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RESEARCH ARTICLE

DETERMINING HEATING REQUIREMENTS OF A PLASTIC TUNNEL EXPOSED TO TEKİRDAĞ WEATHER CONDITIONS BASED ON DAYTIME AND NIGHTTIME TEMPERATURE DIFFERENCES

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ABSTRACT

Heating costs of greenhouse production are the costs incurred for increasing the temperature inside the greenhouse on cold days and nights, as required by the plants produced in the greenhouse. Heating costs of a protected cultivation has a high rate, namely 60 to 70 %, in production costs. Therefore, it is very important to calculate temperature requirements of greenhouses accurately for reducing production costs. In this study, a different method has been used to calculate temperature requirements of the greenhouse. Generally, calculation of temperature requirement is based on the difference between the lowest average exterior temperature on that region and optimum temperature required for plants. In other words, the calculation of temperature requirement is based on the assumption that the entire day is at the lowest average exterior temperature. According to this calculation, the temperature requirements of the greenhouse seem higher. Since the plants do not photosynthesize at night, the temperature inside the greenhouse should be lower at night and higher in the daytime. This study made separate calculations based on nighttime and daytime hours for determining temperature requirements of high tunnel. These calculated values were multiplied with nighttime – daytime hour rates to determine the average daily temperature requirement of the high tunnel. This method was used to determine heating requirements of a plastic high tunnel under climatic conditions of Tekirdağ province, based on months that plants require heating, for nighttime – daytime hours separately. As a result of this study, the temperature saving in January, which has the highest heating requirement, increased up to 25,7 %; 48,0 % in November, 36,0 % in December, 29,5 % in February, 33,4 % in March and 52,2 % in April.

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INTRODUCTION

Greenhouse is defined as a high-system greenhouse cultivation designed in different shapes by covering the structure with glass, plastic and such other light transmitting cover materials for assuring optimum conditions of plant growth and cultivation, preventing negative impacts of outdoor climate conditions on cultivated plants, growing and displaying seeds, seedlings and saplings of plants by keeping factors such as temperature, relative humidity, radiation, carbon dioxide (CO_2) and air motion and composition under control, if required, and thus the system is completely or partially independent from environmental conditions related to climate (Anonymous, 2000). Greenhouse is a structure that is covered with a light transmitting cover material such as glass and plastic and that offers optimum climate conditions for the cultivated plants such as light, temperature, humidity, air motion and CO_2. History of greenhouses providing optimum climate conditions for certain vegetables, fruits and ornamental plants dates back to ancient times (Öztürk, 2008). If daily average outside air temperature is less than 12 ºC, greenhouses must be heated for plant production (von Zabeltitz, 1994). Greenhouse heating requirements are defined as heating load required to be generated by heating system in case of a certain outside temperature value so that desired temperature value can be achieved in the greenhouse (Akyüz *et al*., 2017). Heating costs of greenhouse cultivation are the highest one of all production costs (Popovski, 1997; Çolak, 2002). Hence, greenhouse heating requirements must be calculated accurately. The heating requirement is calculated to be lower according to the temperature difference between day and night. A lower result is obtained when the heating requirement of the greenhouse is calculated according to the temperature difference between day and night. When the heat requirement calculation is carried out by the conventional method, the minimum average temperature

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values for that month have been used. This leads to overestimation of the heating requirement and the need for the heating system to be larger than what would normally be adequate. Calculating lower heating requirements will significantly lower operational costs in a greenhouse (Gürdil *et al*., 2009).

Greenhouse Heating Requirements

For assuring quality, quantity and cultivation time of products cultivated in greenhouses, greenhouses must be heated in cold winter time (Kürklü and Bilgin, 2001). The daytime temperature inside the greenhouse must be 5 to 8 ºC higher than the nighttime temperature since plants photosynthesize and respire during the day and respire at night. Daytime and nighttime temperature difference must be taken into consideration for calculating greenhouse heating requirements because daytime and nighttime greenhouse heating requirements are different. Table 1 illustrates the optimum environmental temperatures for various types of plants under greenhouse conditions. Air temperature in greenhouse has different impacts on physiological processes such as plant photosynthesis, respiration and water intake. Temperature is the most important factor that has impact on the respiration of plants cultivated in greenhouses. An increase of 10 ºC in the air temperature of greenhouse environment doubles the respiration rate. Temperature's impact on plant development in case of lower light level is more than the conditions where light level is higher (Öztürk, 2008). The lowest and highest air temperatures are the temperatures stopping plant development depending on the plant variety. The optimum temperature value for plants cultivated in greenhouses is the temperature that assures the fastest plant development (Moore, 1975). Majority of plant varieties develops better when temperature at nighttime is lower than the temperature in daytime. When temperature is lowered at nighttime, carbohydrate losses will be reduced due to respiration (Öztürk, 2008).

