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EVALUATION OF TEMPERATURE DATA USAGE THE METHOD OF DEGREE-HOUR IN GREENHOUSES: PEPPER PLANT CASE

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Abstract

Greenhouses where the production is carried out and optimum environmental conditions achieved according to many plant species are the agricultural structures. Degree-hour or degree-day methods can be used to get knowledge about energy requirements of any buildings. These methods can provide information about on the amount of energy by using measured and meteorological values and obtaining the heating and cooling values of buildings. The study was chosen in the Kumluca district of Antalya, the place where the most intensive of greenhouse cultivation was made in our country. Autumn cultivation is being done for the pepper plant. This study was conducted between October 2015 and June 2016 in plastic greenhouse. The temperature inside the greenhouse values were recorded during the growing period of the pepper plant. The obtained values were analyzed by Student-t test. The regression coefficients were obtained by calculating the prediction equations between the basic temperature values and the heating and cooling degree-hour values. These coefficients are found between 0.997 and 0.999 for heating degrees-hours and between 0.982 and 0.997 for cooling degrees. As a result, efficiency and quality can be increased through air conditioning improvements in the greenhouses located in mild climate areas such as Antalya, where heating is maintained for frost protection and ventilation difficulties are experienced.

Key words: *pepper, greenhouse, degree-hour, temperature.*

INTRODUCTION

Greenhouses are the agricultural production facilities where production is planned based on technical and economic factors with a view to ensuring the right air conditioning and production planning required for the type of plant to be cultivated.

Having a history of more than 50 years, greenhouse cultivation is conducted on nearly 66,000 hectares of land throughout Turkey, primarily in the Mediterranean Region as well as the Aegean, Marmara and Black Sea regions (Olgun, 2011; Anonymous, 2016).

Antalya is the city in the Mediterranean Region where greenhouse cultivation is most extensively conducted. Kumluca county in the province of Antalya, however, provides the biggest greenhouse cultivation. When the cultivation of the pepper plant in Kumluca area is compared to the overall greenhouse cultivation in Turkey in 2015, it is observed that while the entire greenhouse cultivation of peppers in Turkey took place in nearly 1000 hectares of land, the area devoted to the production of peppers in Kumluca accounted for 30% of the entire production area (300 hectares), which represented 34% (36,000 tons) of the total national production of 105,000 tons. In the same way, of the entire domestic plastic greenhouse cultivation of peppers performed on a land of 3580 hectares, 755 hectares (21%) of it is performed in Kumluca.

Of the 301,600 tons of peppers produced in the plastic greenhouses in Turkey, 90,600 tons

(30%) are produced in Kumluca county (Anonymous, 2016).
Pepper is a plant that is quite fond of light yet insensitive to the duration of daylight. Although it is capable of germinating at above 8°C, the best germination is achieved at 21°C to 28°C.
While the ideal environmental temperature is between 18-23°C, during day and night, when it is a seedling, care should be taken to ensure that night temperature is not below 12°C. While the daily temperature can be allowed to rise to 25°C on sunny days, ventilation should nevertheless be performed when the temperature hits 30°C. Cultivation is ceased fully at 45°C (Sevgican, 1999).
Planning on heating, cooling and ventilation systems in greenhouses are related to the outside air conditions.
While planning such systems, reliance on long term climate data rather than the climate conditions of several years will help planners adopt a more realistic approach in determining future results (Ileri and Uner, 1998). Degree-day values are one of the most basic measurement units used in the estimation of annual energy requirements of a building located in any place or location (Bayram and Yesilata, 2009).
This study aims to identify the relationship between the indoor temperature and the values of heating and cooling degree-hour values in greenhouse cultivation.
To this end, the indoor temperature values measured inside the greenhouse have been calculated and interpreted based on the heating and cooling durations during the cultivation period of peppers through degree-hour method.

MATERIALS AND METHODS

This study was conducted in Kumluca county, Antalya, where pepper production is extensively performed, in a 4 x 19.5 x 62 m size plastic greenhouse (Figure 1).
It was conducted during the dates between October 2015 and June 2016, a period considered to be the cultivation period of peppers. The temperature was measured by using four TESTO 175 H1 brand temperature and moisture meter sensor.

