plastic (Brumfield et al. 1997; TUIK 2009). Turkey is divided into seven geographical regions: the Marmara, Aegean, Mediterranean, Central Anatolia, Black Sea, East Anatolia and Southeastern Anatolia regions. The most important region within the country for greenhouse cultivation is the Mediterranean region, covering almost 85% of total production with plastic and glass covered greenhouses (Table 1). The majority of the greenhouses in the Mediterranean region are located in city of Antalya (Kacıra et al. 2004; TUIK 2009). The area of the main greenhouse production countries is shown in Table 2 (Kacıra et al. 2004). As shown in Table 2, China ranked the first in terms of the total greenhouse area in the world while Turkey ranked the sixth. Turkey is one of the major greenhouse production countries not only in the Mediterranean region but also in the world, with total of 30,312 ha glass and plastic greenhouse area (Kacıra et al. 2004). Although Turkey ranked the sixth in terms of the total greenhouse area in the world, it can be said that the amount of product which is obtained per unit area is under the product of the other world countries. For example, despite Turkey's having approximately 3 times as many greenhouse areas as Netherlands country's total greenhouse areas (Table 2), Turkey are unable to obtain the desired quality and quantity of product. One of the most important reasons for this is that greenhouse production in Turkey is usually carried out with traditional methods in family farms when greenhouse production in countries such as Hollanda and so on is usually done with modern production techniques in modern farms. According to the works of Garcia-Martinez et al. (2010), in the Netherlands and Central Europe it is common to find the glass-Venlo greenhouse type, with high energy intake, trying to improve climate and cultivation. The main advantage of the greenhouses in the Mediterranean region of Turkey has been their low cost and very low energy use. Growers use only a small amount of energy for controlling the greenhouse environment and the production is mainly carried out by taking advantage of the favorable climate. For example, heating is done only to protect from frost in winter time. However, most of the greenhouses in Turkey have small ventilation openings compared to their ground area. The consequence of this situation is that the resulting microclimate is far from being satisfactory for the crop during a large part of the year, since for extreme outside climate conditions the present (low temperatures) systems cannot maintain inside temperatures within acceptable levels. However, to maintain the competitive position of Turkey production it is necessary to improve the quality and yields, which requires raising the technological level of greenhouses.

Table 1. Regional distribution of covered production area in Turkey (TUIK 2009).

Region	Glasshouse+ plastic-film greenhouse		High+Low tunnels		Total	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Mediterranean	26090	86	22086	84	48176	85
Aegean	3541	12	1617	6	5158	10
Marmara	389	1	461	2	850	1
Other regions	292	1	2242	8	2534	5
Total	30312	100	26406	100	56718	100

In recent years, it is observed that the number of modern greenhouses increases in Turkey. These greenhouses are located mostly the Antalya province in the Mediterranean region. Moreover, modern greenhouses where heating is performed with geothermal energy have also begun to be established in the other inner regions. The modern greenhouses where initial investment costs are higher have automation systems to maintain climate control soilless growing. Installation costs of a modern plastic greenhouse for 30 ha are 1,395,000 Euros (Titiz 2004; Canakcı and Akıncı 2007).

Table 2. Production area of the main greenhouse production countries excluding low tunnels (Kacıra et. al. 2004).

Country	Greenhouse area (ha)
China	1000000
Japan	53518
Korea	52189
Spain	33750
Italy	26000
Turkey	**22064**
Netherlands	**10416**
USA	7016
France	8108
Israel	3510

Heating of a greenhouse is an essential requirement for proper growth and development of winter growing crops (Tiwari 2003). Heating and cooling of agricultural greenhouses are the utmost important activities to extend its application throughout the year for crop production (Jain and Tiwari 2003). Greenhouse heating costs has an important place in the annual operating expenses (Yüksel 2004). Based on growing season and location, greenhouse enterprises heating costs may change between 40 and 80% of total production costs (Kendirli and Cakmak 2010). In many Mediterranean countries, even in cold nights heating is not made. However, this situation leads to low quality and efficiency in products. Instead of fossil fuels to heat the greenhouses alternative energy sources and energy conservation should be taken into consideration. Solar energy is an important alternative energy source and is a significant opportunity for the Mediterranean and the Arab countries zone. In spite of being a cheap and favourable source, solar energy has some economic and technical drawbacks (Zabeltitz 1988). The most important renewable energy source is the solar energy. In case solar energy for greenhouse heating is made use of, greenhouse heating costs in total production costs will decrease. Therefore, greenhouse production costs will decrease (Ozturk et al. 2010).

