Effect of light condition and leaf position on photosynthesis efficiency in (Eucalyptus microtheca L.)

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Abstract

The experiment was conducted in Koya university campus. Two groups of eucalyptus trees selected, first group was grown under the shade of high building, while second group was grown in un-shaded adjacent area. Branches from the two groups were selected and leaves from basal, middle and apical positions were sampled, during January 2014, in order to investigate the effect of shade condition and leaf position on photosynthesis pigments and stomata characteristics. Results showed a significant increase in the percentage of leaf dry matter content in sunny trees leaves compared to those grown in shady conditions. Light conditions had non- significant effects on leaf area, whereas, leaf position had significant effects. The results also showed non-significant differences between light conditions on leaves content of chlorophyll a, b and total chlorophyll, whereas, basal leaves gave higher chlorophyll a, b and total chlorophyll contents compared to each of the middle and apical leaves. Number of stomata increased significantly in the adaxial leaf surface in trees grown under shady conditions. Significant decrease in stomata number on the abaxial leaf surface was obtained from the basal leaves compared to middle leaves, whereas, there were no significant differences between different leaf positions on the number of stomata on the adaxial leaf surface.

Introduction

Eucalyptus is an evergreen aromatic tree that belongs to the family Myrtaceae, it contains about 600 species. It cultivated as ornamental plants in forests, parks, public and home gardens. Several species of eucalyptus are used in traditional medicine, and it is distributed in Asia and Australia (Adeniyi *et al.*, 2006).

Light environment and interception of light strongly influence plant growth and development. Whole plant growth and competitive ability at different irradiances are dependent on photosynthetic rate and structure of individual leaves and canopy geometry and dynamics (Givnish, 1988). It has been noted that juvenile leaves of eucalyptus species have the morphology and structure of leaves developed under shade conditions, whereas adult leaves form in the high-light environment of the mature tree canopy and are considered to be sun-adapted (Ashton and Turner, 1979).

One of the important factors which effects on growth and productivity of plants is photosynthetic efficiency, and the photosynthetic rate of the entire plant canopy depends on the photosynthesis of individual leaves. Leaf photosynthesis can be influenced by many plant factors such as leaf position and age, as well as environmental factors such as light, temperature, nutrition and water availability (Shelley and Bell, 2000 and Aighewi and Ekanayake, 2004). Hgazaabd *et al.* (2009) found that the leaf area of purple yam (*Dioscorea alata* L.) and readings of chlorophyll meter increased with plant age, also they found that leaves at different positions on the vine differed in photosynthetic capacity, both young (below 4th position) and older (above 20th position) leaves had lower photosynthetic capacity than the intermediate mature leaves.

The chlorophyll content is an important experimental parameter in agronomy and plant biology research, amount of chlorophyll shows alteration depending on many factors such as light (Johnston and Onwueme, 1998).

Stomata are the portals for gas exchange between the leaf mesophyll cells and the environment, they occupy between 0.5% and 5% of the leaf epidermis. The exchange of CO_2 and water vapor between a leaf and the atmosphere is principally controlled by stomatal density (number of stomata per unit leaf area) and their mean aperture. Stomatal density is known to be affected by environmental variables such as light and atmospheric CO_2 (Casson and Gray, 2008 and Ogaya *et al*., 2011). A genotypic decrease in stomatal density has been observed induced by shading conditions (Schoch *et al*., 1980) and an increase in response to high irradiance (Thomas *et al.,* 2003).

Light energy directly controls the stomatal reaction by its influence on receptor systems in the guard cells. It has also an indirect, but very significant, effect on stomatal aperture as it controls photosynthetic CO_2 fixation and, consequently, the CO_2 concentration in the intercellular space of the mesophyll to which guard cells react (Zeiger, 1990). Irradiance usually changes drastically under natural conditions either due to cloudy weather or the incidence of sun flecks in the canopy. Understory plants were found to react specifically to these varying irradiance conditions (Knapp and Smith, 1990; Tinoco-Ojanguren and Pearcy, 1992 and Ogren and Sundin, 1996). This study aimed to identify the effect of leaf position on growth and photosynthetic efficiency of leaves under sun and shady conditions.

Materials and methods

Two groups of eucalyptus (*Eucalyptus microtheca* L.) trees aged about (12) years and cultivated in the parks of Koya University campus were selected, first group was grown in an open area (the average of light density was about 39.73 K Lux at midday), and second group grown between high building (the average light density was about 7.33 K Lux at midday), the density of light was measured by a Light Meter (EXTECH Instruments Corporation, China). Different leaves were sampled from three positions of the branches from the oldest to youngest (basal, middle and apical) for each group of trees, during January 2014.

