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DETERMINATION OF OPTIMUM HEATING AND COOLING DEGREE-HOUR VALUES FOR PEPPER PLANT

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Abstract

Information on the energy needs of agricultural production activities carried out in any region can be obtained in advance. Many methods are used for this purpose. One of them is a degree-hour method. Kumluca district of Antalya province where pepper cultivation is done intensively was chosen as a study area. The growers prefer autumn production of pepper plants inside the greenhouses in this region. Production starts in early October and last until June. The long-term (1960 – 2015) thermometer temperatures in the study area were obtained from the Turkish State Meteorological Service. In this study, by using only meteorological data, during each growing season (planting, flowering, pollination, fruit ripening and harvesting) were obtained degree-hour values for the pepper plant and evaluated with Student-t test. Regression coefficients were obtained by correlating heating and cooling degree-hour values with different temperature values which are recommended during the vegetative growing season for the pepper plant. Regression analysis was performed between obtaining heating and cooling degree-hour values (dependent variable) and annual mean heating and cooling degree hour values (independent variable) which are suggested basic temperature values. In conclusion, the regression coefficients were determined as 0.99 for out of greenhouse heating degree-hour and as 0.90-0.99 for cooling degree-hour, respectively. Heating and cooling-hour values were found between 0.96-0.88 and 0.99-0.87, respectively. It was determined that there are very high correlations

in the positive direction. According to different growing seasons of pepper, knowing how much less or more of heating and cooling degree-hour values is needed, one can give information in advance in terms of energy consumption or usage. Areas or regions where less energy is to be used can be determined in terms of agricultural production to be done in any region.

Key words: Cooling, Degree-hour, Heating, Kumluca

INTRODUCTION

Greenhouses are agricultural structures in which production is carried out year round by providing suitable climatic and environmental conditions for cultivated plants. In our country, while the tomato plant takes place on the top in greenhouse cultivation, the pepper plant is ranked as the fourth, after cucumber and eggplant. While greenhouse activities are carried out mostly in the Mediterranean region, Antalya province is in the first place.

Pepper Solanaceae is the most cultivated vegetable species in the open field among the vegetable species after tomato. It has different types and in our country, mostly long green peppers, Charleston peppers, and bell peppers are cultivated. However, the cultivation of California Wonder type peppers, known as coarse square-sectioned pepper, and thicker, fleshy bell peppers commonly cultivated in European countries in recent years is rapidly spreading (Aktas et al., 2009).

For the greenhouse design, it is very important that the regional climatic conditions are sufficiently known. Climatic conditions are the most important factor affecting the design and functional characteristics of greenhouses. In the greenhouse design, it is aimed to provide a suitable micro-climate in the indoor environment depending on the climatic conditions in the outdoor environment. Thus, the greenhouse design is significantly affected by the regional climate and latitude. Climatic factors such as temperature, solar radiation, and the wind are important in the greenhouse design (Ozturk, 2003).

The planning of heating, cooling and ventilation systems in greenhouses is closely related to outdoor conditions. While air-conditioning systems are planned, the use of long-term climatic data instead of climatic conditions for a few years will provide more realistic approaches in the determination of the results (Ileri and Uner, 1998). Degree-day values are one of the basic and simplest units of measure used to estimate the annual energy requirement of a building in anywhere and location (Bayram and Yesilata, 2009).

In this study, it is aimed to investigate the temperature values recommended for pepper cultivation by the degree-hour method. For this purpose, heating

and cooling degree-hour values of each growing period of pepper plant were determined and interpreted.

MATERIAL AND METHODS

Long-term meteorological data were used for determining the heating and cooling degree hour values for the autumn growing of the pepper plant. The temperature values of pepper plant for autumn growing in greenhouse were determined according to Ozalp et al. (2006) and Anonymous (2016).

Degree-Hour Method: In structures and air conditioning systems, degree-hour and degree-day methods are used in the calculation of heating and cooling. In practice, degree-hour method results more reliable results than Degree-Day method (Pusat et. al, 2014). Calculation of 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).

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

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

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

Number of Heating Hours (HHN): It is defined as the difference between the balance point temperature and air temperature for the hours of each day. Various studies in the literature suggest that the Degree-Hour values can be measured using a variety of approaches and techniques (Matzarakis and Balafoutis, 2004). The number of HH can be calculated based on the equation provided in the figure 3 below.

$$HHN = \sum_{i=1}^{n} HDH \tag{3}$$

Here, *n* represents the number of total daily hours within the selected period, while the HHN represents the number of hours in which heating is maintained (Buyukalaca, et al., 2001; Matzarakis and Balafoutis, 2004).

