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Effect of Seasonal, Altitudinal and Climatical Variations on SLA and LMA Parameters of *Diospyros kaki* L.

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Highlights:
- SLA
- LMA
- Altitude, *Diospyros kaki* L.

Keywords:
- Environmental change
- specific leaf area
- Trabzon persimmon

ABSTRACT:

In the present study, the variation of key leaf characteristics, such as SLA and LMA in plant samples collected from four locations were determined using a Li-Cor portable leaf area measuring device. The effect of seasonal, altitudinal and climatic variations on SLA and LMA was evaluated. There were significant differences ($P<0.01$) in SLA and LMA values in terms of localities, months, temperature and precipitation. There were both elevation and seasonal variables in SLA and LMA values. The highest SLA and LMA values were in May and December, respectively. SLA and LMA values increased and decreased with increasing elevation, respectively. SLA and LMA of *Diospyros kaki* were related with temperature and precipitation. Results indicated that there were variations on SLA and LMA parameters due to ecological factors.

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INTRODUCTION

Specific leaf area (SLA) and leaf mass per area (LMA), among the most important leaf characteristics, play a critical role in the ability of plants to procure and conserve resources, thereby influencing many central ecosystem processes (Chen et al., 2012). Therefore, SLA is considered the most effective tool for understanding the relationships between leaf nutrient contents and nutrient resorption, soil-plant interactions, and evaluating nutrient utilization strategies (Chen et al., 2012). SLA is associated with net assimilation and relative plant growth rate (Reich et al., 1992; Cornelissen et al., 2003).

Key leaf characteristics, such as SLA and LMA, are used to distinguish patterns of variation, constraints and relation to nutrient availability and climate within and among plant species (Rentería and Jaramillo, 2011). Relationships between leaf characteristics contribute to a better understanding of the definition of plant functional groups, as well as processes such as productivity, decomposition, and nutrient limitation in plants (Wright et al., 2005).

In most of the studies on plant ecology and plant physiology, SLA and LMA are generally among the preferred leaf characteristics (Jullien et al., 2009). SLA can be used to base a particular plant's reproductive strategy on light and moisture contents (Milla et al., 2008). SLA is the ratio of plant leaf area to dry weight and is related to the light intensity of the area where the plants are located, vegetation cover, water extraction capacity, plant species, leaf structure and net photosynthesis rate (Sellin, 2001). LMA is the ratio of leaf dry weight to leaf area (Sürmen et al., 2016). LMA values may vary depending on the species as well as among individuals of the same species. In addition, depending on the season and environmental conditions, LMA values may vary for the same species or even for the same leaf.

Diospyros kaki L., locally called Trabzon persimmon, is a deciduous plant native to China, but nowadays it is grown in many countries (China, India, Japan, Kore and Türkiye). Persimmon (*Diospyros kaki*) has been long and widely used as a traditional medicine. It was also reported to be the best fruit yielding species (Mallavadhani et al., 1998). With a wide spectrum of biological and pharmacological properties, persimmon leaves were traditionally utilized as a medicine, health beverage, and cosmetic (Xie et al., 2015). There is little information on how different plant life forms in high altitudes may differ in their leaf mass per area (LMA) and specific leaf area (SLA) with altitude. It is vital to comprehend how plant characteristics react to environmental change. Therefore, this study was undertaken to determine the effect of season, elevation and climate parameters on the SLA and LMA of *Diospyros kaki* located at different elevations during the growing season.

MATERIALS AND METHODS

This research was carried out within the borders of Trabzon province located in the A7-A8 square. The elevation of the research area above sea level varies between ~ 170-800 m. The research area consists of four different localities, ~170, ~ 350, ~ 500 and ~ 800 m, starting from the entrance of Barışlı Village in Esiroğlu Town of Maçka District of Trabzon Province. Humid subtropical climate regime is dominant in the region where the research was carried out.

In order to investigate the relationship of SLA and LMA with temperature and precipitation, the monthly average total precipitation and temperature values for the period during which the fieldwork was carried out were obtained from the Turkish State Meteorological Service (Table 1). Besides, Walter climate diagram was drawn using the meteorological station data in Maçka district. When the diagram drawn according to the Walter method was examined, it was determined that there was a dry period from July to the middle of August (Figure 1).