The current situation is highly dependent on the opening of markets, which is boosted by the Euro Mediterranean Agreement, as it imposes the obligation of Spanish production to compete with other countries, especially in the Mediterranean, including Morocco, Egypt or Turkey, which have different socioeconomic characteristics and labor available at much lower prices. Knowledge of the overall current state of equipment and technology is necessary both in political and in business decision-making to increase the efficiency of greenhouse production (Garcia-Martinez et al. 2010).

The aims of this study were to determine technical, structural properties and heat requirements of modern greenhouses in Antalya.

2. Material and Method

2.1. Study area

Mediterranean region is located on the south of Turkey. The total surface area of the region is approximately 89,493 km^2, and about 14% of the total surface area of Turkey. Greenhouse facilities in Mediterranean region are common in especially Antalya, Adana, Mersin and Hatay province. According to statistics of 2009, 70 % of the total greenhouse area in Mediterranean region is located in Antalya and 83.3 % of the glasshouses and 51.4 % plastic houses in Turkey are located in the province (Table 3). Greenhouse production makes a significant contribution to regional economy (Ozmerzi and Ozkan 2002; TUIK 2009; Kacıra et al. 2004).

Greenhouse production is mainly carried out by taking advantage of the favorable climate with small family enterprises in Antalya while keeping the operational cost at a minimum level. The planning and sizing criteria of most of these types of greenhouses are not suitable for ecological conditions of the environment. They are constructed without performing static and strength calculations. Heating have been carried out only for protection of frost hazard in the greenhouses (Emekli 2007). However, large modern greenhouse enterprises have become widespread with soil or soilless of culture and automation applications in the study area (Canakcı and Akıncı 2007). The province of Antalya, with applications of modern greenhouse, is ahead of our country.

Antalya has a Mediterranean climate, characterized by warm, relatively humid winters and hot, dry summers. Climate data recorded by Antalya Meteorology Station for study area were given in Table 4 (Antalya Meteorology Station 2008).

2.2. Study data

According to 2008 statistics, there were 34 modern greenhouse farms in Antalya and the total modern greenhouse area was 956,1 ha of which 431,1 ha was under glass and 525,0 ha was under plastic (Antalya Provincial Agriculture Directorate 2009). Modern greenhouse farms are applied densely in Center, Serik, Kumluca, and Manavgat districts of Antalya (Figure 1).

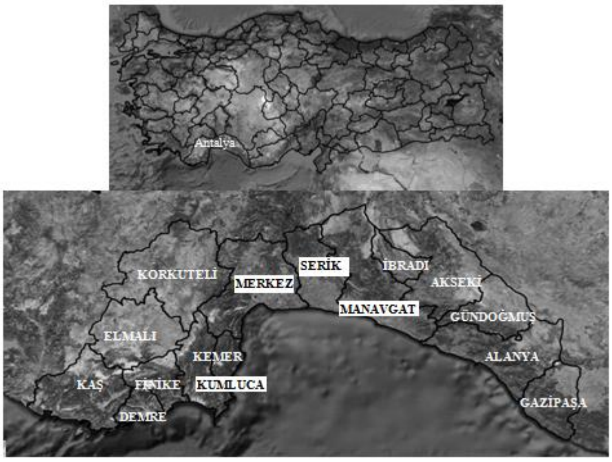


Figure 1. Maps of Turkey and Antalya Province (CNES/SPOTIMAGE satellite imagery).

Since the number of modern greenhouse farms in the region, (total 34), is limited, there is not a specific samplingmethod in the selection of the modern greenhouses used in the study. Only 19 out of 34 modern greenhouse enterprises allowed us to interview and questionnaire survey. Therefore, about 56 % of the modern greenhouse farms were used as a material in this study. Data have been collected from 19 modern greenhouse farms by using face to face questionnaire method in 2009 production year. Survey study was carried out in the Central and Serik districts of Antalya province where an intensive modern greenhouse exists. The structural caharacteristics of 19 modern greenhouse farms were given in Table 5. Sample farms were randomly selected from the districts in the study area.

Table 3. Distribution of the protected area in Turkey and Antalya (TUIK 2009).

Protected Cultivation	Turkey		Antalya		Share of Antalya in Turkey (%)
	Area (ha)	%	Area (ha)	%	
Glasshouse	8293.2	14.6	6907.8	33.4	83.3
Plastic-film greenhouse	22018.6	38.8	11311.5	54.7	51.4
Total greenhouse area	30311.8	53.4	18219.3	88.1	60.1

Table 4. Climate data for long-term averages of Antalya (1975-2008).