Number of Cooling Hours (CHN): In the method developed similarly to that of HHN, it can be calculated in the form of hours of the days where the air temperature is higher than the balance point temperature for the CDH in a certain timeframe as provided in the equation 4 below.

$$CHN = \sum_{i=1}^{n} CDH \tag{4}$$

Here, *n* represents the total number of days within the selected period and CHN the number of daily hours in which cooling is maintained (Buyukalaca et al., 2001; Matzarakis and Balafoutis, 2004). In the calculation of heating and cooling degree-hour, number 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 pepper plant

Growth period	Suggested temperature	Date	Period
Greenhouse planting	22-28 °C	The end of September – Beginning of October	7-14 days (168-336 hours)
Flower formation, pollination, Insemination	20-25 °C	2nd of October week – 4th of October week	5-6 weeks (840-1008 hours)
Fruit ripening	16-25 °C	2nd of November week – 4th of December week	6 weeks (1008 hours)
Harvest	20-35 °C	2nd of February week – 1st of May week	10 weeks (1680 hours)

RESULTS AND DISCUSSION

In the study, it was attempted to determine the heating and cooling degree-hour and heating and cooling-hour numbers in different periods of development of the pepper plant for greenhouse cultivation. Equations 1 and 2 were used in the preparation of Figures 1 and 2, and Equations 3 and 4 were used in the preparation of Figures 3 and 4. Upon examining Figure 1, it was calculated that the heating degree-hour values of the pepper plant according to different temperatures required during the planting period ranged from 426.2 to 1194.8. It was determined that there was a polynomial relationship between the

recommended temperature values for the pepper plant and the heating degree-hour values (R^2=0.99 p<0.05).

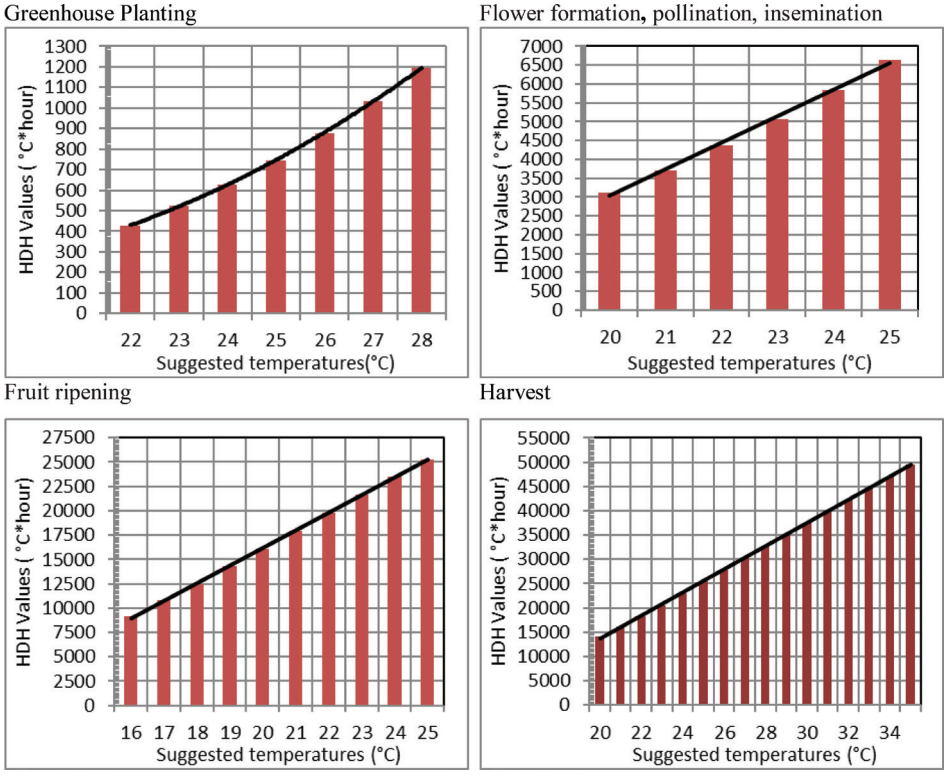

Figure 1. Heating degree hour values according to different temperature values recommended for pepper plant

