Journal of Medicinal Plants Research Vol. 4(7), pp. 551-558, 4 April, 2010
Available online at http://www.academicjournals.org/JMPR
DOI: 10.5897/JMPR10.012
ISSN 1996-0875© 2010 Academic Journals

*Full Length Research Paper*

# The quantitative effect of temperature and light intensity at growth in *Origanum onites* L.

**Omer Caliskan[1]*, Mehmet Serhat Odabas[1], Cuneyt Cirak[1], Jolita Radušienė[2] and Ferhat Odabas[3]**

[1]Ondokuzmayis University, the High School of Profession of Bafra, 55400 Samsun, Turkey.
[2]Institute of Botany, Zaliuju ezeru 49, Vilnius LT-2021, Lithuania.
[3]Ondokuzmayis University, Faculty of Agriculture, 55139 Samsun, Turkey.

Accepted 5 February, 2010

**The study was aimed to define the relationships between temperature, light intensity and growth parameters. Namely, net assimilation rate, relative growth rate, leaf weight ratio, leaf area ratio and specific leaf area for oregano (*Origanum onites* L.). The quantitative effects of temperature and light intensity on growth parameters were examined in greenhouse-grown oregano plants. All equations produced for growth parameters were derived as affected by temperature. Growth parameters were not affected by light intensity. As a result of ANOVA and regression analysis, it was found that, there was close relationship between actual and predicted growth parameters. The regression coefficients ($R^2$) of the produced equations for growth parameters changed from $R^2$ = 0.93 (specific leaf area) to $R^2$ = 0.97 (net assimilation rate and leaf area ratio).**

**Keywords:** Modeling, Oregano, *Origanum onites* L.*,* growth, light intensity, temperature.

## INTRODUCTION

Origanum plants are widely used all over the world as a very popular spice, under the vernacular name 'oregano'. They are of great economic importance which is not only related to their use as a spice. In fact, as recent studies have pointed out, oregano is used traditionally in many other ways, as their essential oils have antimicrobial, cytotoxic and antioxidant activity (Lagouri et al., 1993; Sivropoulou et al., 1996).

Oregano has been used in the Anatolian region of Turkey since ancient times. In this region the crop has mainly been used as a spice and as a medicine to treat various health disorders. The cultivation of oregano is very popular in Turkey and a marked increase in the area devoted to the cultivation of this crop and it has been noticed in the last few years (Kitiki, 1996). Today, it is still used as a spasmodic, antimicrobial, expectorant carminative and aromatic for whooping and convulsive coughs, digestive disorders and menstrual problems. It is used topically as an antiseptic and astringent, and for gargling. Of course, oregano herbs and their volatile oils are also widely used in the spice industry. With regard to the above mentioned properties, leaves and inflorescence (spicules) are used as herbal tea in many locations across Turkey (Baytop, 1984; Nakiboglu et al., 1994; Tanker and Tanker, 1985; Zeybek, 1995; Caliskan et al., 2009).

Environmental factors affect plant growth and development. It will be useful to know optimum temperatures and light intensity required for plant growth (Arechiga and Carlos, 2000; Hakansson et al., 2002; Odabas and Mut, 2007; Albayrak and Camas, 2007). But, there are biological limitations as in how the temperature can be raised. The upper limit of rising temperature varies with plant species. These factors determine plant species which will be grown productively in a region.

Plant growth can be defined as the increase of dry material in plant or the increase of plant parts numerically. One of the most useful indices of plant growth is the relative growth rate (RGR). It assumes that new growth is related to existing biomass and is therefore exponential (Odabas et al., 2005). Most of the researches have

*Corresponding author. E-mail: ocaliskan@omu.edu.tr. Tel: +90-362-5426762 / 123. Fax: +90-362-5426761.

investigations focused on plant growth and develop mental periods from seed sowing to reproductive stages and from reproductive stages to harvest (Ellis et al., 1990).

Different physiological processes occur in different periods of plant growth stage (Celik and Odabas, 2009; Odabas et al., 2009; Odabas et al., 2005). To date, there have been a few attempts to describe the relationship between oregano growth, temperature and light intensity but with no wide temperature and light ranges. Therefore, this research quantitatively examined the effects of temperature and light intensity on oregano growth, using a wide range of temperature and light intensity.

## MATERIALS AND METHODS

In present study *Origanum onites* L. seeds were used and set up in 100 pots. Greenhouse indoor and outdoor were separated under shaded and unshaded parts, however, 50% transparent polyethylene cover was used for shading. The peat used in the research had a pH value of 7. Dimension of the greenhouse length; width and height were separately 15, 8 and 3 m. Temperatures were measured in the greenhouse indoor and outdoor with a Sato Keiryoki MFG R - 704 thermo hydrograph ($0^oC$ with $50^oC \pm 1$) and soil temperature with a soil thermometer Testo 615 (0°C with 50°C ± 0, 4). Light measurements were performed 1 m high on the plants by Delta -T Sun Scan Canopy Analyser (Celik and Odabas, 2009). As the research focused on growth of oregano, the parameters examining growth were analyzed as affected by temperature and light intensity.