Months	Mean temp. (°C)	Maximum temp. (°C)	Minimum temp. (°C)	Mean high temp. (°C)	Mean low temp. (°C)	Daily shiny (h,min)
January	9.6	22.0	-2.0	15.0	5.6	05:20
February	9.9	23.4	-4.0	15.3	5.7	06:06
March	12.2	28.2	-1.6	17.9	7.4	06:57
April	15.8	33.2	1.4	21.4	10.6	08:01
May	20.3	37.6	6.7	25.9	14.5	09:51
June	25.3	44.8	11.1	31.3	19.0	11:37
July	28.3	45.0	14.8	34.4	22.1	11:58
August	27.8	43.3	15.3	34.3	21.8	11:33
September	24.3	41.2	10.6	31.3	18.6	10:02
October	19.5	37.7	4.9	26.9	14.5	08:07
November	14.2	33.0	0.8	20.8	9.8	06:19
December	10.8	25.4	-1.9	16.3	6.8	04:49

Table 5. The structural caharacteristics of 19 modern greenhouse farms.

Greenhouse No	Width	Length	Side height	Ridge height	Cover (Side wall-Roof)	Block number	Application purpose
1	8	45	3.5	5	PE	15	Vegetable
2	9.6	100	5.5	8	PE- PE+TS*	11	Vegetable
3	9.6	105	4.5	7	PC- PE+TS*	14	Vegetable
4	9.6	130	4.5	6	PC-PE	30	Vegetable
5	9.6	100	4.5	6.5	PE- PE+TS*	23	Vegetable
6	8	150	4	5.5	PE	23	Vegetable
7	9.6	170	4.5	6.5	PC- PE (DL**)+TS*	18	Vegetable
8	9.6	180	4.5	6.5	PE	10	Vegetable
9	9.6	135	4.5	7.5	PE- PE+TS*	10	Vegetable
10	9.6	150	4.5	6.5	PE	20	Vegetable
11	8	100	4.5	5.5	Glass- Glass+TS*	28	Vegetable
12	9.6	135	4.5	7.5	PE- PE+TS*	10	Vegetable
13	9.6	125	4.5	7	PC- PE (DL**)+TS*	27	Vegetable
14	9.6	125	4.5	7	PC- PE (DL**)+TS*	27	Vegetable
15	9.6	120	4.5	7	PC- PE (DL**)	5	Seed
16	9.6	100	4.5	7	PC-PE (DL**)	7	Seed
17	9.6	60	4.5	7	PC-PE (DL**)	2	Seed
18	9.6	120	4.5	6	PE	7	Seedling
19	9.6	105	4.5	6	PC-PE	8	Seedling

PE: Polyethylene film, PC: Polycarbonate film; *Thermal Screen, ** Double Layer

2.3. Land and office studies

Land studies of this research were conducted in Antalya during the year of 2009 (March and April). A questionnaire form, scoping plant production in the greenhouses, structural properties, design and planning criterias, adequacy of inside environmental conditions (ventilation, heating and cooling systems) and greenhouse growers'problems is prepared in order to surge the study at all enterprises homogenically. In addition to the survey study, by means of measurement, observation, photography, general properties of the farms are determined. Evaluation of the questionnaire results has been carried out using the software SPSS 15.0 for Windows. At the end of the study, heat requirements were calculated for all the greenhouses taken into consideration in the questionnaire. In this study, it has been identified that heating need not to be done during the daytime since the average sun intensity meets the heat lost of the greenhouse. Therefore, it was taken into account in the study that no heating was applied for the investigated greenhouses out of the solar radiation hours. The amount of heat energy lost from the greenhouse at night time was calculated with the help of following equation:

$$Q_K = \Sigma A_o U (T_i - T_d) \qquad \text{(Equation 1)}$$

where, ΣA_o is total cover surface area (m^2), U is overall heat transfer coefficient (W m^{-2}^{o}C^{-1}), T_i is greenhouse internal ambient temperature (^{o}C), T_d is greenhouse outdoor temperature (^{o}C) (Yagcıoglu 2005).

Calculations were made by taking into account the average temperature values at night time. The total heat transfer coefficient of polyethylene plastic film, double layer plastic film, polyethylene plastic film with thermal screen, double layer plastic film with thermal screen, polycarbonate plastic film, glass and glass with thermal screen in the calculations was taken as 6.8, 4.0, 4.6, 2.5, 3.5, 6.2 and 4.0 W/m^{2o}C, respectively (Asi/asae Ep 1998; Yagcıoğlu 2005; Oztürk 2008). The inside temperature value for all greenhouses in the calculations was taken 16 °C which is accepted as the favorable inside temperature (t_i) in greenhouse vegetable growing (Tiwari 2003).

