Scientific Papers. Series B, Horticulture. Vol. LXII, 2018
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

ANALYSIS OF CHANGES IN GROWING DEGREE-DAY VALUES BY ALTITUDE: OIL ROSE (*ROSA DAMASCENA* MILL.) CASE

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Abstract

Times such as optimum sowing, planting, germination time and duration, fertilization, agricultural pest control, irrigation time, harvest, plant growing stages can be determined by using the Growing Degree-Day (GDD) values. The Isparta region has an ideal climatic area for oil rose growing. For this purpose, meteorological stations were chosen as the study area for Isparta provinces and districts having the most suitable growing ecology in oil rose cultivation. Oil rose is a perennial plant with an active growing period of about 120 days depending on the phenological periods. Different GDD values for different phenological periods were acquired when the GDD values for the active growing period of the oil rose plant were correlated with the elevations of meteorological stations at different locations. It was determined that the study area was divided into 4 groups by the statistical Duncan test, which was made according to the growing degree-day values and optimum temperatures. It was determined that the Sütçüler district is the most suited growing area for the oil rose plant followed by Atabey, Eğirdir, Isparta, Keçiborlu, Senirkent and Uluborlu.

***Key words**: Isparta, phenological periods, rose plant, temperature.*

INTRODUCTION

Volatile oils are obtained from the flowers, leaves, fruits, seeds and roots of plants. Rose is the most popular and most important among all volatile oil plants grown in Turkey (*Rosa damascena* Mill.). Turkey is the biggest global producer of oil rose (Ikiz and Demircan, 2013). Roses have an important place among medicinal and aromatic plants. Some genotypes of *Rosa damascena* have been grown for industrial purposes in Turkey (Region of Lakes) since 1888. Oil production started in 1892 and it has been processed as an industrial plant since 1935 (Özçelik et al., 2013). Turkey and Bulgaria are the countries with the highest amount of oil rose growth in the world. These two countries meet 80% of the total oil rose production in the world. According to 2016 data, a total production of 12,267 tons has been completed on 2,975.3 hectares in Turkey (Tuik, 2017).

Temperature and humidity are among the most important factors with impacts on the flowering intensity of oil rose. Oil rose plants are quite resistant to cold weather during the winter when it sheds its leaves. Resting of mature plants during the winter season helps bud development and differentiation. However, it is very sensitive to low temperatures and frost during the budding period (starting in March). It is desired that the temperature varies between 5-20^{o}C during the flowering period of oil rose. Volatile oil content decreases when nighttime temperatures drop below 5^{o}C or when daytime temperatures exceed 20^{o}C (Baydar and Baydar, 2005; Sangwan et al., 2001).

Climate data should be analyzed accurately since plant growth depends solely on climate conditions. Changes in temperature and rainfall play a determining role on yield especially during phenological periods of plant growth. Plant growing stages such as optimal plantation, germination time, fertilization, pest control, irrigation time and harvesting period, may be determined using the degree day method. The purpose of the study was to determine and interpret the relations between the altitude values of locations included in the study area for the oil rose plant and the calculated GDD values.

MATERIALS AND METHODS

In the study, long term maximum and minimum daily temperature values with different record lengths, measured at different meteorological stations (16 in total) in the Isparta city limits have been used (Table 1). Since meteorological stations in the city of Isparta are built in districts or close-by regions, they are known by the names of these districts. Properties for the 16 meteorological stations in the city of Isparta and its districts used in the study have been given in Table 1. Average altitude of the province was about 1,065 m (Anonymous, 2018).

Temperature values given in Table 2 (Baydar and Kazaz, 2013) have been used for calculating the GDD values of oil rose in different phenological periods. Changes between the calculated GDD values and the altitudes of meteorological stations (H, m) were tested by way of regression analysis. Statistical Duncan test was used for grouping the GDD values of oil rose plant calculated in different phenological periods and the altitudes of meteorological stations.

Table1. Characteristics of Meteorological Stations used in the study

Meteorological stations	Years	Period duration (years)	Latitude	Longitude	Altitude (m)
Aksu	1983 – 2003	21	37°47'	31°04'	1,240
Atabey	1968 – 2015	48	37°57'	30°38'	1,000
Bağkonak	1987 – 1996	10	38°14'	31°17'	1,397
Barla	1987 – 1992	6	38°01'	30°78'	1,085
Eğirdir	1968 – 2015	48	37°50'	30°52'	917
Gelendost	1983 – 1988	6	38°07'	31°01'	952
Isparta	1929 – 2015	87	37°47'	30°34'	997
Kasımlar	1987 – 1993	7	37°53'	31°19'	1,070
Keçiborlu	1971 – 1990	20	37°57'	30°18'	996
Kumdankı	1984 – 1995	12	38°32'	30°97'	1,029
Senirkent	1970 – 2015	46	38°06'	30°33'	959
Sütcüler	1968 – 2015	48	37°30'	30°59'	975
Sarkıkaraağaç	1976 – 2015	40	38°05'	31°22'	1,180
Uluborlu	1968 – 2015	48	38°05'	30°27'	1,025
Yalvaç	1972 – 2015	44	38°16'	31°10'	1,096
Yenisar-Bademli	1983 – 1994	12	37°42'	31°23'	1,183