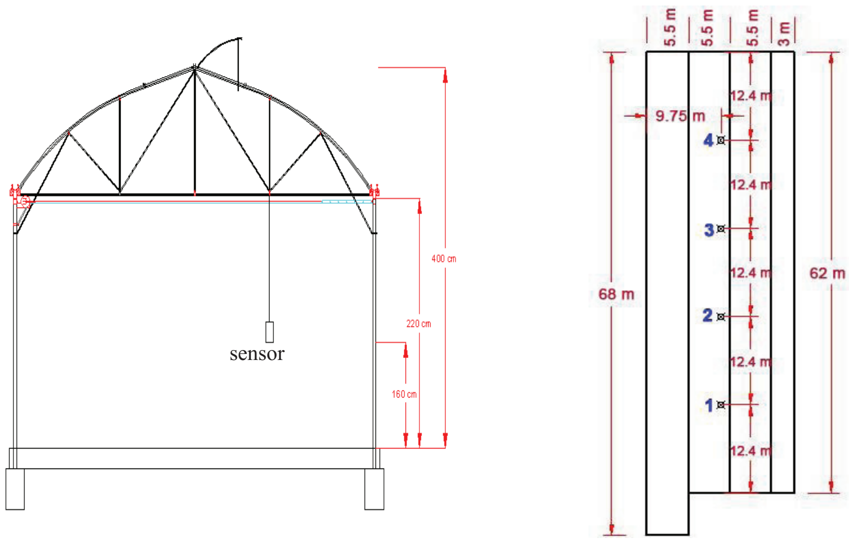

Figure 1. View of the sensors and plastic greenhouse that used in this study

Degree-hour method

Degree-hour and degree-day methods are used in the calculation of heating and cooling loads of structures and air conditioning systems. Degree-hour method yields more precise results than degree-day method (Pusat et. al., 2014).
In the degree-hour method, the energy required for heating or cooling a structure is in proportion with the difference between the air temperature and the balance point temperature. The heating process will be required when the air temperature (Ta) drops below the balance

point temperature (Tb). The cooling process will be required when the air temperature (Ta) rises over the balance point temperature (Tb). Heating degree-hour (HDH) and cooling degree-hour (CDH) values can be calculated based on the following equations (Buyukalaca et al., 2001; Bulut et al., 2007; Pusat et al., 2014; Pusat et al., 2015).

$$HDH = (1hour)\sum_{i=1}^{n}(T_b - T_a)^+ \quad (1)$$

$$CDH = (1hour)\sum_{i=1}^{n}(T_a - T_b)^+ \quad (2)$$

Here; T_a represents the ambient temperature (°C), T_b the balance point temperature (°C), n the hours of the year, the mark in the equations above suggests that only the positive values will be used.

In the calculation of heating and cooling hours of the pepper plant, the temperature values for autumn cultivation was taken as the basis (Table 1) (Ozalp et al., 2006; Anonymous, 2016).

Table 1. Suggested temperature values for autumn period of pepper plant

Growth period	**Suggested temperatures**	**Date**	**Period**
Greenhouse planting	22-28 °C	The end of September- Beginning of October	7-14 days
Flower formation, pollination, insemination	20-25 °C	2nd of October week - 4th of October week	5-6 weeks
Fruit ripening	16-25 °C	2nd of November week -4th of of December week	6 weeks
Harvest	20-35 °C	2nd of February week- 1st of May week	10 weeks

RESULTS AND DISCUSSIONS

The heating degree-hour graphs are presented in the Figure 2 by taking into account the recommended temperature values for each cultivation period of the pepper plant (planting, flower formation**,** pollination, insemination, fruit ripening and harvest). The graphs suggest that the heating degree-hour values increase linearly in accordance with the increasing temperature requirement of the pepper plant in every period. In their study, Bulut et al. (2007) have pointed out that the heating and cooling day values increase linearly depending on the basic temperature values.

The linear increase observed in this study concurs with the findings of Bulut et al. (2007). According to the temperature values measured by the sensors during each cultivation period inside the greenhouse, the calculated numbers of HDHs are found to be fairly close to one another.

It can be argued that there is a homogenous temperature distribution maintained inside the greenhouse. Because heating is maintained in mild climates only for the purpose of protecting the plant against frost and thus heaters are used (Büyüktas et al., 2016). In the greenhouse where the present study was conducted heating was maintained through heaters and it was stated that this practice was exclusively intended for protecting the plant against frost. Availability of HDH values at every heating requirement throughout each cultivation period of the pepper plant and the fact that they follow a different course than that of the recommended temperature values suggest that the greenhouse was not being heated sufficiently.

Insufficient heating in a greenhouse, on the other hand, leads to a significant decrease in both yield and quality (Sevgican, 1999).

The graphs provided herein present the equations and regression coefficients of different base temperature values recommended throughout the cultivation period (independent variable) and the HDH values (dependent variable).

Upon reviewing such coefficients, it has been established that the regression coefficient (R^2) between the dependent and independent variables vary between 0.996 and 0.999.

This can be explained by the presence of a highly positive relationship.