The experiment was set up in 100 pots. Sowing time for viols on March of 2008 in greenhouse and outdoor conditions, and under shaded and unshaded conditions, however, 50% trans-parent polyethylene cover was used for shading seeds. Each block had 50 rows. Three plant samples were collected every 15 days and plant dry weight was determined 80°C.

The data obtained from all the characteristics examined multiple regression analysis were turned into mathematical models by using SAS and the models obtained were turned into three dimension graphics through slide write 2.0 package program. The effects of all characteristics examined were explained depending on light and temperature by using these graphics. A search for the best model to predict the growth parameters were conducted with temperature (°C) and light intensity (µmol $m^{-2}$ $s^{-1}$). The best estimating equations for the growth parameters were formulized as $a + (b \times T) + (c \times T^2)$ where T is temperature (°C) and a, b, and c are coefficients of the produced equation. Regression analysis was carried out until the least sum of square ($R^2$) was obtained. Equation determining the most effective growth parameters was obtained by the equation $[-b / (2 \times c)]$. Destructive harvest measurement and observation were carried out for each replication. Each measurement was repeated ten times starting from early plant growth stage to the harvest. As for quantitative characteristics, (net assimilation rate, relative growth rate, leaf weight ratio, leaf area ratio, specific leaf area and leaf area) were evaluated. The growth parameters were calculated as follows.

### Net assimilation rate (NAR)

The net assimilation rate of a plant is defined as its growth rate per unit leaf area for any given time period (day). It is usually denoted by NAR, and can be calculated as: NAR (g $cm^{-2}$ $d^{-1}$) = (1 / LA) dW /dt. In this equation, LA: total leaf area ($cm^2$); W: total plant dry weight and t is time.

### Relative growth rate (RGR)

The variation in the relative growth rate can be separated into an assimilatory component, net assimilation rate and a morphological component, leaf area ratio (LAR), as they are related as follows: RGR (g $g^{-1}$ $d^{-1}$) = NAR x LAR.

### Leaf weight ratio (LWR)

Leaf weight ratio is the ratio of total leaf weight (g) to total plant weight (g).

### Leaf area ratio (LAR)

The leaf area of the plant ($cm^2$) divided to its total dry weight (g), is called the leaf area ratio ($cm^2$ $g^{-1}$).

### Specific leaf area (SLA)

Specific leaf area is the ratio of leaf area ($cm^2$) per plant to leaf dry weight (g).

## RESULTS AND DISCUSSION

As a result of the regression analysis, it has been found that the effects of light intensity and temperature in oregano on growth parameters are significant. Regression statistics has been shown in Table 1.

### Net assimilation rate (NAR)

As a result of the multi regression analysis, it has been found that the effect of light intensity and temperature in oregano on net assimilation rate is significant. Regression statistics has been shown in Table 1. With regard to the regression statistics belonging to the net assimilation rate, it is observed that $R^2$ is 0.97. ANOVA significance F value has shown the validity of the model, in other words, whether or not the model can be formed. The fact that this value is over 5% shows us the model that cannot be formed.

In this study, as this value is below 1%, the result of analysis has a significance of 1%. Following the determination of the importance level, mathematical equation has been obtained by using coefficients and corresponding independent variable (NAR) and dependent variable (temperature °C).