During the flower formation, pollination and insemination periods, the heating degree-hour values ranged from 3110 to 6630. It was determined that there was a linear relationship between the recommended temperature values and the heating degree-hour values (R^2=0.99 p<0.05). It was determined that these values ranged from 9110 to 25300 during the fruit ripening period and that there was a linear relationship between the recommended temperature values and heating degree-hour values (R^2=0.99 p<0.05). In the harvest period of the pepper plant, the heating degree-hour values required in the greenhouse ranged from 14106 to 49526 and the fact that there was a linear relationship between the recommended temperature values and the heating degree-hour values were determined in Figure 1 (R^2=0.99 p<0.05).

Upon examining Figure 2, the cooling degree-hour values of the pepper plant according to different temperatures required during the planting period ranged from 197.4 to 0. It was determined that each degree of cooling after 26°C in this period did not affect the cooling degree-hour values in the greenhouse. It was determined that there was a polynomial relationship between the recommended temperature values and the cooling degree-hour values (R^2=0.99 $p<0.05$).

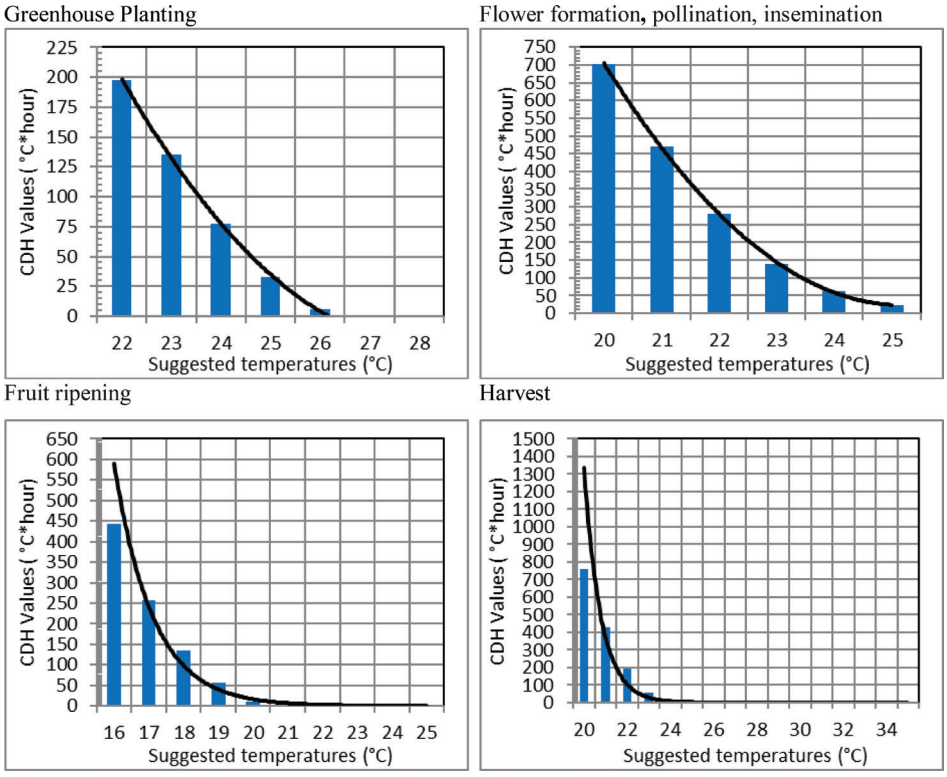

Figure 2. Cooling degree hour values according to different temperature values recommended for pepper plant

The cooling degree-hour values in the flower formation, pollination and insemination periods of the cooling degree-hour values ranged from 702.7 to 22.4. It was determined that there was a polynomial relationship between the recommended temperature values and the cooling degree-hour values (R^2=0.99 $p<0.05$). It was calculated that the cooling degree-hour values calculated during the fruit ripening period ranged from 442.2 to 0. It was determined that each degree of cooling after 20°C in this period would not affect the cooling degree-hour

values in the greenhouse and that there was an exponential relationship between the recommended temperature values and the cooling degree-hour values (R^2=0.94 $p<0.05$). It was determined that the cooling degree-hour values ranged from 760 to 0 in the harvest period. In particular, it was concluded that each degree of cooling after 24°C would not affect the cooling degree-hour values in the greenhouse. It was determined that the relationship between the recommended temperature values and the cooling degree-hour values was exponential (R^2=0.90 $p<0.05$).