Factors Affecting the Greenhouse Heating Requirements

The following factors must be taken into consideration when calculating greenhouse heating requirements.

- Temperature required in the greenhouse and outside air temperature,
- Dimension and outer surface area of greenhouse,
- Type of greenhouse cover material and number of folds,
- Loss of temperature leaking from greenhouse,
- Heat content lost with air conditioning.

The calculation of greenhouse heating requirement is based on difference between average of minimum outside air temperatures and daytime temperatures required in the greenhouse (Başçetinçelik and Öztürk, 1996; Yağanoğlu and Kocaman, 2011; Yüksel and Yüksel, 2012). A review of Table 1 confirms that temperature requirements of plants are lower at nighttime. The solar radiation warms up the greenhouse during the daytime hours and the outside air temperature rises. If the outside air temperature is based on the minimum temperature value for the entire day when calculating ordinary greenhouse heating requirement, the greenhouse heating requirement will be higher. This will require using more energy in the greenhouse. Besides, if heating requirement is higher, we would have to install instruments and equipment larger than necessary. So, investment cost will increase and the system will consume more energy. Purpose of this study is to determine the heating requirements of high tunnel, which is used for cultivation on a plastic high tunnel air conditioned in Tekirdağ, separately for daytime and nighttime by taking into consideration local climate conditions and based on individual months

MATERIALS AND METHODS

Materials

Tekirdağ City located in the Thrace Region is the research area. The Thrace Region is located on the European continent territory of Turkey on 26º-29ºeastern longitudes and 40º-42ºnorthern latitudes. Turkey's location on earth is marked on Figure 1.

Figure 1. Turkey's location on earth (Anonymous, 2017)

The Süleymanpaşa research area, located in Tekirdağ City, Merkez District, is situated on 26º40′-28º10′ eastern longitudes and 40º35′-41º35′ northern latitudes. Climate, soil and water resources of Tekirdağ city are suitable for greenhouse cultivation. It is advantageous in terms of marketing possibilities because it is located at a distance of 135 km to a large consumption center like Istanbul. Some climate details of Tekirdağ city are illustrated on Table 2. Technical details of the high plastic tunnel used as research material are given on Table 3. In addition to the technical properties given on Table 3, the cover material used on the high tunnel of study is single layer polyethylene (PE). Framework of the high plastic tunnel is made up of galvanized pipes with a diameter of 50-mm. 20*30 cm cylindrical concrete bases are used, as foundation, on the sections of framework that contact the soil. There are two-piece ventilation openings on the side surfaces of the high tunnel (Figure 1).

Plants Cultivated on the High Tunnel

The high plastic tunnel used on the study cultivates cucumber and tomato on the spring cultivation season. It is also used to cultivate lettuce and radish on the autumn cultivation season.

Table 1. Optimum greenhouse temperatures for various plants (Varış, 1984)

Plant	Daytime temperature (°C)	Nighttime Temperature (°C)	Air conditioning Temperature (°C)	Highest Temperature (°C)
Tomato	18-20	15-17	22-24	27
Pepper	18-20	15-17	22-24	27
Eggplant	18-20	15-17	22-24	27
Okra	18-20	15-17	22-24	27
Cucumber	22-25	16-20	27	30
Bean	21	15	23-25	27
Sweet pea	21	15	23-25	27

Table 2. Some multi-year climate data of Tekirdağ City (Anonymous, 2011)