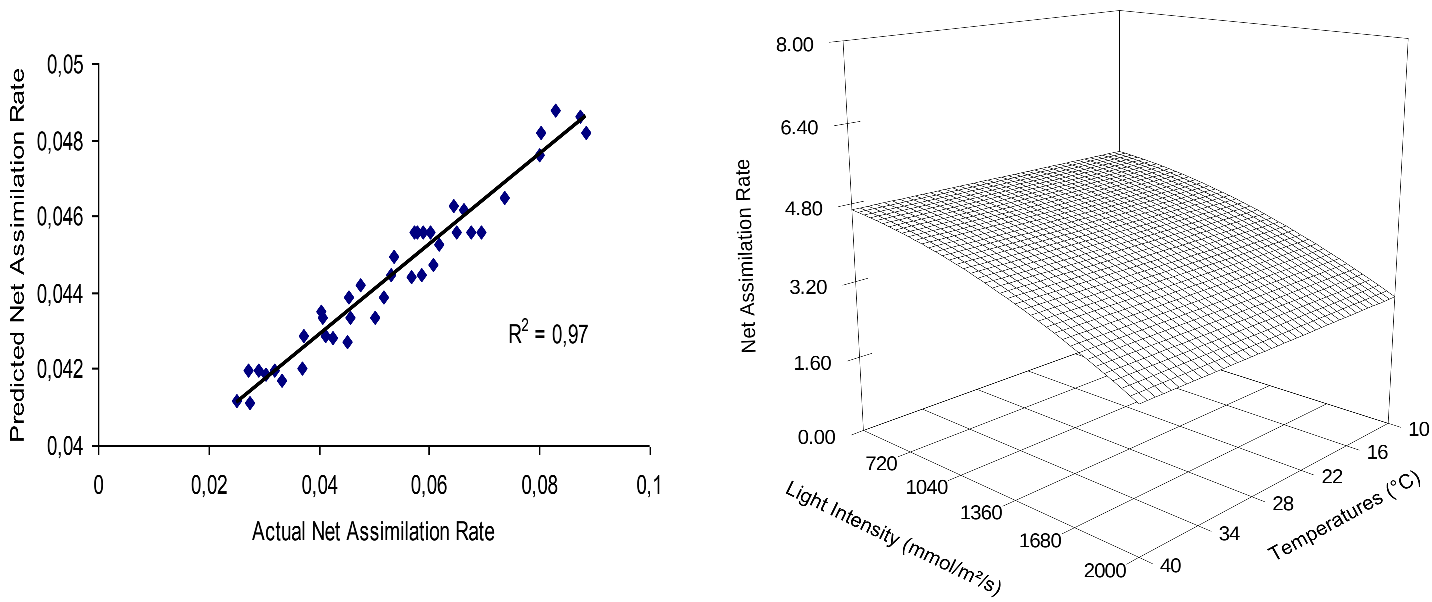
General mathematical model for oregano has been formed as $a + (b \times T) + (c \times T^2)$. In this formula a, b and c symbolizes the coefficient obtained as a result of multi regression analysis, and T symbolizes the temperature. By taking into consideration, the coefficient in the regression statistics, net assimilation model in oregano has been formed.

Net assimilation rate (NAR) = $(0.311) + (-0.015 \times T) + (3.6E^{-4} \times T^2)$

**Table 1.** The coefficients, their standard errors and R² values of the new produced equations predicting growth parameters in *Origanum onites* L.

| Growth parameters with SE | Coefficient | T | T² | R² |
|---|---|---|---|---|
| Net assimilation rate | 0.311 ± 0.105** | - 0.015 ± 7.89E$^{-3}$ ** | 3.6E$^{-4}$ ± 1.39E$^{-4}$** | 0.97 |
| Relative growth rate | 12.811 ± 3.121** | - 0.798 ± 0.279** | 0.019 ± 4.96E$^{-4}$** | 0.96 |
| Leaf weight ratio | 0.16 ± 0.172** | 0.023 ± 5.81E$^{-3}$** | | 0.95 |
| Leaf area ratio | 151.11 ± 50.001** | - 9.021 ± 3.378** | 0.203 ± 0.081 | 0.97 |
| Specific leaf area | 299.251 ± 100.111** | - 16.014 ± 8.059** | 0.385 ± 0.151** | 0.93 |

R²: regression coefficiency, SE: standard error, T: temperature of produced equations. *, **, ***: Significant at the level of p < 0.05, 0.01 and 0.001 respectively.




a b

**Figure 1.** The relation between the real net assimilation rate and the approximate net assimilation rate and the change caused by the daily light intensity (µmol m$^{-2}$ s$^{-1}$) and temperature (°C) on oregano in the net assimilation rate.

Standard Error (SE) = 0.105** 7.89E$^{-3}$ ** 1.39E$^{-4}$ **
Regression Coefficiency ($R^2$) = 0.97

The relation between the net assimilation rate corresponding to the real values and the approximate net assimilation rate obtained from mathematical equation has been shown in the Figure 1. When the graphic is examined, it is observed that linear represents the reality that is, $R^2$ =0.97. The other points represent the net assimilation rate obtained from the model. The closer these values are to reality, the higher $R^2$ value of the mathematical model is. In this study, $R^2$ value obtained (0.97) shows that a model with 97% close to the reality has been formed.

The effects of light intensity and temperature on net assimilation have been shown in Figure 1b. The optimum temperature ($T_o = -b / 2c$) for the ideal net assimilation rate has been calculated as 20.83°C by using the equation obtained. While this value has been calculated, coefficients belonging to the net assimilation rate equation have been used. In this equation when coefficient b (-0.015) and coefficient c (3.6E$^{-4}$) have been applied to the formula, the result obtained is 20.83°C. This temperature has directly provided the ideal temperature value for the net assimilation of the oregano.