3. Results and Discussion

3.1. General properties of modern greenhouse farms

According to the application purpose, 74, 16% and 10% of the modern greenhouse farms were the vegetable production greenhouses, the seed production greenhouses and the seedling production greenhouses, respectively. It can be said that vegetable production was dominant in modern greenhouse farms in Antalya.

According to the application purpose, some properties of the modern greenhouse farms were given in Table 6. Modern greenhouse farms in the region were constructed between 1999 and 2009 years and the average age of the vegetable, seedling and seed production greenhouses are 6, 5 and 2, respectively. The total greenhouse production area is 335,528 m^2 of which 91% is vegetable production, 5% is seedling production and 4% is seed production (Table 6). The average greenhouse area is 17,659 m^2. In the vegetable production greenhouses is only done tomato production with soilless culture (Fig. 2). Tomatoes grown are marketed domestically or abroad in certain centers. It was determined that tomato yield varies between 25 and 35 t/1000 m^2. The production in all vegetable production greenhouses is applied directly in the form of solid media culture (Table 6). It has been determined that vegetable producers use 36% of perlite, 36% of kokopit and 28% of rock wool as the media culture. In media culture, after the implementation of nutrient melt management to the environment, the removal of drainage water (open system) or re-circulation collected in the system (closed system) is based on the principle of the system (Winsor and Schwarz 1990). Nutrient melt management in the vegetable production greenhouses is applied in the form of open system. In this study, it has been observed that the producers drain the drainage of water from the system into the adjacent land or water resources. It can be said that this situation will lead to pollution of water resources and agricultural land in the future. Meric (2006) stated that soilless culture can be done in the form of closed systems that allows a high water use efficiency than in open systems, so less damage to the environment can be given and adequate and efficient production can be done. Ground cover in the greenhouses of this type is used to disconnect the greenhouse from soil. It has also been determined that 69% of the farmers prefer the cover of white and 5% of them would rather the cover of gray. On the other hand, the seedling production greenhouses in the region are produced on plant growth tables for various vegetables grown in the spring and autumn periods. In these types of greenhouses, slags are laid out on the ground to disconnect from soil. However, soil is used as growth culture in the seed production greenhouses (Fig. 2).

Engineers, technicians and workers who provide a controlled and timely execution of agricultural activities work in modern greenhouse farms in the region. These greenhouses have benefited from consulting service for plant production and 42% of modern greenhouse farms were found to have been EUROGAP (Euro Retailer Producer Working Group for Good Agricultural Practices). Kacıra et al. (2004) reported that Turkey is in the process of becoming a European Union (EU) country. Consumers's buying habits have changed in EU member countries. They would like to have healty and high quality products and to know how and where the products are produced. Since 2003, all of EUROGAP have requested the producers to meet the standarts of EUROGAP protocols. Thus, the growers should pay much attention to using proper technologies and healthy products. For this, growing techniques have to be improved in Turkey.

Figure 2. Some samples of modern greenhouse farms investigated in Antalya.

3.2. Structural characteristics and planning criteria of modern greenhouse farms

Dimensional characteristics of modern greenhouse farms in Antalya were given in Table 6. As seen in Table 7, all modern greenhouse farms in the region have the characteristic of block greenhouse and the average block numbers in the vegetable, seedling and seed production greenhouses is 19, 8 and 5, respectively. Based on greenhouse area, the average width of greenhouse in the vegetable, seedling and seed production greenhouses is 175, 72 and 45 m, respectively and the average length in the greenhouses of this type is 125, 113 and 93 m, respectively. Side and ridge height of the vegetable production greenhouses varies between 3.5-5.5 and 5.0-8.0 m, respectively whereas side and ridge height of the other production greenhouses is the same as all the farms (Table 7). However, truss width of all production greenhouses is 2.5 m.

According to the roof shapes, the distribution of the modern greenhouse farms is given in Table 8. The vegetable production greenhouses are constructed gable, arc or gothic shaped but these greenhouses are generally constructed with gothic shaped. The seedling and seed production greenhouses are only constructed with gothic shaped. That the roof width of gothic shaped greenhouses is 9.6 m and that of arc and gable shaped greenhouse is 8 m.