I- Measured parameters:

- **Leaf dry matter (%):** It calculated by dividing the dry weight of leaves by the wet weight of leaves multiplied by 100.
- **Leaf area (cm^2):** It determined by the method of (Pandey and Singh, 2011).
- **Chlorophylls content (mg/100g fresh weight):** The amount of chlorophyll a, b and total chlorophyll were estimated according to the method of (Ranganna, 1977) by using a spectrophotometer (PD-303) at 642 nm and 660 nm wavelengths, as follows:
  - mg chlorophyll a/ ml solution = (9.93) (A660nm)-(0.777) (A642nm)
  - mg chlorophyll b/ ml solution=(17.60) (A642nm)-(2.81) (A660nm)
  - mg total chlorophyll / ml solution=(7.12) (A642nm)-(16.8) (A660nm)
- **Number, length and width of stomata in adaxial and abaxial surfaces of leaves:** measured by the method of lasting impressions as it described in (Rai and Mishra, 2013).

II- Statistical analysis

The experiment was conducted as factorial experiment in randomized complete block design (RCBD) in three replicates per treatment, the first factor was the light condition (shady and sunny), and the second factor was three positions of leaves on branch (basal, middle and apical). The data were analyzed and Duncan multiple range test at 5% probability level were done by using SAS program (Reza, 2006).

Results and discussion

Leaf dry matter content and Leaf area

Results in Table 1 show a significant increase in the percentage of dry matter content for sunny tree leaves (45.80%) compared to those grown in shady conditions (41.46%), while there were no significant differences between different leaf position and its interaction with light conditions on percent of leaves dry matter content.

Light conditions had non- significant effects on leaf area, whereas the leaf area obtained from basal leaves was higher significantly (18.74 cm^2) than leaves of middle position (15.36 cm^2), which significantly increased compared to apical leaves (14.14 cm^2). Basal leaves from sunny and shady trees increased significantly the leaf area to (18.81 and 18.67 cm^2), respectively compared to apical leaves from sunny and shady trees and shady middle leaves (13.72, 14.65 and 14.33 cm^2), respectively.

Leaf area determines light interception, photosynthesis and CO_2 fixation (Liu and Stutzel, 2002), which influences on dry matter production of plants, therefore, the increase in leaf dry matter content in sunny condition may return to increase of leaf area (Table 1).

The increase in leaf area from the apical towards the basal leaves of the branch may suggest the increase in leaf expansion rate with age. Similar result has been reported in purple yam (*Dioscorea alata* L.) in which the leaf area increased with plant age (Hgazaabd *et al.*, 2009). Insufficient light supply to plant results directly in a decrease in final leaf area of individual leaves due to its key role in cell division, if cell division is decreased, the leaf area decreases (Granier and Tradieu, 1999). The important consequence of the inhibited leaf area growth is that the amount of solar radiation intercepted by a leaf canopy decreases, thereby decreasing the ability of crop canopy to assimilate carbon dioxide (Hgazaad *et al.*, 2009). The results agree with (Hgazaabd *et al.,* 2009) who found that the leaf area increased with plant age. Results also agreed with (Ludlow et al., 1974) who found that shade-grown plants have a higher specific leaf area and lower dry weight fraction than sun plants. The photosynthetic machinery of shade-adapted leaves is more efficient at harvesting light but will assimilate less CO_2 than sun-leaves (Stewart et al., 2012).

Chlorophyll a,b and total chlorophyll

The results in Table 2 shows non-significant differences between light conditions on the leaf content of chlorophyll a, b and total chlorophyll, whereas basal leaves gave higher chlorophyll a, b and total chlorophyll content (2.98, 1.96 and 5.92 mg/ 100 g fresh weight), respectively compared to each of the middle and apical leaves. The interactions between light condition and leaf position show significant increases in chlorophyll a, b and total chlorophyll contents in the basal leaves of trees grown in shade conditions compared to other interactions, whereas the lowest values obtained from apical leaves of trees grown in shady conditions.

The increase in basal leaves content of chlorophyll a, b and total chlorophyll may due to increase in leaf age and leaf expansion rate with leaf position toward the base, where biochemical changes, production of fully developed chloroplasts, and the total number of chloroplasts also increased (Lieth and Pasian, 1990; Aighewi and Ekanayake, 2004, Hgazaabd *et al.,* 2009 and Gond *et al.*, 2012). Decreasing in photosynthetic pigment towards apical position may due to decreasing in leaf area (Table 1), when young expanding leaves are characterized by low efficiency of photochemistry and photosynthesis, low capacity for both electron transports through photo-system II, low CO_2 fixation, high capacity for non-radiative thermal dissipation and high respiration rate (Greer and Halligan, 2001). The increase in chlorophyll content in shade plants agree with results of (Jaqueline *et al.,* 2007 and Stewart *et al*., 2012) who found that the contents of a, b and total chlorophyll of *Lithraea molleoides* and avocado were higher in the shade leaves compared to the sun leaves.