The mathematical model obtained has ensured to find the temperature directly needed for providing the net assimilation of physiologic events such as growing and maturing of oregano from sowing time till harvesting without any value interval. In addition, when different temperature values are applied to this model, net assimilation rate to occur can be estimated. Mathematical equation has been benefited while showing this change caused by daily light (µmol m$^{-2}$ s$^{-1}$) and temperature (°C)

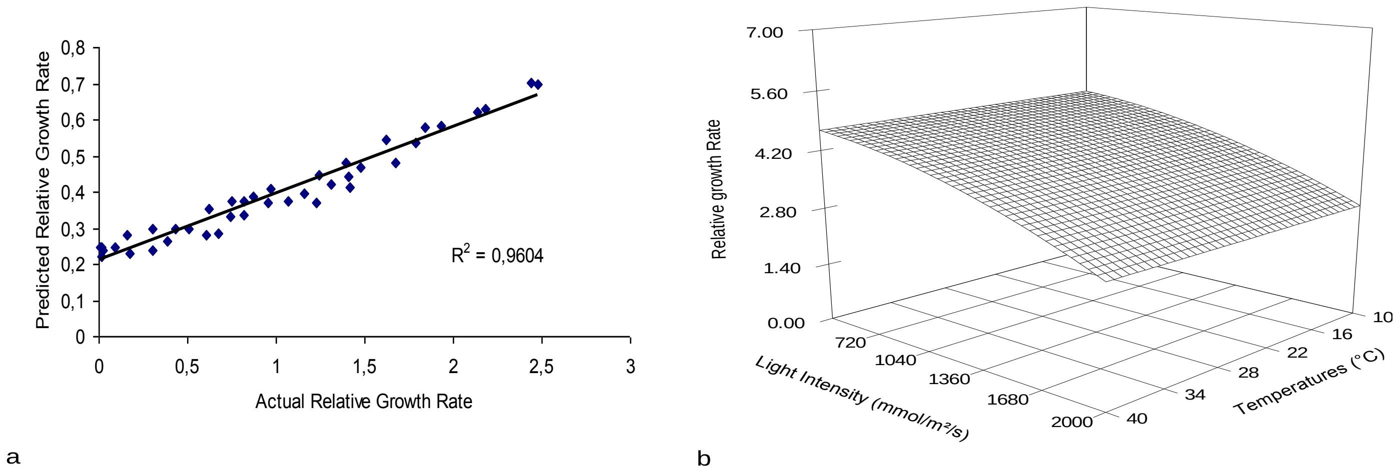



**Figure 2.** The relation between the actual relative growth rate and approximate values obtained from the mathematical model and the change caused by daily light (µmol $m^{-2}$ $s^{-1}$) and temperature (°C) on relative growth rate.

on oregano in the net assimilation rate. In this graphic (Figure 1) mesh part shows the change in the net assimilation rate throughout oregano's whole life cycle. The most important feature of this program is to draw 3 dimension graphic by using not only the values entered but also the mathematical equation obtained. Figure 1b shows that the net assimilation rate increases as the temperature rises. While the temperature and the light intensity increasing till 680 µmol $m^{-2}$ $s^{-1}$ affects the net assimilation rate positively, and the light intensity is higher than 680 µmol $m^{-2}$ $s^{-1}$ which affects it negatively.

## Relative growth rate

The effects of light and temperature on relative growth rate are found important and regression statistics are provided in Table 1. When the regression statistics belonging to the relative growth rate is examined, it is observed that $R^2$ is 0.96. The model of relative growth rate in oregano has been formed with regard to the coefficient in regression statistics. In the following equation relative growth rate is modeled mathematically. In the equation, T symbolizes the temperature.

$$RGR = (12.811) + (-0.798 \times T) + (0.019 \times T^2)$$

$$SE = 3.121^{**} \quad 0.279^{**} \quad 4.96E^{-3}\ ^{**}$$

$$R^2 = 0.96$$

$R^2$ value obtained (0.96) shows that, we have formed a model which provides us an actual value at a rate of 96%. In Figure 2, the relation between the actual relative growth rate and approximate values obtained from the mathematical model is shown.

By using the equation obtained, the optimum temperature value required for the ideal relative growth rate is calculated as 21°C. While calculating this value, the coefficients belonging to the equation net assimilation rate are used. In this equation when coefficient b (-0.798) and coefficient c (0.019) are applied to the formula ($T_o = -b/2c$), the result is 21°C. This temperature directly provides the ideal temperature for the relative growth rate of oregano. It has been observed that light intensity and temperature have a similar effect on relative growth rate as in the net assimilation rate. It has been determined that, relative growth rate increases as the temperature rises and it decreases as the light intensity increasesover 680 µmol $m^{-2}$ $s^{-1}$. While the increase in the light intensity and temperature up to 680 µmol $m^{-2}$ $s^{-1}$ affects the relative growth rate positively, the increase over 680 µmol $m^{-2}$ $s^{-1}$ affects it negatively shown in Figure 2.