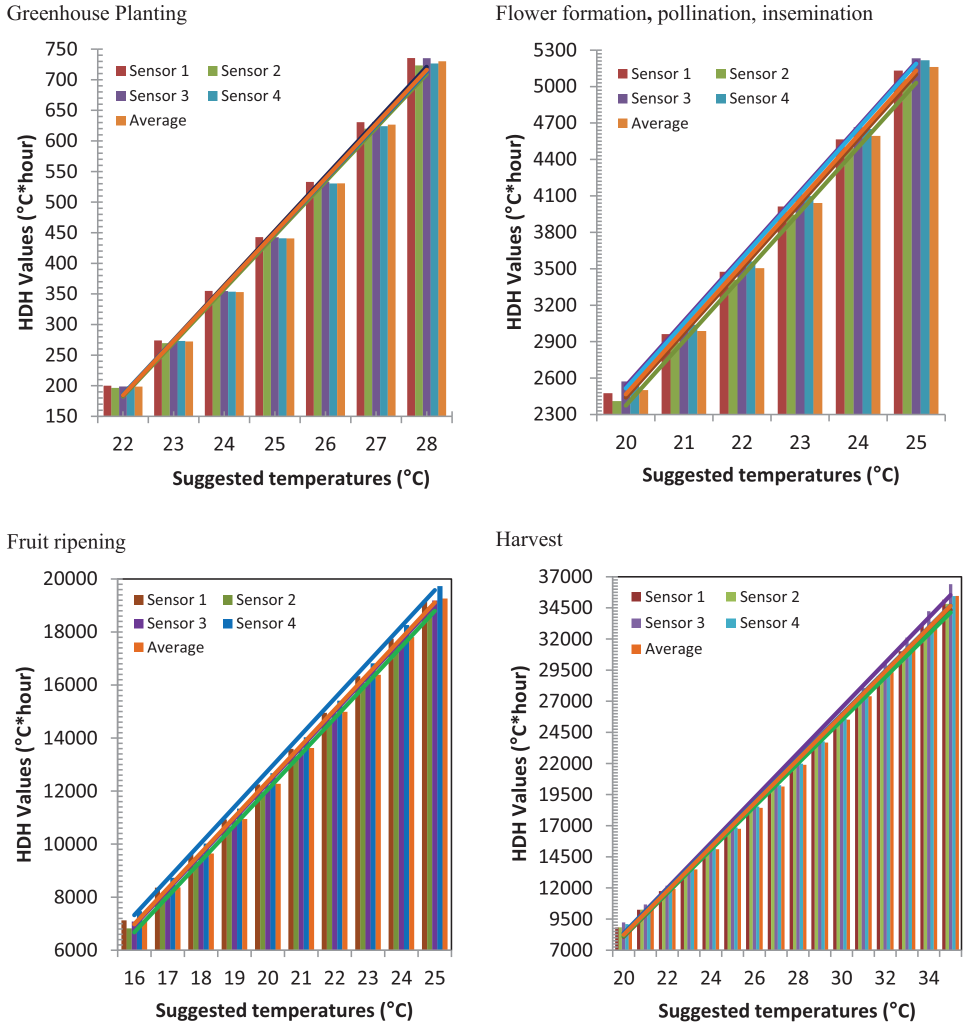

Figure 2. Heating degree-hour values dependent on different temperature values for the pepper plant

The CDH values of the pepper plant have been calculated and presented in the Figure 3.

The CDH values were found to be at a maximum of the values where the heating requirement is reduced for the pepper plant at each cultivation period.

The heating requirement of 22^{o}C during planting, 20^{o}C during florescence, 16^{o}C during fruit development and 20^{o}C during harvesting were determined as the maximum CDH values. The greenhouse, in its current condition, is capable of providing such temperature values. The fact that the daytime temperature values are higher than that of the night time temperature can be explained by the availability of the CDH values even at the minimum temperature requirements required for the pepper plant.

In their study, researchers (Bayram and Yesilata, 2009; Yucel et al., 2014) state that the numbers of heating degree-days and cooling degree-days are important in terms of determining the capacity and costs of the heating and cooling systems.