The distribution of modern greenhouse farms is given in Table 9 according to their cover material on sidewall. As seen in Table 9, the vegetable production greenhouses are widely covered with plastic cover. While glass cover in these greenhouses is used in Venlo-type greenhouses, either plastic or polycarbonate cover on sidewall is used in the gothic shaped and arc shaped greenhouses. In the research area, the seedling production greenhouses are covered with either plastic or polycarbonate cover while the seed production greenhouses are only covered with polycarbonate cover. Roof walls of all production greenhouses covered with polycarbonate cover on sidewall are covered with double layer polyethylene films. It is determined that producers prefer wide ranging polyethylene films (UV+IR+AF+AV+PE) as plastic covering material. Thus, a crucial problem with plastic cover materials is the concentration of the moisture on the inner surface of the cover material. Due to high evapotranspiration rates and low insulation levels in greenhouses, condensation on the inner surface of greenhouse covers often occurs. Especially on plastic cladding materials not treated with surfactants, condensation drops can cause a considerable decrease of the amount of incoming solar radiation (Pollet and Pieters 1999). That the producers prefer plastic cover materials which include especially anti-fog additive materials has suggested that a conscious greenhouse production has been done in the region.

Placement of greenhouses on land varies with position of enterprise plots, sunshine direction, and dominant wind direction (Kendirli 2006). Based on these criteria, among the vegetable production greenhouses, 14% of them were placed in the east-west direction although these greenhouses are block.

Table 6. Some properties of the modern greenhouse farms.

Property		Vegetable production greenhouses	Seedling production greenhouses	Seed production greenhouses
Number of farm		14	2	3
The average age of farm		6	5	2
Total production area (m^2)		305768	16128	13632
Average greehouse area (m^2/farm)		21841±2611.2	8064±0.0	4544±1718.5
Cultivation		Soilless culture	Growing tables	Soil
Production	Single product	Tomato	-	-
	Autumn	-	Tomato, pepper, cucumber, eggplant	Tomato, pepper
	Spring	-	Tomato, pepper, cucumber, eggplant	Tomato, pepper

Table 7. Dimensional characteristics of the modern greenhouse farms.

Property	Vegetable production greenhouses			Seedling production greenhouses			Seed production greenhouses		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Block number	10.0	30.0	19.0±1.9	7.0	8.0	8.0±0.5	2.0	7.0	5.0±1.4
Width (m)	96.0	288.0	175.0±18.1	67.0	77.0	72.0±4.8	19.0	67.0	45.0±13.9
Length (m)	45.0	180.0	125.0±9.1	105.0	120.0	113.0±7.5	60.0	120.0	93.0±17.6
Side height (m)	3.5	5.5	4.0±0.1	4.5	4.5	4.5±0.0	4.5	4.5	4.5±0.0
Ridge height (m)	5.0	8.0	7.0±0.2	6.0	6.0	6.0±0.0	7.0	7.0	7.0±0.0
Truss width (m)	2.5	2.5	2.5±0.0	2.5	2.5	2.5±0.0	2.5	2.5	2.5±0.0

Table 8. Roof shapes of the modern greenhouse farms.

Roof shape	Vegetable production greenhouses		Seedling production greenhouses		Seed production greenhouses	
	Number	%	Number	%	Number	%
Gable	1	7	-	-	-	-
Arc	3	21	-	-	-	-
Gothic	10	72	2	100	3	100
Total	14	100	2	100	3	100

Table 9. Cover materials used the modern greenhouse farms.

Cover on sidewall	Vegetable production greenhouses		Seedling production greenhouses		Seed production greenhouses	
	Number	%	Number	%	Number	%
Glass	1	7	-	-	-	-
Plastic	9	64	1	50	-	-
Polycarbonate	4	29	1	50	3	100
Total	14	100	2	100	3	100

Placement of block greenhouses in the north-south direction improves the efficiency of solar energy utilization whereas placement of block greenhouses in the east-west direction doesn't improve the efficiency of solar energy utilization. Tiwari (2003) reported that in case of multispan grenhouses, however, shadow of structural components pesists in some areas of the greenhouses are oriented east-west. This leads to loss of production in the shaded area.

In the region, all seedling and seed production greenhouses were placed in the north-south direction. Therefore, the modern greenhouse farms can be said to have been directed appropriately in general but the modern block greenhouses which will be built in the future must be directed to the north-south direction.