Table 2. Optimum Temperature Requirements for Different Phenological Periods of Oil Rose

Phenological Periods	Temperature (°C)	Date	Period duration (days)
Bud break	5 – 10	1 March– 15 March	15
Shoot bud	10 – 15	16 March – 31 March	16
Leaf and Flowering bud	15 – 18	1 April – 30 April	30
Flowering and harvesting	15 – 25	1 May – 30 June	61
Total			122

Growing Degree-Day (GDD) Method
Agriculturally cultivated plants benefit differently from the temperature in each growth period. Temperature is one of the most important meteorological factors with impacts on plant growing. Various methods for estimating plant growing using temperature values have been used in agricultural studies. Growing Degree Day (GDD) method is the most frequently used method. In this method, calculations are made based on the daily maximum (T_{Max}) and daily minimum (T_{Min}) values measured in meteorological stations. GDD values are calculated using the below

equation (McMaster and Wilhelm, 1997; Kadıoğlu and Şaylan, 2001; Snyder et al., 2001; Matzarakis et al., 2007; Rulm et al., 2010; de Souza et al., 2011).

$$BDG = \sum_{i=1}^{n} \left(\frac{T_{Max} - T_{Min}}{2} - T_O \right) \qquad (1)$$

where: T_{Max} stands for the daily maximum temperature value (°C), T_{Min} stands for the daily minimum temperature value (°C), whereas T_O denotes the temperature value suggested for different phenological periods for the rose plant (°C) and n represents the yearly number of days. In case $(T_{Max} - T_{Min})/2 > T_O$ growing degree-day (GDD) value is calculated. It means that growing of the plant is determined. On the contrary, when $(T_{Max} - T_{Min})/2 < T_O$ growing degree-day (GDD) not calculated. It means that there is no growing in the plant (McMaster and Wilhelm, 1997; Kadıoğlu and Şaylan, 2001; Snyder et al., 2001; Matzarakis, et al., 2007; Rulm et al., 2010; de Souza et al., 2011).

Statistical methods

Regression analysis. The objective with the dependent variable to be determined is to put forth an estimation method for determining the relationship between one or more independent variables. The method developed for this purpose can be used to make estimations. The general equation is expressed with the following equality.

$$Y = a + b.x \qquad (2)$$

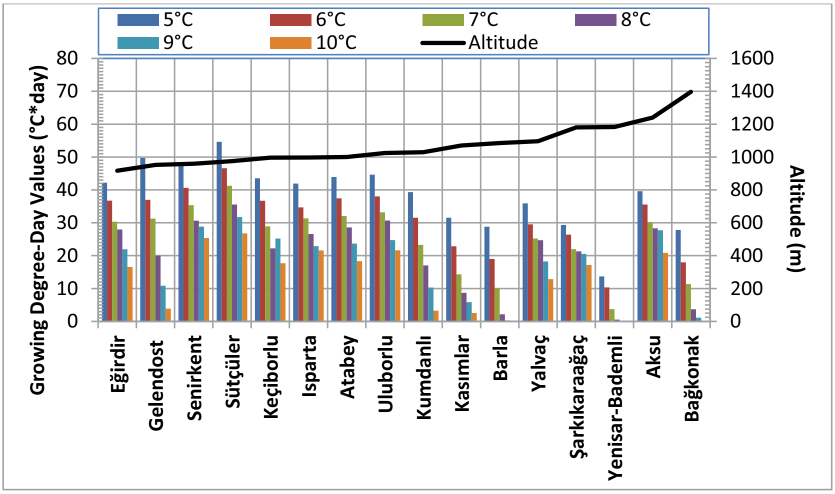
where: Y is the dependent variable, x is the independent variable, whereas a and b are equation regression coefficients. Regression analysis statistical fit is evaluated by; correlation coefficient (r), F test and probability (p) (Haan, 1977; Helsen ve Hirsch, 1993; Shammugasundram, 2012).