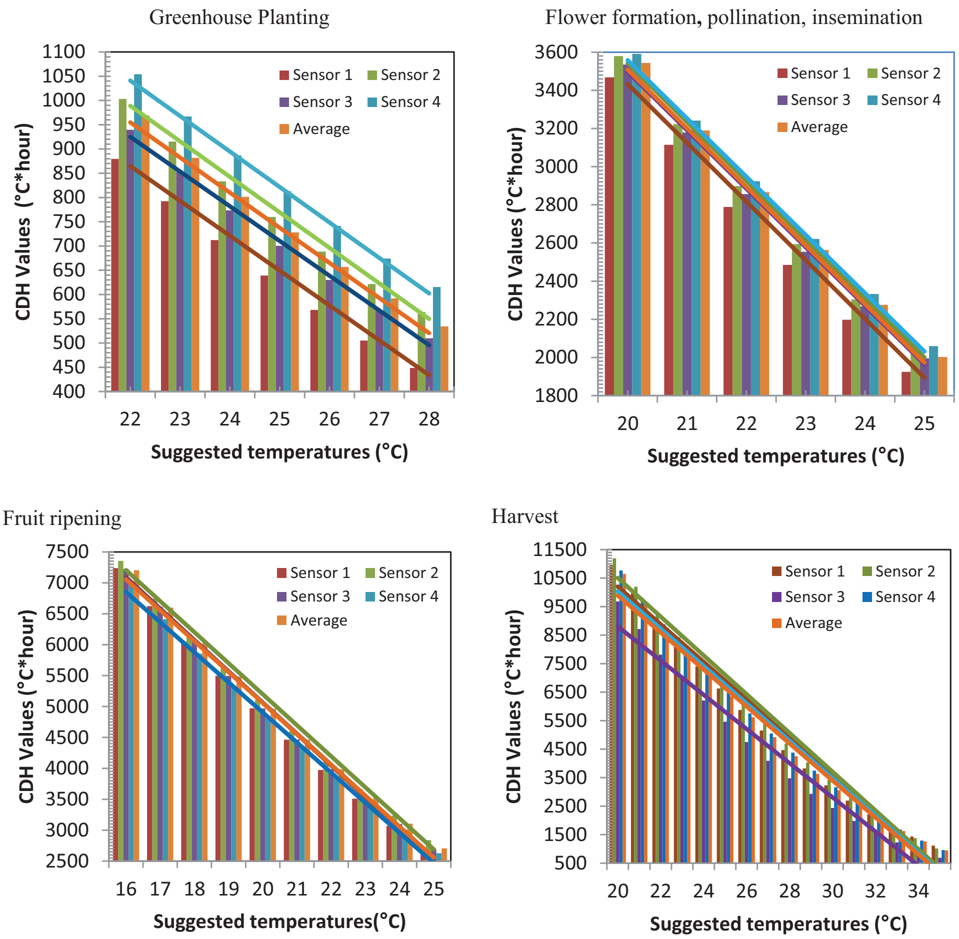

Figure 3. Cooling degree-hour values dependent on different temperature values for the pepper plant

It is reported that the biggest problem encountered in plastic greenhouses is the issue of ventilation. In their study, Monetero et al. (2001) and Fatnassi et al. (2009) report that there are serious efficiency and quality related issues in the greenhouses located around the Mediterranean area, especially at the beginning of the spring and end of the autumn, due to high indoor temperature and insufficient ventilation.

Despite the ventilation provided through both the side walls and the roof, the greenhouse in which the present study was conducted was found to be insufficiently cooled based on the CDH values.

This can help explain the higher cooling degree-hour values even when the heating is least required with the rise in the outside temperature and in line with the cultivation periods of the pepper plant. Again, the equation and regression coefficients of the dependent and independent variables obtained based on the Figure 3 are presented. It is established that such coefficients (R^2) vary between 0.972 and 0.998.

This can also be explained by the presence of a highly positive relationship.

Based on the heating and degree-hour values, we can argue that the plastic greenhouse where this study has been conducted has failed, in its present condition, to provide the temperature values required for the cultivation of peppers at an optimum level. The recommended temperature value of the pepper plant at any cultivation period can be explained by the presence of both heating and cooling values.

CONCLUSIONS

This study has been conducted in a plastic pepper cultivation greenhouse in Kumluca, Antalya where pepper cultivation is extensively performed. Heating and cooling degree-hour values have been determined as per the recommended temperature values for each cultivation period of the pepper plant. Both the heating and cooling degree-hour values were found to have varied based on the temperature requirement of the pepper plant. It was ascertained from the greenhouse growers in the area that the heating was maintained mostly for the purpose of protecting the plant against frost, and it was verified based on the heating and cooling degree-hour values that both heating and cooling was insufficiently maintained for each cultivation period of the pepper plant due to ventilation problems encountered particularly in block plastic greenhouses. In conclusion, yield and quality can be increased through air conditioning improvements in the greenhouses located in mild climate areas such as Antalya, where heating is maintained for frost protection and ventilation difficulties are experienced. Moreover, the fluctuation in the heating and cooling degree-hour values depending on different cultivation periods of the pepper plant may give an idea to the manufacturers beforehand in terms of energy consumption or use.

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