Table 1. Climatic data at the time of the fieldwork

Year	Months	Average Temperature (°C)	Average Total Precipitation (mm)
	January	0.6	53.5
	February	4.7	55.3
	March	5.7	54.3
	April	8.9	71.8
	May	11.9	75.4
2015	June	15.2	74.1
	July	17	29.4
	August	18.7	36.1
	September	14.9	49.3
	October	10.2	66.3
	November	5.6	61.2
	December	1.5	52.1

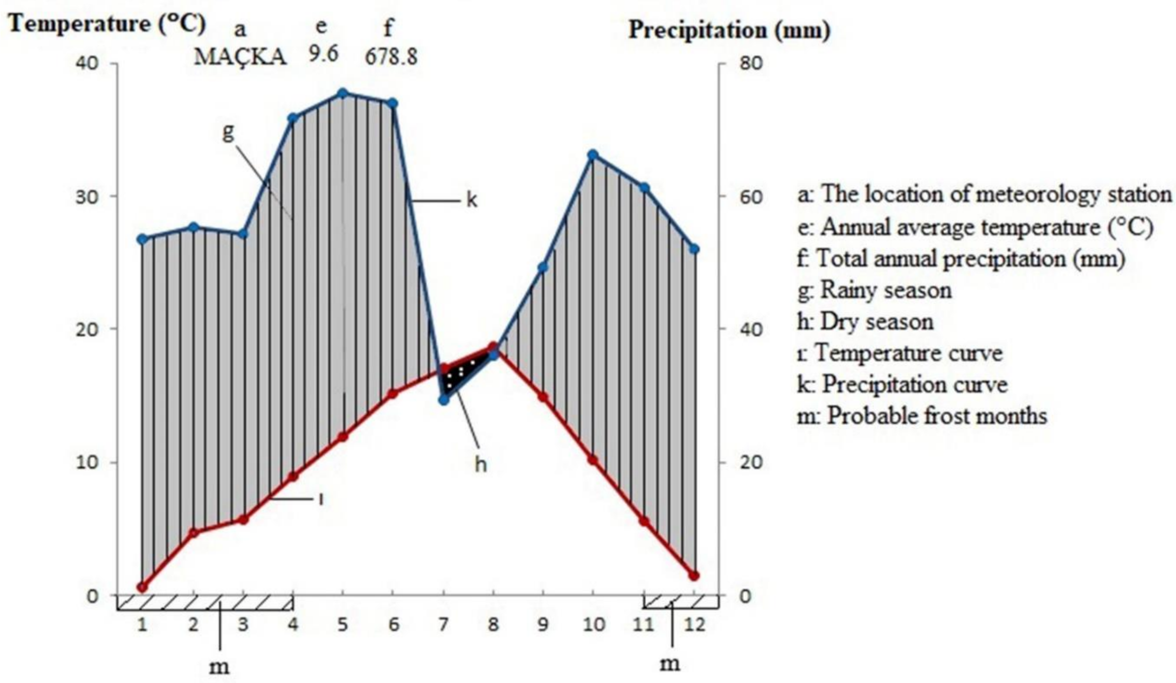

Figure 1. Climate diagram of Maçka district according to Walter method

The fieldwork was carried out between May 2015 and December 2015 in selected sample areas considering the elevation factor. *Diospyros kaki* individuals were chosen in the sample area selected at four different elevations. The coordinates for each of the localities were determined, within 12m accuracy, using a handheld global positioning system (GPS). At each locality, individuals were selected at least 2.5 m from the stems of neighboring canopy trees to avoid potential microsite variation (Boerner and Koslowsky, 1989). In order to minimize variability among and within trees caused by light, tree species were selected from an open area, and leaf samples were collected from an outer location of the tree crown to avoid effects of crown position. Current year, leaf samples were collected from southern-exposed branches of trees per elevation in the afternoon (15:00-17:00 h). A lateral branch which was unshaded from each tree was selected and marked and leaf samples were always collected from the same branch. Leaf samples (as similar in size and shape) from equal positions (direction, height, branch, etc.) for all of trees were collected monthly from May (beginning of the growth period) to December 2015 (senescence phase). The leaf samples were consisted of the leaves with no evidence of insect attack and undamaged. The leaf samples collected monthly from the field were cleaned, pressed and dried. The areas of leaf samples belonging to individuals were measured using a Li-Cor portable leaf area measuring device. Leaf samples whose areas were measured were dried in an oven at 65 °C until they reached a constant weight, and their dry weights were determined. Analyses were performed with three replicates.

SLA and LMA values were calculated using the formula below:

$$SLA\ (dm^2/g) = \sum LA\ (dm^2) / \sum LDW\ (g) \tag{1}$$

$$LMA\ (g/dm^2) = \sum LDW\ (g) / \sum LA\ (dm^2) \tag{2}$$

LA: Leaf area (dm^2)

LDW: Leaf dry weight (g)

Statistical analysis was performed by using the SPSS version 22 (IBM SPSS Statistics for Windows, Armonk, NY). One-way ANOVA used to expose whether SLA and LMA changed with respect to months and elevations. After the analysis of variance, Tukey’s honestly significant difference (HSD) test was used to rank means following the analysis of variance. The Two-Way ANOVA test was performed to examine the effect of elevation and months on SLA and LMA values. Pearson correlation analysis at $P<0.05$ significance level was used to determine whether there is a relationship between precipitation and temperature and SLA and LMA.