Climate parameters	January	February	March	April	May	June	July	August	September	October	November	December
Maximum Temperature (°C)	21,5	24,7	28,1	30,0	32,0	40,2	38,4	37,5	34,5	35,1	26,0	22,4
Minimum temperature averages(°C)	2,2	2,4	4,3	8,2	12,5	16,6	19,1	19,3	16,0	11,9	7,6	4,2
Average temperature (°C)	4,9	5,1	7,4	11,9	16,7	21,4	23,8	23,6	19,9	15,3	10,5	7,0
Average relative humidity (%)	82,6	80,6	80,5	78,5	77,1	73,7	70,9	72,0	75,0	78,9	81,9	82,6
Sunshine duration (hour)	2,8	4,0	4,7	6,2	8,1	9,5	10,0	9,3	7,8	5,4	3,8	2,6
Total rainfall average (mm)	60,3	54,5	55,2	41,9	38,4	37,1	24,3	14,6	37,8	65,2	73,7	73,8
Average wind speed (m s^{-1})	3,0	3,1	2,9	2,4	2,3	2,3	2,7	2,9	2,8	2,9	2,8	3,2

Table 3. Technical properties of the high plastic tunnel

Length (m)	Width (m)	Roof ridge height (m)	Side surface height (m)	Truss distances (m)	Front and back doors		Ventilation openings	
					Height (m)	Width (m)	Height (m)	Length (m)
38,2	7,8	3,6	2,2	2,0	1,96	2,05	0,9	16,5

Table 4. Day and night durations in Tekirdağ

Months	Duration of Day	Duration of Night
January	$9^h17'$ - $10^h03'$	$14^h43'$ - $13^h57'$
February	$10^h05'$ - $11^h08'$	$13^h55'$ - $12^h52'$
March	$11^h15'$ - $12^h39'$	$12^h45'$ - $11^h21'$
April	$12^h41'$ - $13^h55'$	$11^h19'$ - $10^h05'$
November	$10^h26'$ - $9^h28'$	$13^h34'$ - $14^h32'$
December	$9^h27'$ - $9^h15'$	$14^h33'$ - $14^h45'$

Table 5. Average duration of days and nights in Tekirdağ for the months subject to greenhouse heating

Hours	January	February	March	April	November	December
Average day length						
	$9^h\ 36'$	$10^h\ 36'$	$11^h\ 55'$	$13^h\ 32'$	$9^h\ 35'$	$9^h\ 16'$
Hour	$9{,}60^h$	$10{,}60^h$	$11{,}92^h$	$13{,}53^h$	$9{,}58^h$	$9{,}27^h$
Average night length						
	$14^h\ 24'$	$13^h24'$	$12^h\ 05'$	$10^h\ 28'$	$14^h25'$	$14^h44'$
Hour	$14{,}40^h$	$13{,}40^h$	$12{,}08^h$	$10{,}47^h$	$14{,}42^h$	$14{,}73^h$

Table 6. Minimum average temperate at night and average daytime temperatures used for calculating greenhouse heating requirement based on climate conditions in Tekirdağ (Anonymous, 2016b)

Average temperatures	January	February	March	April	November	December
Minimum average temperature at night (ºC)	2,1	2,3	4,2	8,2	8,0	4,3
Average daytime temperature (ºC)	4,9	5,2	7,4	11,9	11,0	7,2

Table 7. Heating requirement values and energy saving rates of the high tunnel based on daytime and nighttime differences

	November	December	January	February	March	April
Normal Calculation(kcal h^{-1})	30223,0	41405,5	48054,6	47450,1	41707,7	29618,5
Calculation based on night – day difference (kcal h^{-1})	15708,6	26502,6	35723,6	33454,4	27776,9	14166,7
Saving rate(%)	48,0	36,0	25,7	29,5	33,4	52,2

(a) (b) (c)

Figure 1. Exterior (a) and interior (b)-(c) images of the high plastic tunnel used on the research

Cucumber seeds rapidly germinate and develop if exposed to high temperatures. Nighttime temperatures are reduced down to 19ºC and daytime temperatures down to 21 ºC after germination. If the temperature is above 27 ºC, cooling should start (Anonymous, 1983; Sevgican, 1999). Optimum conditions of growing tomato in greenhouses will be assure if the daytime temperatures are between 17 and 26 ºC and nighttime temperatures are between 11 to 18 ºC (Sevgican, 1999). The optimum temperature for growing lettuce and romaine lettuce must be between 15, 5 ºC and 18,3 ºC. The transition from vegetative phase to generative phase starts at temperatures higher than 18 ºC (Anonymous, 2015). Radish is a vegetable of warm and cool climates. The optimum temperature at germination stage after planting the seeds is 12 to 15 ºC and 14 to 15 ºC for growth after germination (Anonymous, 2016a).