## Leaf weight ratio (LWR)

As a result of the analysis, the effects of light and temperature on leaf weight ratio have been found significant and an equation has been formed. Regression statistics are provided in Table 1. Following the determination of the importance level, mathematical equation has been formed by using the coefficients and corresponding dependent value (temperature °C) and independent value (LWR). The model of leaf weight ratio in oregano has been formed with regard to the coefficient in regression statistics.

$$LWR = (-0.16) + (0.023 \times T)$$

$$SE = 0.172^{**} \quad 5.81\ E^{-3}\ ^{**}$$

$$R^2 = 0.95$$

In the following equation leaf weight ratio is modeled

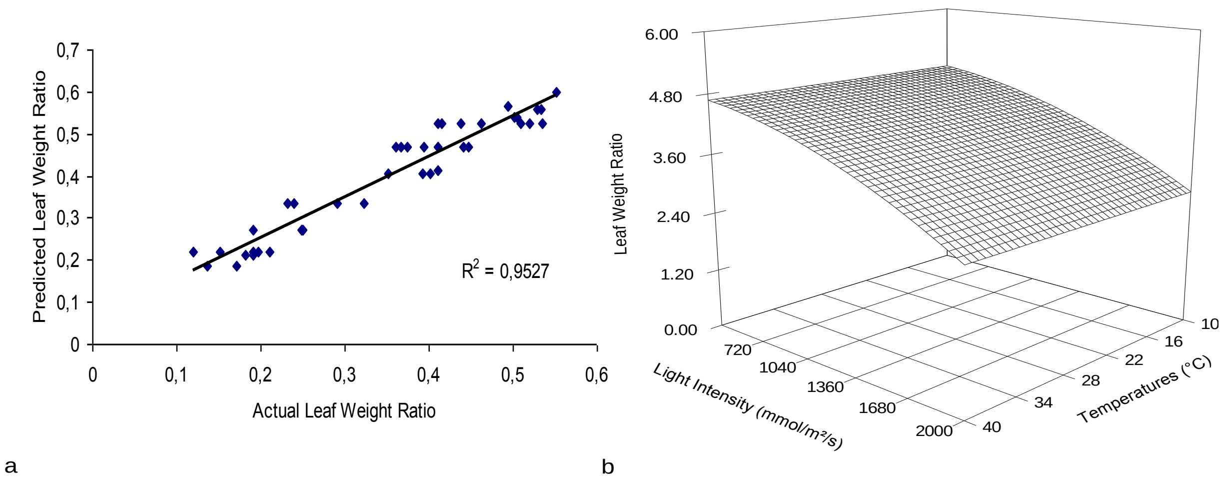



**Figure 3.** The relation between the actual leaf weight ratio , the approximate leaf weight ratio and the change in oregano caused by the daily light (µmol $m^{-2}$ $s^{-1}$) and the temperature (°C) in the leaf weight ratio.

mathematically. $R^2$ value obtained (0.95) shows that, we have formed a model which provides us an actual value at a rate of 95%. The relation between actual leaf weight ratio and the approximate values obtained from the equation has been shown in Figure 3.

Figure 3 shows that, leaf weight ratio increases as the temperature rises and as the light intensity increases higher value than 680 µmol $m^{-2}$ $s^{-1}$, it decreases. While the increase in the light intensity and temperature up to 680 µmol $m^{-2}$ $s^{-1}$ affects the leaf weight ratio positively, the increase over 680 µmol $m^{-2}$ $s^{-1}$ affects it negatively.

## Leaf area ratio (LAR)

The change in leaf area ratio depends on the light and temperature, and it is observed that, the leaf area ratio is in inverse proportion with them, shown in Table 1. The model of leaf area ratio in oregano has been obtained with regard to the coefficient in regression statistics. In the following equation leaf area ratio is modeled mathematically. In the equation, T symbolizes the temperature.

$$LAR = (151.11) + (-9.021 \times T) + (0.203 \times T^2)$$

SE = 50.001** 3.378** 0.081**

$R^2 = 0.97$

$R^2$ value obtained (0.97) shows that, we have formed a model which provides us an actual value at a rate of 97%. The relation between actual leaf area ratio and the approximate values obtained from the equation has been shown in Figure 4. The optimum temperature for the ideal leaf area ratio has been calculated as 22.21°C by using the equation obtained. While the highest leaf area ratio has been obtained at a low temperature and light intensity, the lowest leaf area ratio has been obtained at a high temperature and light intensity (Figure 4).