3.3. Material characteristics of modern greenhouse farms

Galvanized steel profiles and aluminum profiles are used as building material in the construction of modern greenhouse farms in the study area. Profil types used construction of the modern greenhouse farms in Antalya were given in Table 10. The columns of the vegetable production greenhouses are made up of steel pipe profile and prectangular or square box profiles which are obtained from the combination of two steel profiles of L 70,50,5; L 80,40,5; L 80,60,6; L 80,80,8; L 100,100,10 (Table 10). The columns of the seedling production greenhouses are made up of steel prectangular or square box profiles whereas the columns of the seed production greenhouses are only made up of steel square box profiles. The columns in the exterior wall of all production greenhouses have been spaced 2.5 m from each other untill the desired length and the interior walls have been spaced 5.0 m from each other. The roof truss of all production greenhouses are made up of the same size steel pipe profiles (Table 10). The beams of the Venlo type vegetable production greenhouse are made up of T30 aluminum profiles and these profiles are placed with an interval of 73 cm. The glass cover material is 73 ×165 cm. The purlins and vent apertures of all production greenhouses are made up of square box profiles which are obtained from the combination of two steel profiles of L 30,30,3. It has been determined that the doors in these greenhouses are made from aluminum profile. The sizes of the doors are 2.5 × 2.5 m or 3.0 × 3.0 m. Two doors have usually been placed on the sidewalls.

3.4. Control of greenhouse environmental conditions in modern greenhouse farms

Ventilation, heating and cooling systems is planned for controlling and improving environmental conditions in greenhouses/crop system (Emekli 2007). The internal environment conditions of greenhouse in the modern greenhouse farms are controlled by climate control automation systems. For this purpose, the climatic data are continuously monitored with several sensors (temperature, humidity, solar radiation, wind speed, wind direction and rain sensor) placed inside the greenhouse and meteorological stations located in the external environment (Fig. 2). The data obtained is collected in a control unit. These data are evaluated the control center of the system or with the help of software. The control center of the system or the software compares the measured value from the sensor and the value set the computer for greenhouse environment control. According to these values, ventilation and heating systems are command.

Heating in modern greenhouse farms is done by taking demands of plant into consideration (Canakcı and Akıncı 2007). Heating systems used the modern greenhouse farms in the region were given in Table 11. As shown in Table 11, heating in the vegetable and seedling production greenhouses is done with central heating systems, with hot water (Fig. 1). Coal is only used as a fuel in this system. In greenhouses where hot-water heating systems are used, heating pipes serves as a ray for the multipurpose vehicle as well (Fig. 2). Workers on these vehicles fulfill the necessary agricultural activities for the production of the plant. However, heating in the seed production greenhouses in the region is done with central heating systems, with hot air (Fig. 2). In this heating system is used the LPG or coal as a fuel.

Table 10. Profil types used construction of the modern greenhouse farms.

Application area	Vegetable production greenhouses	Seedling production greenhouses	Seed production greenhouses
	Material characteristics	Material characteristics	Material characteristics
Column	$L_{70,50,5}$ Steel profile $L_{80,40,5}$ Steel profile $L_{80,60,6}$ Steel profile $L_{80,80,8}$ Steel profile $L_{100,100,10}$ Steel profile ∅80 mm Steel pipe profile	$L_{80,40,5}$ Steel profile $L_{80,80,8}$ Steel profile	$L_{80,80,8}$ Steel profile
Roof truss	∅32 mm Steel pipe profile ∅40 mm Steel pipe profile ∅60 mm Steel pipe profile	∅32 mm Steel pipe profile ∅40 mm Steel pipe profile ∅60 mm Steel pipe profile	∅32 mm Steel pipe profile ∅40 mm Steel pipe profile ∅60 mm Steel pipe profile
Beam	T30 Aluminum profile	-	-
Purlin	$L_{30,30,3}$ Steel profile $L_{30,30,3}$ Aluminum profile	$L_{30,30,3}$ Steel profile	$L_{30,30,3}$ Steel profile
Door material	Aluminum	Aluminum	Aluminum
Vent aperture	$L_{30,30,3}$ Steel profile	$L_{30,30,3}$ Steel profile	$L_{30,30,3}$ Steel profile

Table 11. Heating systems used the modern greenhouse farms.

Heating system	Vegetable production greenhouses		Seedling production greenhouses		Seed production greenhouses	
	Number	%	Number	%	Number	%
Hot water piped heating systems	14	100	2	100	-	-
Hot air heating systems	-	-	-	-	3	100
Total	14	100	2	100	3	100

Table 12. Structural properties of natural ventilation systems applied the modern greenhouse farms.