Stomata number, length and width

Results in Table 3 show that light conditions had non-significant effects on the stomata number /mm^2 on the lower (abaxial) leaf surface, whereas, number of stomata increased significantly in the upper (adaxial) leaf surface in trees grown under sunny conditions. Significant increase in stomata number on abaxial leaf surface was obtained from the middle leaves compared to basal and apical leaves, whereas there were no significant differences between different leaf positions on the number of stomata on adaxial leaf surface. The interactions between light condition and leaf position showed significant increase in the stomata number (101.67 stomata/ mm^2) on the abaxial leaf surface for middle leaves of shady trees compared to other interactions, whereas adaxial surface, basal leaves of shady trees gave the significant lowest value (56.67 stomata /mm^2) compared to other interactions (Figures 1 and 2).

The results in Table 3 have shown no significant effects for each of light conditions and leaf positions in stomata length on both of abaxial and adaxial surfaces, respectively. The effects of the interactions between light condition and leaf position show significant increase in the stomata length (22.17 micron) on the abaxial leaf surface of the middle leaves of shady trees compared to middle leaves of sunny trees, whereas, there were no significant differences between different interactions regarding to stomata length on the adaxial surface.

Regarding to stomata width on both abaxial and adaxial surfaces, the results showed significant increases in stomata width in shady plants to 20.15 micron on the abaxial leaf surface compared to sunny trees (17.91 micron), whereas, this difference was not significant on the adaxial leaf surface. Each of leaf position and interaction between light condition and leaf position had non-significant effect on the stomata width.

The results was agree with (Kurschner, 1997) who reported for *Quercus petraea*, typical shade leaves have lower stomatal densities. The results also agree with (Pompelli *et al.*, 2010) who confirmed that leaves of coffee plants grown under sun condition had more stomata density compared to those grown under shady conditions.

From this study we can conclude that light had significant effects on each of eucalyptus (*Eucalyptus microtheca* L.) leaf dry matter content and stomata number on adaxial leaf surface, while, leaf position on branch had significant effects on leaf area, chlorophyll a , chlorophyll b , total chlorophyll and stomata number on abaxial leaf surface.

Table 1: Effect of light conditions, leaf position and there interactions on dry matter and leaf area.

Treatments	Dry matter (%)	Leaf area (cm^2)
Light conditions		
Shady	41.46 b	15.85 a
Sunny	45.80 a	16.30 a
Leaf position		
Basal	44.34 a	18.74 a
Middle	43.17 a	15.36 b
Apical	43.38 a	14.14 c
Interaction		
Shady x Basal	41.44 a	18.67 a
Shady x Middle	41.07 a	14.33 c
Shady x Apical	41.87 a	14.56 c
Sunny x Basal	47.23 a	18.81 a
Sunny x Middle	45.27 a	16.38 b
Sunny x Apical	44.89 a	13.72 c

Means followed by the same letters within columns are not significantly different according to the Duncan`s Multiple Range Test ($p \leq 0.05$).

Table 2: Effect of light condition, leaf position and there interactions on leaves content of a, b and total chlorophyll.

Treatments	Chlorophyll a	Chlorophyll b	Total Chlorophyll
	mg/ 100g fresh weight		
Light condition			
Shady	2.65 a	2.63 a	5.26 a
Sunny	2.71 a	2.50 a	5.14 a
Leaf position			
Basal	2.98 a	2.96 a	5.92 a
Middle	2.60 b	2.40 b	4.67 b
Apical	2.45 b	2.34 b	4.82 b
Interaction			
Shady x Basal	3.39 a	3.43 a	6.76 a
Shady x Middle	2.39 bc	2.41 bc	4.80 bc
Shady x Apical	2.15 c	2.04 c	4.23 c
Sunny x Basal	2.56 bc	2.48 bc	5.08 bc
Sunny x Middle	2.81 b	2.38 bc	4.93 bc
Sunny x Apical	2.75 b	2.64 b	5.41 b

Means followed by the same letters within columns are not significantly different according to the Duncan`s Multiple Range Test ($p \leq 0.05$).

Table 3: Effect of light condition, leaf position and there interactions on some stomata characteristics.