Duncan Multiple Comparison Test: It is one of the most frequently used methods in agricultural studies. It is used for determining whether there are statistically significant differences between the variables obtained as a result of statistical analyses such as Regression, Variance analyses. It takes into account the positions of the averages according to their magnitudes when comparing group averages for this purpose. The minimum difference between two group averages in this method is calculated by way of Duncan table. Group averages are evaluated according to the distances between them when ordered based on magnitude and it is one of the most frequently used methods (Duncan, 1955; Harter, 1960; Efe et al., 2000).

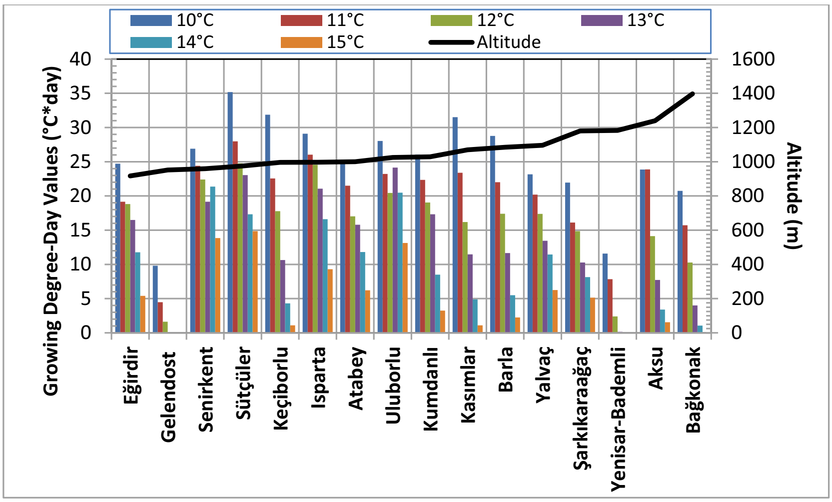
RESULTS AND DISCUSSIONS

Altitude and temperature values acquired from measurement stations at 16 different locations in the city of Isparta and its districts have been used in the study. Figure 1 was prepared depicting the graphical relations between the GDD values for different phenological periods of the oil rose plant and the elevations of the districts. Oil rose is a perennial plant with an active growing period of about 120 days depending on the phenological periods (Baydar and Kazaz, 2013). Different GDD values for different phenological periods were acquired when the GDD values for the active growing period of the oil rose plant were correlated with the elevations of meteorological stations at different locations. The average elevation of the city of Isparta is 1,065 m and Sütçüler region with an elevation of 975 m was determined as the district with the highest GDD value during the bud break period. Whereas the lowest GDD values during the bud break period were determined in Yenişar Bademli. It was determined upon an examination of the shoot bud period that the Sütçüler region had the highest GDD values during this period as well. The lowest GDD values were determined in the Gelendost district. No linear relationship was determined between the phenological temperature demands of the oil rose plant and the elevation values of the districts during the shoot bud period as well. It was determined that the GDD values during the leaf and flowering bud periods are above 70 for the Sütçüler region. The lowest GDD value was observed at Yenişar Bademli. Sütçüler region was observed to have the highest GDD value during the final phenological period of oil rose which is flowering and harvesting period. It can again be observed in this stage that GDD values do not have a linear relationship with elevation. Yenişar Bademli had the lowest GDD values during the flowering and harvest period.

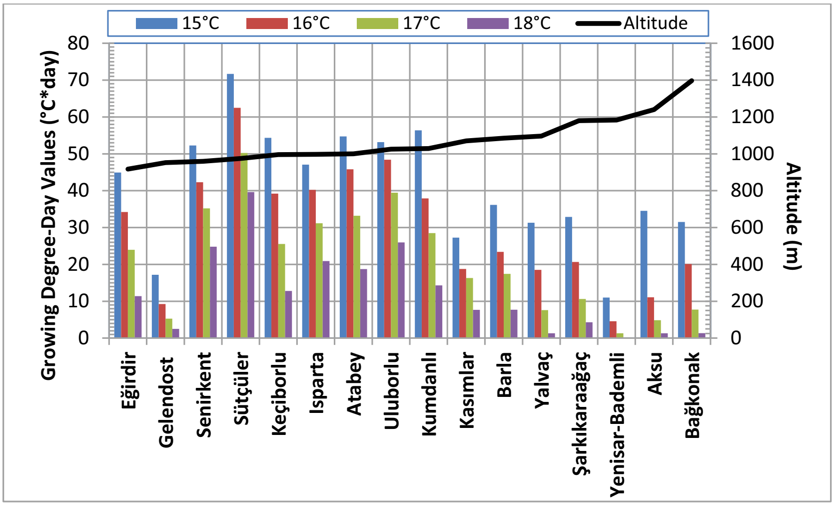
As put forth by Serter (2004), Nield and Smith (1997), determined during their study on the maturing of corn plant at different locations, maturity times varied according to locations. Thus, the GDD values acquired for 16 different locations in the study area were different for oil rose plant. It can be indicated that Sütçüler district is the best in the study area with regard to the temperature demands of the oil rose plant during its phenological periods. Local producers in the region along with Baydar and Kazaz (2013) indicate that Keçiborlu, Isparta central villages, Atabey, Eğirdir, Uluborlu, Senirkent and their environs, are the best areas for oil rose. Therefore, it was determined that all areas, excluding Sütçüler, were determined to be compatible with regard to GDD values and elevation.