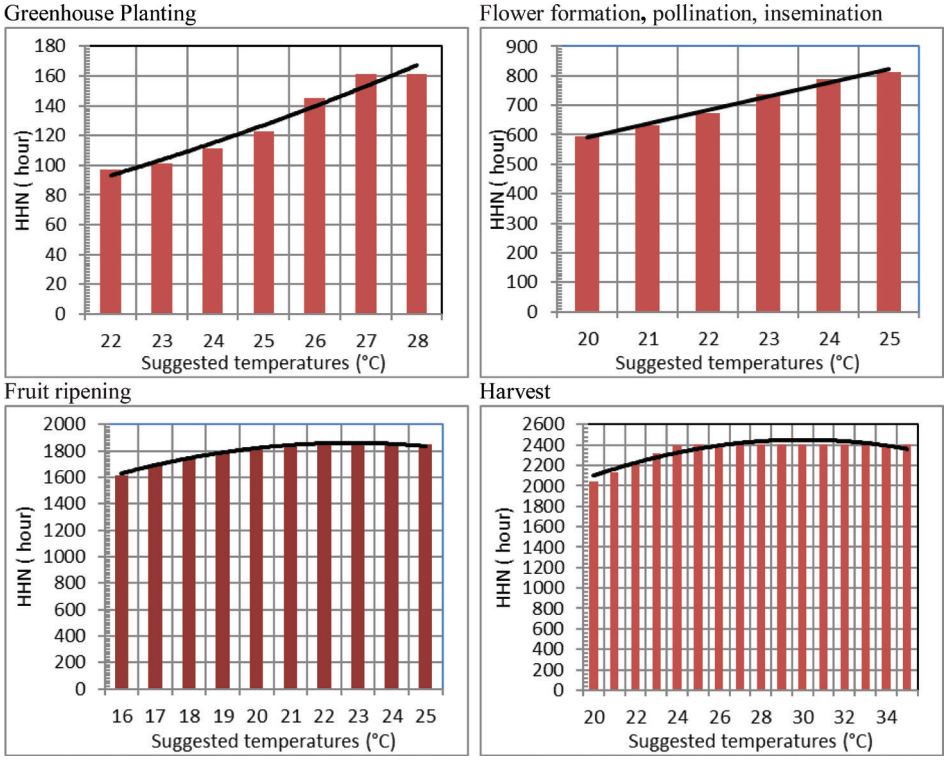

Figure 3. Number of heating hours according to different temperature values recommended for pepper plant

It was calculated that the number of heating hours ranged from 97 to 161 hours for the planting period in Figure 3. In this period, it was concluded that every degree of heating after 27°C would not affect the number heating hours in the greenhouse. It was determined that there was a polynomial relationship between the recommended temperature values and the number of heating hours (R^2=0.96 $p<0.05$). It was determined that the number of heating hours in the

flower formation, pollination and insemination periods ranged from 595 to 814 and that there was a linear relationship between the recommended temperature values and the number of heating hours (R^2=0.99 $p<0.05$). The number of heating hours calculated for the fruit ripening period of the pepper plant ranged from 1617 to 1848. In this period, it was concluded that each degree of heating after 21°C would not affect the heating hour values. It was determined that the relationship between the recommended temperature values and the number of heating hours was polynomial (R^2=0.99 $p<0.05$). In the harvest period, it was calculated that the calculated heating hour numbers changed between 2045 and 2411. It was concluded that each degree of heating after 25°C for the harvest stage would not affect the number of heating hours and it was determined that there was a polynomial relationship between the recommended temperature values and the number of heating hours (R^2=0.88 $p<0.05$).