## Specific leaf area (SLA)

As a result of the analysis, the effects of light and temperature on specific leaf area have been found significant and regression statistics are provided in Table 1. With regard to the regression statistics belonging to the specific leaf area, it has been observed that $R^2$ is 0.93. The model of relative growth rate in oregano has been formed with regard to the coefficient in regression statistics. In the following equation, specific leaf area is modeled mathematically.

$$SLA = (299.521) + (-16.014 \times T) + (0.385 \times T^2)$$

SE = 100.111** 8.059** 0.151**

$R^2 = 0.93$.

$R^2$ value obtained (0.93) shows that, we have formed a model which provides us an actual value at a rate of 93%. The relation between actual specific leaf area and the approximate values obtained from the equation has been shown in Figure 5. The interaction between the specific leaf area and the temperature and light is shown in Figure 5.

It is observed that, there is a linear connection between the specific leaf area and light intensity. The increase in temperature also increases the specific leaf area. The optimum temperature for the ideal specific leaf area has been calculated as 20.79 °C by using the equation obtained. While the highest specific leaf area has been determined as the temperature and light are high, the lowest specific leaf area has been determined as the temperature and light are low.

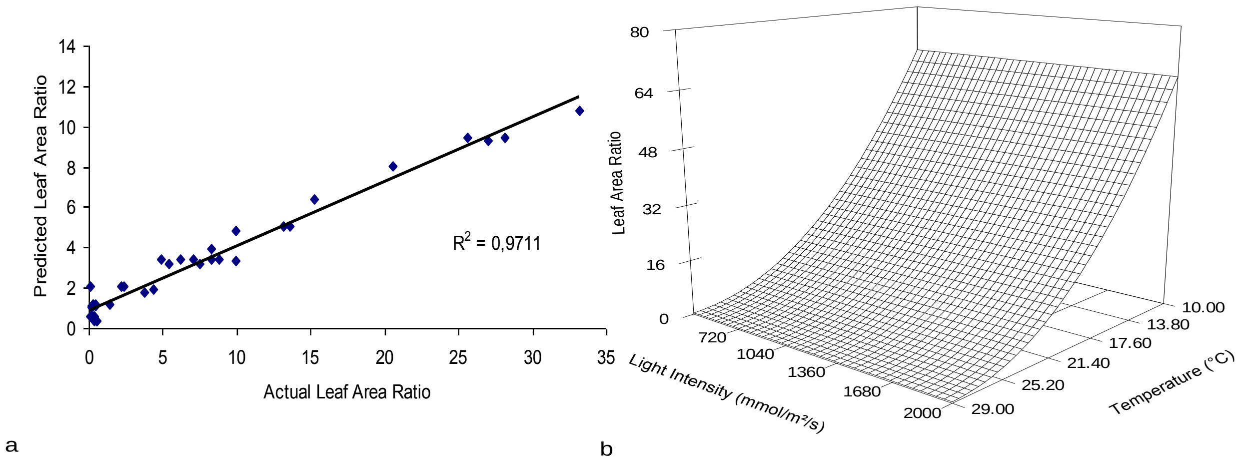



**Figure 4.** The relation between actual leaf area ratio, the approximate leaf area ratio and the change in oregano caused by the daily light (µmol $m^{-2}$ $s^{-1}$) and the temperature (°C) on the leaf area ratio.

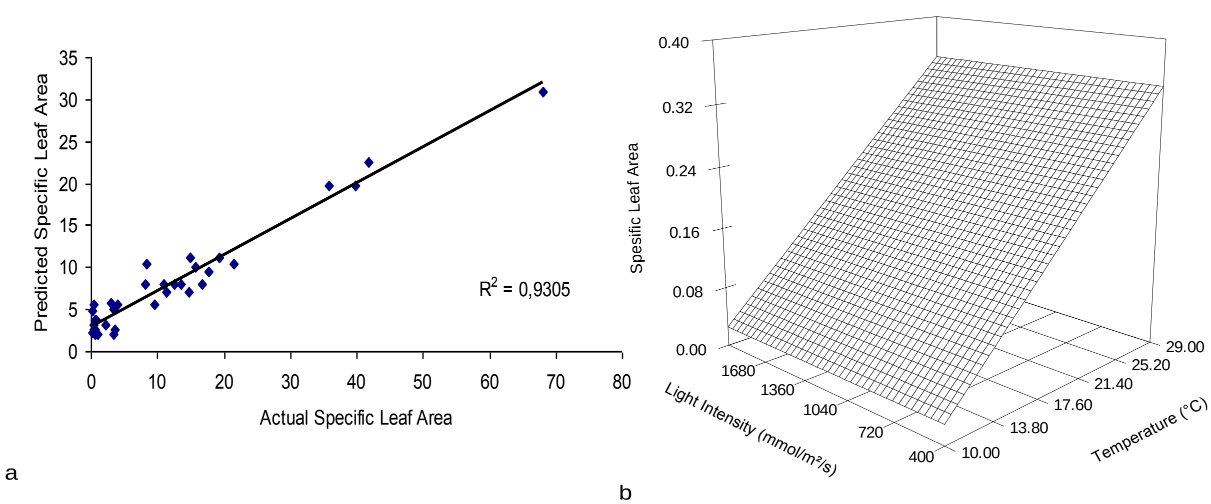



**Figure 5.** The relation between the actual specific leaf area , the approximate specific leaf area and the change oregano caused by the daily light (µmol $m^{-2}$ $s^{-1}$) and the temperature (°C) on the specific leaf area.