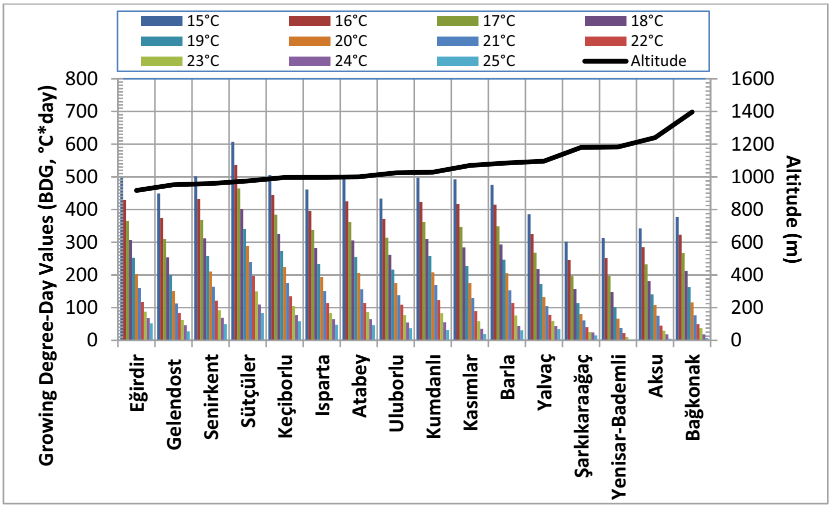
a. Bud break



b. Shoot bud



c. Leaf and flowering bud



d. Flowering and harvesting

Figure 1. Relationship between GDD values and altitude in different phenological periods of oil rose plant

The relationships between the elevation (H, m) values for the different meteorological stations at different locations in the study area and the GDD values calculated for the different phenological periods of oil rose plant, were examined by way of regression analysis and the statistical values for which two-parameter parabolic equation ($GDD = a + b.H + c.H^2$) has been developed are given in Table 3.

Table 3. Relations between GDD values, altitude and statistical results

Suggested Temperature (T_o, °C)	Equation Coefficients			r	F_{Result}	F_{Table}	Probability (p)
	a	b	c				
Bud break							
5	0.000181	- 0.4676	328.70	0.754	8.58	3.810	0.004
6	0.000126	- 0.3378	246.80	0.709	6.55	3.810	0.011
7	0.000130	- 0.3474	246.50	0.666	5.18	3.810	0.022
8	0.000068	- 0.2039	159.60	0.563	3.02	3.810	0.084
9	0.000034	- 0.1171	102.80	0.465	1.79	3.810	0.205
10	0.000025	- 0.0893	79.30	0.415	1.35	3.810	0.293
Shoot bud							
10	- 0.000033	0.0590	- 0.40	0.307	0.68	3.810	0.526
11	- 0.000041	0.0813	- 19.80	0.261	0.47	3.810	0.633
12	- 0.000010	0.0021	26.00	0.415	1.35	3.810	0.292
13	- 0.000014	0.0006	28.50	0.536	2.62	3.810	0.111
14	0.000010	- 0.0527	53.80	0.531	2.56	3.810	0.116
15	0.000012	- 0.0473	41.45	0.474	1.89	3.810	0.190
Leaf and Flowering bud							
15	0.000145	- 0.3904	290.60	0.501	2.18	3.810	0.152
16	0.000178	- 0.4782	334.60	0.589	3.46	3.810	0.063
17	0.000112	- 0.3262	240.10	0.633	4.34	3.810	0.036
18	0.000083	- 0.2427	175.10	0.602	3.68	3.810	0.054
Flowering and harvesting							
15	0.001226	- 3.2680	2520.00	0.774	9.71	3.810	0.003
16	0.001198	- 3.1630	2375.00	0.756	8.66	3.810	0.004
17	0.001143	- 3.0080	2213.00	0.758	8.74	3.810	0.004
18	0.001012	- 2.6680	1968.00	0.759	8.84	3.810	0.004
19	0.000888	- 2.3820	1734.00	0.752	8.44	3.810	0.004
20	0.000708	- 1.9460	1431.00	0.744	8.06	3.810	0.005
21	0.000550	- 1.5510	1152.00	0.754	8.54	3.810	0.004
22	0.000433	- 1.2380	919.80	0.749	8.29	3.810	0.005
23	0.000448	- 1.2190	854.20	0.762	9.03	3.810	0.003
24	0.000358	- 0.9810	683.50	0.806	12.00	3.810	0.001
25	0.000262	- 0.7303	511.70	0.794	11.05	3.810	0.002