Property		Vegetable production greenhouses		Seedling production greenhouses		Seed production greenhouses	
		Number	%	Number	%	Number	%
Vent opening	Sidewall	-	-	-		-	
	Roof	14	100	-		3	100
	Roof and sidewall	-	-	2	100	-	-
	Total	14	100	2	100	3	100
Circulation fan	Used	10	71	2	100	-	-
	Not used	4	29	-	-	3	100
	Total	14	100	2	100	3	100

All production greenhouses in the study area have natural ventilation systems. Structural properties of natural ventilation systems applied the modern greenhouse farms in the region were given in Table 12. Vent openings in the vegetable and seed production greenhouses comprise only the roof opening whereas vent openings of the seedling production greenhouses comprise both roof and sidewall opening (Table 12). In this study, it was found that 71% of the vegetable production greenhouses and all of the seedling production greenhouses used circulation fans (Fig. 3). Circulation fans prevent the formation of dead temperature and humidity zones in greenhouse (Kurklu 2008). Also, the producers provide a uniform distribution of temperature in the greenhouse by running the fans together with the heating systems. However, the seed production greenhouses didn't use these fans. In the greenhouses ventilated by natural systems, the ratio of opening area to ground area is an important factor in the greenhouse crop cultivation. The average ratio in the research area varies between 32 and 52% (Table 13). Kürklü (2008) reported that this ratio should not be less than 35% for proper natural ventilation in the modern greenhouses. That is why, this ratio of the vegetable and seedling production greenhouses had some problems concerning ventilation.

Table 13. The ratio of the opening area to greenhouse floor area of the modern greenhouse farms.

Application purpose	The ratio of the opening area to greenhouse floor area		
	Min	Max	Mean
Vegetable production greenhouses	19	54	32±2.4
Seedling production greenhouses	31	37	34±3.0
Seed production greenhouses	52	52	52±0.0

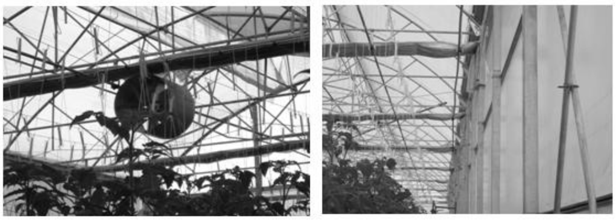


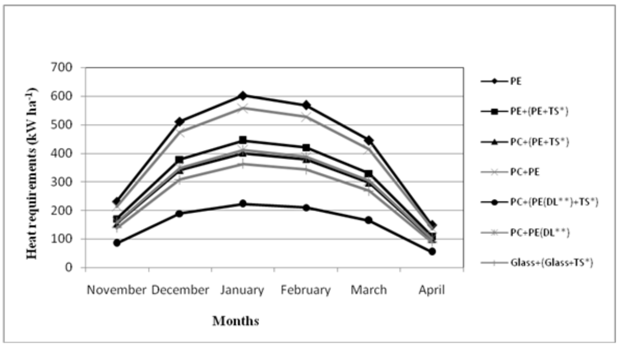
Figure 3. The modern greenhouses farm used circulation fan and thermal screen.

In modern greenhouses, there are also fogging, CO_2 fertilization and thermal screen. In this study, it was found that 36% of the vegetable production greenhouses used to increase air humidity with fogging system. CO_2 is an important element in photosynthesis. According to CO_2 fertilization, the distribution of the modern greenhouse farms is given in Table 14. As shown in Table 14, It has been found that CO_2 fertilization is only made in 50% of the vegetable productiongreenhouses to increase yield while CO_2 fertilization is not make the seedling and seed production greenhouses. As shown in the Table 15, thermal screen is used 64% of the vegetable production greenhouses whereas thermal screen is not use the seedling and seed production greenhouses. Most of the producers use the thermal screen to make use of saving energy (Table 15). It has also been determined that the thermal screen is generally placed in the gutter to the gutter and have an opening and closing mechanism which is moved by sliding (Fig. 3). The producers use more aluminum doped polyester films as thermal screen. All of the investigated modern greenhouse farms in the province of Antalya, water and fertilizer necessary for plant growth is applied to the growing media by an automation system of irrigation-fertilizer throughout the day. For this purpose, while drip irrigation systems are used in the vegetable and seed production greenhouses, sprinkler systems are used in the seedling production greenhouses. Kacıra et al. (2004) reported that automation is becoming a necessity in Turkish greenhouses to produce high quality products and to meet the export market quality demand.