Data obtained from the present study showed that, the change in the leaf area was caused by the effect of temperature rather than light intensity. For maize, it was reported that, date of appearance and expansion duration of leaves had critical parameters for calculating leaf area of a canopy (Stewart and Dwyer, 1994). During the experiment, temperature values were chancing between 10 - 40°C under the greenhouse condition. Increasing temperature up to 40°C at low light intensity led a decrease in the net assimilation rate. The highest net assimilation rate was obtained at high light intensity and low temperatures conditions. The lowest net assimilation rate was found at low light intensity and high temperatures. Net assimilation rate is one of the most important growth parameters. This describes the net production efficiency of the assimilatory apparatus. In a study carried out in egg plant, it was observed that net assimilation rate was increased as the temperature rose in time.

This increase in the plant grown at 20.83°C reached the maximum value. Both in this study and in other similar studies, net assimilation rate increased depending on time. In the first periods, plant growth was slower at low temperature than at high temperature. Consequently, a general evaluation of net assimilation rate revealed the fact that, rapid increase in the net assimilation rate led to rapid decrease in the latter stages and thus, this feature being closely related with plant growth rate, the vegetation period was shortened. A significant advantage is acquired by expanding the vegetation period of the plant and accordingly increasing the dry material accumulation at a certain temperature when the net assimilation rate becomes the highest. That’s why NAR is a useful growth index which has been used for many years. At high temperature, increasing light integrally increased relative growth rate linearly. At the low light intensity, increasing temperature up to 40°C did not lead to a significant change in the relative growth rate. The highest relative growth rate was found at high light intensity and high temperatures. The optimum temperature was found to be 21°C for the maximum relative growth rate for oregano. The change in leaf weight ratio occurred in oregano with the effect of temperature rather than light integral. While the highest leaf weight ratio was obtained at 23°C, the lowest leaf weight ratio occurred at 33°C. Leaf weight ratio can be regarded as a reflection of the plants own ability to protect its normal growth characteristics (Fitter and Hay, 1987).

Due to the fact that plant growth is quite rapid with the early stages of plant life, the relative growth rate continuously changes and generally decreases with time. With respect to the total plant weight, the decrease in meristemic tissues production was considered as the major cause of the decrease in relative growth rate.

The decrease in leaf area ratio occurred with low light intensity much quicker than those of plants grown under higher light intensities. It is because the period of plant's growth is long and at the end of this period plant is older. It was stated that, the leaf area decreased as the plant got old (Charles and Edwards et al., 1986). Because leaf area is a function of leaf area ratio and leaf weight, a decrease or an increase in leaf area leads to a change in the leaf area ratio. The decrease in the leaf weight in time following the emergence is completely reflected in leaf area. Many researchers have stated that, the increase in temperature increases the leaf area (Hunt et al., 1984; Picken et al., 1986). The optimum temperature was found to be 22.21°C for the maximum leaf area ratio for oregano. Specific leaf area can change with the environment under which the plant develops. A number of environmental factors are known to influence SLA including light intensity, air, temperature and soil factors (Friend, 1966; Casal et al., 1987; Andrade et al., 1993 and Rebetzeke et al., 2004). The optimum temperature was found to be 20.79°C for the maximum specific leaf area for oregano.

## Conclusion

Present study concluded that, net assimilation rate, relative growth rate, specific leaf area, leaf area ratio, and leaf weight ratio are used as the growth parameters in oregano. Changes in plant growth caused by the effects of environmental conditions (temperature, light, moisture etc.) have been intended to be described by plant growth models. The regression coefficients among the growth parameters are between 0.93 and 0.97. Using multiple regression equations it is very much likely to predict the variation in plant growth as related to temperature and light intensity with high probability. According to the statistical results the equations of growth parameters were not affected by the light intensity directly. Although the light intensity is a very important ecological factor for the plant growth and development stages, we did not use the light intensity values in the equations. Because the light intensity affects the temperature, we have discussed the light intensity in this study.