RESULTS AND DISCUSSION

SLA is a feature that responds strongly to environmental changes (Koike, 1988). LMA is a key feature in plant growth (Lambers and Poorter, 1992) and is an important indicator of plant strategies widely used in plant ecology (Grime, 2001; Westoby et al., 2002). In this study, there were statistically significant differences at the $P<0.01$ level in SLA (dm^2/g) and LMA (g/dm^2) values between localities and among the months (Table 2). Similarly, Sürmen et al. (2016), Bilgin and Güzel (2017) reported that there were statistically significant differences in SLA and LMA values between both localities and months. The highest and the lowest SLA values (dm^2/g) were at 485 m (1.62 dm^2/g) in May (2.15 dm^2/g) and 170 m (1.24 dm^2/g) in December (0.99 dm^2/g), respectively. The highest and the lowest LMA values (g/dm^2) were at 170 m (0.85 g/dm^2) in December (1.01 g/dm^2) and 485 m (0.65 g/dm^2) in May (0.46 g/dm^2), respectively (Table 2).

According to the Two-Way ANOVA results, it was determined that the interaction of elevation and months caused a statistically significant difference on SLA ($F=5.084$, $P<0.01$) and LMA ($F=5.739$, $P<0.01$) values. It was determined that there was a statistically significant difference ($P<0.01$) between the months in terms of SLA values at each location. When the LMA results were evaluated, statistical differences ($P<0.01$) were found between all months for 170 m. There were statistically significant differences at the $P<0.05$ level in May and June and, at the $P<0.01$ in other months for 344 m. While significant differences ($P<0.01$) were determined in September, October and December at 485 meters, no difference was observed in other months. There were statistically significant differences at the $P<0.01$ level in other months except for May and June at 976 m.

It was determined that the highest SLA values were in May, when the leaves first occurred to form and the lowest SLA values were in December, when the leaves were completely senescent (Table 2). On the other hand, the opposite situation was observed in the LMA values.

Table 2. SLA and LMA values of *Diospyros kaki* according to elevation gradients and months (Mean ± Standart Error)

		SLA (dm^2/g)	LMA (g/dm^2)
Elevations	170 m	1.24±0.07**b**	0.85±0.03**a**
	344 m	1.36±0.08**ab**	0.79±0.04**a**
	485 m	1.62±0.07**a**	0.65±0.03**b**
	796 m	1.45±0.08**ab**	0.73±0.04**ab**
Months	May	2.16±0.03**a**	0.46±0.006**d**
	June	1.59±0.04**b**	0.63±0.01**c**
	July	1.47±0.07**b**	0.70±0.03**c**
	August	1.45±0.07**bc**	0.71±0.03**c**
	September	1.15±0.06**de**	0.89±0.04**ab**
	October	1.19±0.06**cde**	0.86±0.04**ab**
	November	1.36±0.08**bcd**	0.76±0.04**bc**
	December	0.99±0.05**e**	1.01±0.01**a**

Different letters denote significant differences between the groups according to Tukey's HSD test (rejection level 0.05)

When the leaves are first formed, they are light in weight and very thin, and the amount of water they contain is also high. Therefore, the amount of leaf area per unit weight (SLA) is higher in newly formed leaves than in other months, the opposite is true for the LMA. The reason for the high SLA values in May may be due to this situation. Depending on the nutrient and tissue increase as a result of photosynthesis, SLA values tended to decrease until September, the beginning of senescence. LMA values gradually increased due to the high photosynthetic activity until the ripest period of the leaves, and then decreased again due to the onset of the senescence period, that is, the reabsorption of nutrients. Similarly, Çakmak (2011) reported that SLA value was highest in the young period and decreased significantly between the young period and the mature period. The lowest SLA value is in the senescence period. The reason for this is that the mature period coincides with the summer months. The plant wants to minimize the loss by lowering the SLA value, especially in summer, due to the increase in water loss. The LMA value increased from juvenile to senescence, especially between juvenile and mature. SLA increases rapidly during leaf expansion, followed by a decrease again, possibly due to accumulation of cell wall material and chloroplasts (Jurik, 1986). In order to maximize the utilization of limited nutrients, developing a high LMA is occasionally thought of as a way to lengthen the life of a leaf (Van de Weg et al., 2009).

SLA values increased with increasing elevation (Table 2). Similarly, Bilgin and Güzel (2017) reported that SLA values increased with increasing elevation. It has been reported that there are physiological and morphological changes in the plant depending on the elevation gradient (Körner et al., 1989; Doğan, 2012). This situation is thought to be due to the fact that *D. kaki* is a moisture-loving plant, and that with the increase in height, the humidity decreases and it causes changes in the physiological and morphological characteristics of the plant.