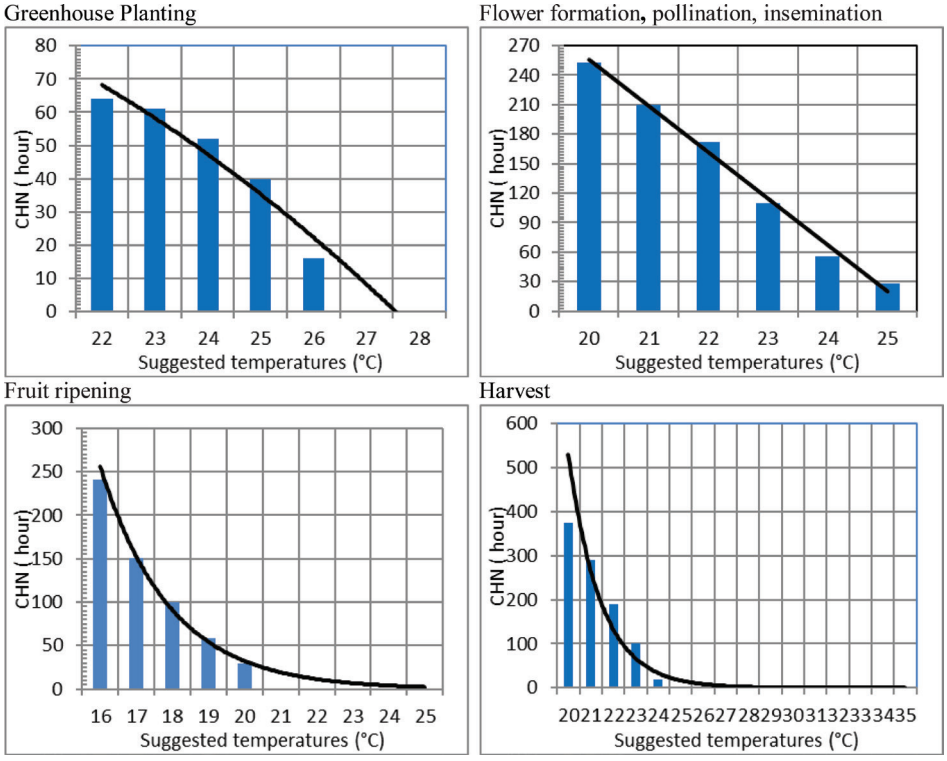

Figure 4. Number of cooling hours according to different temperature values recommended for pepper plant

Upon examining Figure 4, it was calculated that the number of cooling hours ranged from 64 to 0 according to the recommended temperature values of the pepper plant during the planting period. It was determined that each degree of cooling after 26°C in this period would not affect the cooling hour values for the pepper plant. It was determined that there was a polynomial relationship between the recommended temperature values and the number of cooling hours (R^2=0.95 $p<0.05$). It was determined that the number of cooling hours ranged from 253 to 28 during the flower formation**,** pollination and insemination periods and that there was a linear relationship between the recommended temperature values and the number of cooling hours (R^2=0.99 $p<0.05$). It was calculated that the cooling hour values ranged from 241 to 0 according to the recommended temperature values during the fruit ripening period of the pepper plant. It was concluded that each degree of cooling after 20°C in this period would not affect the cooling hour values for the pepper plant. It was determined that there was an exponential relationship between the recommended temperature values and the number of cooling hours (R^2=0.99 $p<0.05$). It was calculated that these values ranged from 374 to 0 in the harvest period. It was concluded that each degree of cooling after 24°C would not affect the cooling hour values for the pepper plant. It was determined that the relationship between the recommended temperature values and the number of cooling hours was exponential (R^2=0.87$p<0.05$).

The researchers stated that heating hour values showed a linear increase depending on the basic temperature values in a study they conducted on heating degree-hour values (Bulut et al., 2007; Erturk et al., 2015). According to Bulut et al. (2007) and Erturk et al. (2015), cooling degree-hour values did not show a linear decrease depending on the basic temperature values. It was determined that these findings match up with our heating and cooling degree-hour values.

CONCLUSIONS

In the study area, heating and cooling degree-hour values and the number of heating and cooling hours were calculated for the greenhouse cultivation of the pepper plant. For the pepper plant, the graphical relationships between the recommended temperature values for each growing period and the number of heating degree-hour, cooling degree-hour, the number of heating hours and the number of cooling hours were also determined. Furthermore, it was determined that the cooling degree-hour values were not suitable for cooling after 26°C in the planting period, after 20°C in the fruit ripening period and after 24°C in the harvest period. It was determined that the number of heating hours was not suitable for heating after 27°C in the planting period, after 21°C in the fruit ripening period and after 25°C in the harvest period. It was concluded that regarding the

number of cooling hours, cooling was not required after 26°C in the planting period, after 20°C in the fruit ripening period and after 24°C in the harvest period.

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