Equations which reflect the relationships between elevation and the GDD values of oil rose plant in different phenological periods have been obtained, which were then examined at a statistical significance value of 5% by way of correlation analysis (r), F test and probability (p) values. It was determined that temperatures of around 8, 9, 10°C suggested for the bud break period, all temperatures for the shoot bud period and temperatures of around 15, 16, 18°C during the leaf and flower bud period, had a relationship with temperature which was not statistically significant. In short, it should be taken into consideration when developing equations for the growing periods of the oil rose plant that factors such as temperature and elevation may be effective factors but that other factors (frost, humidity, rain, fertilization, irrigation, diseases etc.) may also be effective. Therefore, a more exact determination can be made by considering other factors as well in addition to the factors of temperature and elevation.

In addition, the changes in GDD values of oil rose plant at different phenological periods with the elevations of meteorological stations, have been examined via Duncan test (Table 4). Duncan test was used for determining and classifying the changes between the location elevations in the study area and the GDD values for these locations.

Table 4. The results of Duncan test grouping according to the relationship between GDD values and altitude for oil rose

Meteorological stations	Phenological Periods			
	Bud break	Shoot bud	Leaf and Flowering bud	Flowering and harvesting
Aksu	30.40 b	12.40 c	12.90 d	133.00 d
Atabey	30.70 b	16.20 b	38.10 b	228.50 b
Bağkonak	10.30 d	8.60 c	15.20 d	149.70 c
Barla	10.10 d	14.60 b	21.20 c	218.40 b
Eğirdir	29.30 b	16.10 b	28.60 c	231.20 b
Gelendost	25.50 b	2.70 d	8.60 d	188.20 c
Isparta	29.80 b	21.10 a	34.80 b	214.90 b
Kasımlar	14.30 c	14.80 b	17.50 c	206.90 c
Keçiborlu	29.00 b	14.70 b	33.00 b	246.10 b
Kumdanlı	20.80 c	16.10 b	34.30 b	229.00 b
Senirkent	34.70 a	21.40 b	38.60 b	234.40 b
Sütçüler	39.40 a	23.90 a	56.00 a	310.70 a
Şarkıkaraağaç	22.80 b	12.70 c	17.10 d	114.60 d
Uluborlu	32.20 a	21.60 b	41.70 b	199.00 c
Yalvaç	24.40 b	15.30 b	14.70 d	165.50 c
Yenisar-Bademli	4.70 d	3.70 d	4.20 d	104.60 d

According to the Duncan test applied for elevation and the GDD values calculated according to the optimum temperature demands for different phenological periods of oil rose plant (Table 4), it was determined that the study area can be classified into 4 different homogeneous growing groups. The groups were determined as such: 1. (a) group growing area: Sütçüler district; 2. (b) group growing area: Atabey, Eğirdir, Isparta, Keçiborlu, Senirkent, Uluborlu districts; 3. (c) group growing area: Barla, Bağkonak, Gelendost, Kasımlar, Kumdanlı, Yalvaç districts; 4. (d) group growing area: Aksu, Şarkıkaraağaç, Yenisar-Bademli districts. It was determined that the Sütçüler district is the most suited growing area for the oil rose plant followed by Atabey, Eğirdir, Isparta, Keçiborlu, Senirkent and Uluborlu.

CONCLUSIONS

It was concluded upon an examination of the relationships between elevations and the GDD values calculated at 16 different locations for the oil rose plant according to different phenological periods that the best growing locations would be Sütçüler, Atabey, Eğirdir, Isparta, Keçiborlu, Senirkent and Uluborlu. It was also determined that there is no linear relationship between the GDD values calculated for the oil rose plant and elevations. It has led to an opinion that temperature and elevation in equations developed for the different growing periods of the oil rose plant, may be effective factors for determining the growing areas. However, it was also concluded that other factors with impacts on growing (frost, humidity, rain, fertilization, irrigation, diseases etc.) should also be taken into consideration.

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