3.5. Heat requirements of modern greenhouse farms

The total heat requirement values of modern greenhouse farms per unit area calculated for the heat transfer coefficient and application purpose are presented in Table 16. According to the calculations, the average heat requirements of the vegetable production greenhouses vary between 925 and 2484 kW/ha. Greenhouses covered with PE has the highest heat requirement (2484 kW/ha) whereas greenhouses covered with PC+PE(DL**)+TS* has the lowest (925 kW/ha). The seedling production greenhouses have similar the average heat requirements with the vegetable production greenhouses. As shown in Table 15, the average heat requirement for the covered with PE greenhouse was higher than the covered with PC+PE in these greenhouses. The seed production greenhouses are only covered with polycarbonate cover so the average heat requirement was 1708 kW/ha.

Average monthly heat requirements calculated for the the heat transfer coefficient are presented in Figure 4. As shown in Figure 4, the heating process is carried out in the period of November-April. The maximum heat requirement values were calculated for January whereas the minimum heat requirement values were calculated for April at all of the investigated greenhouses. The highest and lowest heat requirements were determined from PE and PC+(PE(DL**)+TS*) covereed greenhouses, respectively. According to the results, thermal screen and DL PE film decrease heat requirement of greenhouses (Fig. 4).



PE: Polyethylene film, PC: Polycarbonate film; *Thermal Screen, ** Double Layer

Figure 4. Changes of the average monthly heat requirement values according to the cover material.

4. Conclusion

Modern greenhouses in the region, in terms of sizing and planning criteria, have been found to meet local area's ecological conditions. Greenhouses are constructed by doing static and strength calculations. Environmental conditions inside the greenhouse are controlled by climate control automation system. The heating and ventilation systems are on or off in accordance with the received climatic data. Thus, the necessary environmental conditions for crop production are met to ensure optimum conditions during the production season. The heating requirements were calculated for investigated greenhouses based on climate parameters of Antalya province. Heating is not carried out in the daytime hours due to the sufficient intensity of solar radiation. Heating process in the region is carried out at night in between November and April period. The highest and lowest heat requirements were determined from PE and PC+(PE(DL**)+TS*) covered greenhouses, respectively.

Table 14. CO_2 fertilization in the modern greenhouse farms.

CO_2 fertilization	Vegetable production greenhouses		Seedling production greenhouses		Seed production greenhouses	
	Number	%	Number	%	Number	%
LPG roof gas	4	29	-	-	-	-
Liquid CO_2	3	21	-	-	-	-
Not used	7	50	2	100	3	100
Total	14	100	2	100	3	100

Table 15. The use of thermal screen in modern greenhouse farms.

Purpose use of thermal screen	Vegetable production greenhouses		Seedling production greenhouses		Seed production greenhouses	
	Number	%	Number	%	Number	%
Energy saving	6	43	-	-	-	-
Energy saving+shading	3	21	-	-	-	-
Not used	5	36	2	100	3	100
Total	14	100	2	100	3	100

Table 16. Distribution of the total heat requirements of modern greenhouses in the region for unit area in the period of November-April.

Cover Material and Thermal Screen Usage		The number of greenhouse	Vegetable production greenhouses				Seedling production greenhouses				Seed production greenhouses			
Side Wall	Roof		Unit	Total Area (ha)	Total cover surface area (m^2)	Average kW ha^{-1}	Unit	Total Area	Total cover surface area	Average kW ha^{-1}	Unit	Total Area	Total cover surface area	Average kW ha^{-1}
PE	PE	5	4	0.5 2.8 1.7 1.3	6982 31813 20690 33486	2484±66.2	1	0.8	10108	2591	-	-	-	-
PE	PE+TS*	4	4	1.0 2.2 1.3 1.3	13644 26347 16145 16145	1851±39.6	-	-	-	-	-	-	-	-
PC	PE	2	1	3.7	42834	2264	1	0.8	10074	2379	-	-	-	-
PC	PE+TS*	1	1	1.4	17349	1668	-	-	-	-	-	-	-	-
PC	PE (DL**)+TS*	3	3	2.9 3.2 3.2	34251 38218 38218	925±3.6	-	-	-	-	-	-	-	-
PC	PE (DL**)	3	-	-	-	-	-	-	-	-	3	0.6 0.7 0.1	7696 8748 1974	1708 ±141.2
Glas	Glass+TS*	1	1	2.2	26229	1511	-	-	-	-	-	-	-	-

PE: Polyethylene film, PC: Polycarbonate film; *Thermal Screen, ** Double Layer

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