Methods

Heating requirements and energy saving rates of the high tunnel used on the research are calculated based on daytime and nighttime differences. The following equation is used to determine heating requirement of the high tunnel used on the study (Yüksel, 1987; Yağcıoğlu, 2009).

$$Q = A \times U \times (t_i - t_d) \qquad (1)$$

In Formulation 1:

Q: Greenhouse heating requirement (kcal h^{-1})
A: Exterior surface area of the greenhouse (m^2)
U: Heat transfer coefficient of plastic cover material (kcal $h^{-1}(m^2)^{-1}(^oC)^{-1}$)
t_i: Air temperature inside greenhouse (ºC)
t_d: Air temperature outside greenhouse (ºC)

Generally, average minimum outside air temperature is taken as basis when calculating the heating requirement. The calculation is made as if the same minimum temperature continues the entire day. Daytime and nighttime temperature requirements of plants are different and air temperatures are also different; thus, it is agreed that basing the calculation on daytime and nighttime differences would be appropriate. First, the heating requirement of the high tunnel was calculated based on the minimum average temperature level. Then, the heating requirement of the high tunnel was calculated based on nighttime and daytime temperatures and these two values were compared.

RESULTS AND DISCUSSION

When the ambient temperature of the place where greenhouses are located is at the lowest level, greenhouses must be heated to keep the temperature inside the greenhouses at required level. Normally, the greenhouse heating requirement is calculated according to the meteorological records of the place where the greenhouse is to be constructed and based on the difference between average of the lowest temperatures and temperature optimum for the plants cultivated in that greenhouse within a specific period of time. If based on this calculation, heat load of greenhouse would be higher and heating system would be bigger than necessary. As illustrated on Table 1, different daytime and nighttime temperature requirements of plants are taken into consideration on the calculations. Also, outside air temperature averages are different at daytime and nighttime and these values are used on the calculations.

Day and night durations

Calculation of greenhouse heating requirement must be made based on day and night durations on different months. The day and night durations in months subject to greenhouse heating under climate conditions of Tekirdağ are obtained from Tekirdağ Directorate of Meteorology and the numbers are illustrated on Table 4.

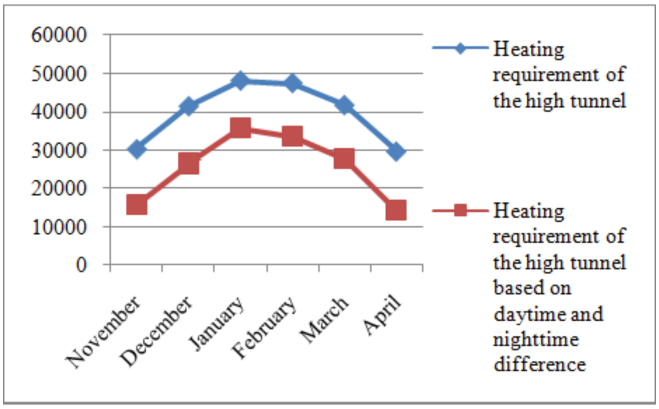

Figure 2. Heating requirement of the high tunnel (kcal h^{-1})and heating requirement of the high tunnel based on day and night differences (kcal h^{-1})

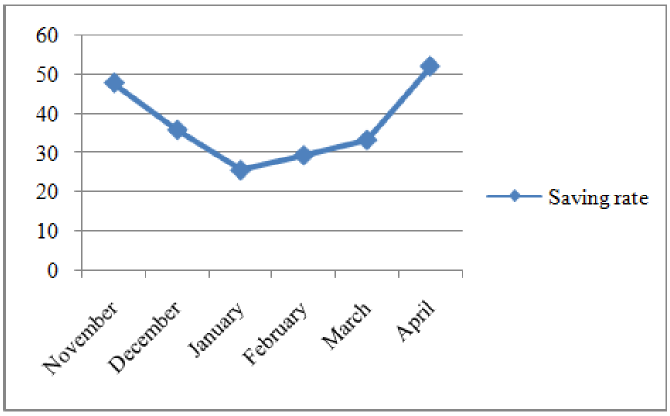

Figure 3. Monthly heat saving rates of the high tunnel (%)

Arithmetic means of monthly values given on Table 4 are calculated to obtain the day and night duration to be used on the calculations. These values are illustrated on Table 5. Day and night values calculated in a month are added one by one and divided by the number of days to calculate the average values.