LMA values decreased with increasing elevation (Table 2). It is known that LMA values decrease towards the lower layers in forest ecosystems (Jurik, 1986). Poorter et al. (2009) reported that LMA values may change depending on seasonal and other environmental conditions. The results in the literature support the results we found in our study.

Along an altitudinal gradient, individual leaf characteristics like longevity, leaf mass per area (LMA), specific leaf area (SLA), stomatal conductance, nitrogen content, and photosynthetic activity also alter (Suzuki, 1998). Previous research has demonstrated that deciduous plants' leaf nitrogen concentrations and/or photosynthetic rates tend to rise at high elevations across and within species (Körner et al., 1986; Friend et al., 1989; Körner et al., 1989; Kudo 1996; Suzuki, 1998).

Particularly deciduous plants react in a way that decreases leaf production and increases photosynthetic activities when the optimum period for plant development shortens with increasing elevation. The carbon balance hypothesis regards this pattern of activity as an adaptation behavior (Taguchi and Wada, 2001). In the temperate zone, an increase in N content is observed in all organs of the plants in terms of both dry weight and leaf area ratio with increasing height (Körner et al., 1989).

Numerous researches revealed that the growth of trees' height, diameter, and biomass reduced linearly with elevation. According to Körner (2003), as elevation rises, the size of the leaves and needles gets smaller but thicker, which results in a lower SLA (Pan et al., 2009). Leaf density is decreased by the buildup of carbon-rich compounds, the development of secondary vascular bundles, and sclerenchyma. Leaf thickness increases with the amount of spongy or palisade mesophyll layers. Leaf dry mass increases with increasing leaf density and thickness while SLA decreases (Karavin, 2013).

Suzuki (1998) reported that compared to plants at the lower site, those at the higher site had leaves with higher nitrogen levels and lower LMA. Additionally, some deciduous species' LMA was shown to decrease with elevation, along with a reduction in the length of the plant's foliage season. When the growth period is brief, the rise in leaf nitrogen and fall in LMA may help to maintain positive photosynthetic carbon gain (Kudo, 1996; Suzuki, 1998). Indeed, earlier research suggests that whereas low LMA permits plants to maximize light interception, high LMA is often linked to poor nutrient concentrations and low photosynthetic activity (Liu et al., 2021).

The difference in SLA and LMA values with increasing elevation may be due to the soil nutrient content values in the environment where the plants live. Westoby et al. (2002) and Doğan (2012) stated that plants living in nutrient-poor soils have higher average LMA values and longer leaf life than plants living in nutrient-rich soils. Ozbucak et al. (2011) reported that SLA and LMA values changed significantly during the growing season and with the topographic gradient. Guo et al. (2016) also reported that LMA values change significantly with elevation. Poorter et al. (2009) stated that LMA values may change depending on seasonal and other environmental conditions.

According to the correlation analysis, it was determined that SLA was related to precipitation and temperature, and this relationship was also positive at medium level. We observed a negative relationship between LMA and precipitation and temperature. The weak relationship between LMA and precipitation was observed, while a medium relationship between LMA and temperature was detected (Ural and Kılıç, 2006; Table 3). It has been reported in many studies that SLA is in parallel with the amount of precipitation (Faria et al., 1998; Prior et al., 2004; Warren et al., 2006, Turner et al., 2008; Karavin and Kilinc, 2011). It is thought that precipitation increases the leaf surface area by increasing the water potential in the leaf and thus seasonal fluctuations in SLA are in parallel with precipitation. It can be expressed as a result of the increase in the amount of dry weight with photosynthesis activity depending on the temperature increase, or as a result of the decrease in the amount of water in the leaves and the reduction of the leaf area depending on the temperature (Karavin and Kilinc, 2011).

Table 3. Correlation analysis results showing the relationship of SLA and LMA with temperature and precipitation

		Temperature	**Precipitation**
SLA	Pearson Correlation	0.312**	0.333**
	Sig.	0.002	0.001
LMA	Pearson Correlation	-0.394**	-0.261*
	Sig.	0.000	0.01

CONCLUSION

Here, we evaluated the role of season, elevation, temperature and precipitation on the SLA and LMA parameters of persimmon. It is concluded that climatic factors such as temperature and precipitation have a relatively weak-moderate explanatory power for SLA and LMA variations. Overall, SLA and LMA are significantly higher and lower with increasing elevation, respectively. We found that variations in different months of the year compared with elevation had a higher effect on SLA and LMA.

Çıkar Çatışması

The article authors declare that there is no conflict of interest between them.

Yazar Katkısı

The authors declare that they have contributed equally to the article.

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