## REFERENCES


Albayrak S, Camas N (2007). Effects of Temperature and Light Intensity on Growth of Fodder Beet (Beta vulgaris var. crassa Mansf.). Bangladesh J. Bot. 36(1): 1-12.

Andrade A, Wolfe DW, Fereres E (1993). Leaf expansion, photosynthesis and water relations of sunflower plants grown in compacted soil. Plant Soil. 149: 175–184.

Arechiga MR, Carlos V (2000). Cactus seed germination a review. J. Arid Environ. 44: 85-104.

Baytop T (1984). Treatment with plants in Turkey. Istanbul Üniversity Press. No. 3255. Istanbul, Turkey.

Caliskan O, Odabas MS, Cirak C (2009). The Modeling of the Relation among the Temperature and Light Intensity of Growth in *Ocimum basilicum* L. J. Med. Plant Res. 3(11): 965-977.

Celik H, Odabas MS (2009). Mathematical modeling of the indole-3-butyric acid applications on rooting of northern highbush blueberry (Vaccinium corymbosum L.) softwood-cuttings. Acta Physiol. Plantarum. 31: 295–299.

Charles-Edwards AD, Doley D, Rimmingon GM (1986). Modelling Plant Growth and Development. Academic Press. London. relations between temperature and crop development and growth. In: Climatic change and plant genetic resources. Belhaven Press, New York.

Ellis RH, Hadley P, Roberts EH, Summerfield RJ (1990). Quantitative Casal JJ, Aphalo PJ, Sanchez RA (1987). Phytochrome effects on leaf growth and chlorophyll content in Petunia axilaris. Plant Cell Environ. 10: 509–514.

Fitter AH, Hay RKM (1987). Environmental Physiology of Plants. 2nd Edn. Academic Press. London.

Friend DJC (1966). The effects of light and temperature on the growth of cereals. In: Milthorpe, F.L. Ivins, J.D. The Growth of Cereals and Grasses. Butterworths, London.

Hakansson I, Myrbeck A, Ararso E (2002). A review of research on seedbed preparation for small grains in Sweden. Soil Tillage Res. 64: 23-40.

Hunt R, Warron L, Wilson Hand DW, Sweeney DG (1984). Integrated analysis of growth and light interception in winter lettuce. I. Analytical Methods and Environmental Influences. Ann. Bot. 54: 743-757.

Kitiki A (1996). Status of cultivation and use of oregano in Turkey. Proceedings of the IPGRI İnternational Workshop on Oregano8-12 May CIHEAM, Valenzano, Bari, Italy pp. 121-131.

Lagouri V, Blekas G, Tsimidou M, Kokkini S, Boskou D (1993). Composition and antioxidant activity of essential oils from oregano plants grown wild in Greece. Z. Lebensm. Unters. Forsch. 197: 20-23.

Nakiboglu M, Otan H, Kesercioglu T, Tan A (1994). A study on the pollen morphology of some genera in Labiatae. XII. National Biology Congress. Botanic Section 2: 41-51.

Odabas MS, Kevseroglu K, Cirak C, Saglam B (2005). Nondestructive estimation of leaf area in some medicinal plants. Turkish J. Field Crops 1(10): 29–31.

Odabas MS, Mut Z (2007). Modeling the Effect of Temperature on Percentage and Duration of Seed Germination in Grain Legumes and Cereals. Am J. Plant Physiol. 2: 303-310.

Odabas MS, Radusiene J, Camas N, Janulis V, Ivanauskas L, Cirak C (2009). The Quantitative Effects of Temperature and Light Intensity on Hyperforin and Hypericins Accumulation in *Hypericum perforatum* L. J. Med. Plants Res. 3(7): 519-525.

Picken AJF, Stewart K, Klapwicjk K (1986). Germination and Vegetative Development. In: J.G. Atherton J. Rudich (Eds), The Tomato Crop. Chapman and Hall, London.

Rebetzeke GJ, Botwright TL, Moore CS, Richards RA, Condon AG (2004). Genotypic variation in specific leaf area for genetic improvement of early vigour in wheat. Field Crops Res. 88: 179–189.

Sivropoulou A, Papanicolaou E, Nikolaou C, Kokkini S, Lanaras T, Arsenakis M (1996). Antimicrobial and cytotoxic activities of *Origanum* essential oils. J. Agric. Food Chem. 44: 1202-1205.

Stewart DW, Dwyer LM (1994). Appearance time expansion rate and expansion duration for leaves of field-grown maize (*Zea mays* L.). Can. J. Plant Sci. 74: 31-36.

Tanker M, Tanker N (1985). Pharmacognosy. Ankara University, Faculty of Pharmacy No. 58.

Zeybek N (1995). A view at importance of medicinal and aromatic plants for Turkey. Workshop medicinal and aromatic plants. 25-26 May 1995. Izmir, Turkey. pp. 1-10.