Determining Greenhouse Heating Requirement

Heat transfer coefficient and exterior surface area of the greenhouse, outside air temperature and air temperature required in the greenhouse are taken into consideration when calculating greenhouse heating requirement. Minimum average temperatures at night and average daytime temperatures used on the calculations are given on Table 6. These values are obtained from Tekirdağ Directorate of Meteorology Stations. The Directorate of Meteorology and high tunnel used on the study are at sea level and they are close to each other. These meteorological values are also used because they are averages of many years. It is known that daytime temperature inside a greenhouse must be around 18 ºC and the nighttime temperature must be 5 to 8 ºC lower than this (Varış, 1984; Yüksel and Yüksel, 2012). Therefore, it is assumed that the nighttime temperature in the high tunnel must be 12 ºC. As for Tekirdağ greenhouses with plastic covers, it is stated that heat transfer coefficient of plastic cover is 7,0 kcal $h^{-1}(m^2)^{-1}$ $(^oC)^{-1}$at windy weather (Yüksel and Yüksel, 2012). Exterior surface area of the high tunnel used on the calculation is 431.76 m^2. The high tunnel's heating requirement was calculated based the lowest average temperature in an entire day in November and the abovementioned details were used.

$$Q = A \times U \times (t_i - t_d)$$

$$Q = 431{,}76 \times 7{,}0 \times (18 - 8) = 30223{,}0 \text{ kcal h}^{-1}$$

The high tunnel's heating requirement in November was calculated separately based on night and day hours by using the Formulation 1.

$$Q_{day} = 431{,}76 \times 7{,}0 \times (18 - 11) = 21156{,}24 \text{ kcal h}^{-1}$$

$$Q_{night} = 431{,}76 \times 7{,}0 \times (12 - 8) = 12089{,}3 \text{ kcal h}^{-1}$$

Daytime heating requirement is calculated by multiplying heating requirement based on duration of daytime and duration of daytime and then dividing the result by 24 hours.
$21156{,}24 \times 9{,}58/24 = 8444{,}9 \text{ kcal h}^{-1}$

Nighttime heating requirement is calculated by multiplying heating requirement based on duration of nighttime and duration of nighttime and then dividing the result by 24 hours.
$12089{,}3 \times 14{,}42/24 = 7263{,}7 \text{ kcal h}^{-1}$

Daytime and nighttime heating requirement values shall be added to calculate the daily heating requirement of the high tunnel.

$$8444{,}9 + 7263{,}7 = 15708{,}6 \text{ kcal h}^{-1}$$

This calculation made for November was also repeated for December, January, February, March and April. Accordingly, Table 7 illustrates the day and nighttime heating requirements of the high tunnel, heating requirements obtained with ordinary calculation and energy saving rates and the graphical illustrations of these data are given on Figure 2 and Figure 3. Heating expenses account for 60 to 70 % of operational costs in heated greenhouses (Popovski, 1997; Çolak, 2002). As seen on Table 7, Figure 2 and Figure 3; if we calculate the heating requirement of high tunnel based on night and day difference, the energy used for heating will be decreased by minimum 26 %. The energy consumed by the system will decrease when the outside air temperature rises. The energy savings in April and November increase up to nearly 50 %. The overestimation of heating requirement causes the heating system to be installed in the greenhouse at least 26 % bigger. It is known that installing a larger system will have significant impact on the investment and operational costs. This means that heating system's share in investment cost shall be 26 % less. Heating costs account for 60 to 70 % of the greenhouse operating costs. If heating costs, which account for 60 to 70 % of the annual operating costs of a greenhouse, are reduced by 26 %, this will reduce the operating costs by 16 to 18 %.

CONCLUSION AND SUGGESTIONS

Greenhouse businesses are production areas that require sizable investment. Besides, the operating costs are high. Minimizing these costs will be a material factor to increase number of greenhouse businesses. According to the data obtained on the study conducted based on nighttime and daytime temperature differences; if the greenhouse heating requirement is reduced by 26 %, the heating system will be smaller and the heating expenses will be lower. When preparing greenhouse feasibility reports based on this data, a producer might be more easily persuaded to make a greenhouse cultivation investment since the operating and investment costs will be lower. This will allow seasonal producers involved in plant production to focus on greenhouse cultivation at other times and to increase their incomes as well as improving their life quality.

REFERENCES

Akyüz, A., Baytorun, A.N., Çaylı, A., Üstün, S. and Önder, D. 2017. Seralarda Isıtma Sistemlerinin Projelenmesinde Gerekli Olan Isı Gücünün Belirlenmesinde Yeni Yaklaşımlar. *KSU J. Nat. Sci.,* 20(3), 209-217, 2017.

Anonymous, 1983. Cucumbers. Grower Guide, No:15, London.

Anonymous, 2000. T.S.E. Sera Terimler ve Tarifler, Türk Standardı, ICS 65.040.30, Necatibey Caddesi No.112, Bakanlıklar/Ankara.

Anonymous, 2011. Records form Turkish General Directorate of Meteorology

Anonymous, 2015. adana.tarim.gov.tr/Belgeler/.../bitkisel... yetistiriciligi.../Marul.pdf

Anonymous, 2016a. http://megep.meb.gov.tr/mte_program_ modul/moduller_pdf/Turp%20Yeti%C5 %9Ftiricili%C4%9Fi.pdf

Anonymous, 2016b. Records from Tekirdağ Directorate of Meteorological Stations

Anonymous, 2017. https://www.turizm.com.tr/anasayfa/ bilmeniz-gerekenler/turkiye/dunyada-turkiye

Başçetinçelik, A. and Öztürk, H.H. 1996 (translated from C.V. Zabeltitz). Seralarda Isıtma (Enerji Koruma veYenilenebilir Enerjiler). Temav Yayınları:1, Ankara, pp217

Çolak, A. 2002. Isıtılmayan bir cam serada sera içi sıcaklık, çiğlenme sıcaklığı ve bağıl nem deseni üzerine bir araştırma. Ege University, *Journal of Agricultural Faculty*, 39(3), 105-112.

Gürdil, G.A.K, Selvi, K.Ç. and Önder, H. 2009. Seralarda ısıtma kapasitelerinin hesaplanmasına yönelik bir bilgisayar programı. 25th National Congress on Agricultural Mechanization, 01-03 October 2009, Isparta, pp429-434.

Kürklü, A., ve Bilgin, S. 2001. Güneş enerjisinin bir çakıltaşı deposunda depolanması ve plastik bir tünelin ısıtılması amacıyla kullanılması konusunda bir çalışma. 20th National Congress on Agricultural Mechanization, Şanlıurfa, 13-15 September 2001, pp.387-392.

Moore, E.L. 1975. Requirement for optimum greenhouse tomato growth and product quality for Tennessee valley cultivars.Tennessee Valley Greenhouse Vegetable Workshop Bull.Y-94, pp.78-90.

Öztürk, H.H. 2008. Sera İklimlendirme Tekniği. Hasad Yayıncılık, İstanbul, pp 305.

Popovski, K. 1997.Greenhouse climate factors. Geo-Heat Center Quarterly Bulletin, Vol.18, No.1, pp. 14-20.

Sevgican, A. 1999. Örtüaltı Sebzeciliği Cilt I. Ege University, Agricultural Faculty Publications No:528, Bornova-İzmir, pp.302

Varış, S. 1984. Sebze Türlerinin Ekolojik İstekleri. Bahçe Bitkileri, Trakya University, Tekirdağ Agricultural Faculty Publications, Publication Number 17, pp.48-69.

Von Zabeltitz, C. 1994. Effective use of renewable energies for greenhouse heating. Renewable Energy, 5(1-4), 479-485. doi: Doi 10.1016/0960-1481(94)90419-7

Yağanoğlu, A.V. and Kocaman, B. 2011.Seraların Planlanması ve Projelenmesi. Atatürk University, Agricultural Faculty Course Publications Number:240, Erzurum, pp. 241

Yağcıoğlu, A. 2009. Sera Mekanizasyonu. Ege University, Agricultural Faculty Publications; 562, İzmir, pp. 383

Yüksel, A.N. 1987. Tarımda Plastik Örtü KurmaTeknikleri. Hasad Yayıncılık Ltd.Şti., İstanbul, pp. 160

Yüksel, A.N. and Yüksel, E. 2012. Sera Yapım Tekniği. Hasad Yayıncılık Ltd.Şti., İstanbul, pp. 272

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