Treatments	Stomata Number/mm^2		Stomata Length (micron)		Stomata Width (micron)	
	Abaxial surface	Adaxial surface	Abaxial surface	Adaxial surface	Abaxial surface	Adaxial surface
Light condition						
Shady	89.63 a	65.63 b	20.83 a	21.13 a	20.15 a	19.44 a
Sunny	83.61 a	73.67 a	19.09 a	19.44 a	17.91 b	19.20 a
Leaf position						
Basal	81.97 b	65.20 a	19.89 a	20.03 a	19.67 a	19.11 a
Middle	92.64 a	71.75 a	19.83 a	20.75 a	18.64 a	19.64 a
Apical	85.25ab	72.00 a	20.17 a	20.08 a	18.64 a	19.22 a
Interaction						
Shady x Basal	76.94 b	56.67 b	20.11 ab	21.01 a	19.90 a	19.33 a
Shady x Middle	101.67a	70.00 a	22.17 a	21.50 a	20.33 a	19.83 a
Shady x Apical	90.28ab	70.22 a	20.22 ab	20.89 a	20.22 a	19.17 a
Sunny x Basal	87.00 b	73.77 a	19.67 ab	19.05 a	19.44 a	18.89 a
Sunny x Middle	83.61 b	73.50 a	17.50 b	20.00 a	16.94 a	19.83 a
Sunny x Apical	80.22 b	73.77 a	20.11 ab	19.28 a	17.33 a	19.28 a

Means followed by the same letters within columns are not significantly different according to the Duncan`s Multiple Range Test ($p \leq 0.05$).

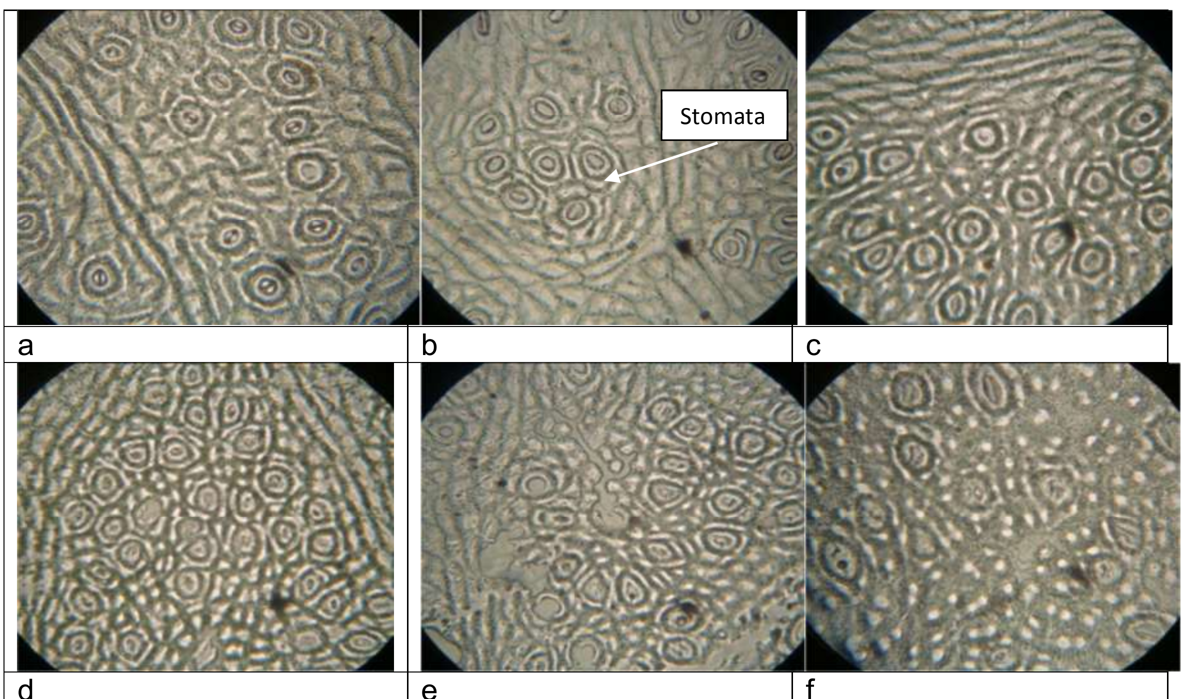

Figure 1. Detail of 400X microscopic observation of stomata in a *Eucalyptus microthica* L. leaf abaxial surface (a) stomata in basal leaves for trees grown in shady condition (b) stomata in middle leaves for trees grown in shady condition (c) stomata in apical leaves for trees grown in shady condition (d) stomata in basal leaves for trees grown in light condition (e) stomata in middle leaves for trees grown in light condition (f) stomata in apical leaves for trees grown in light condition.

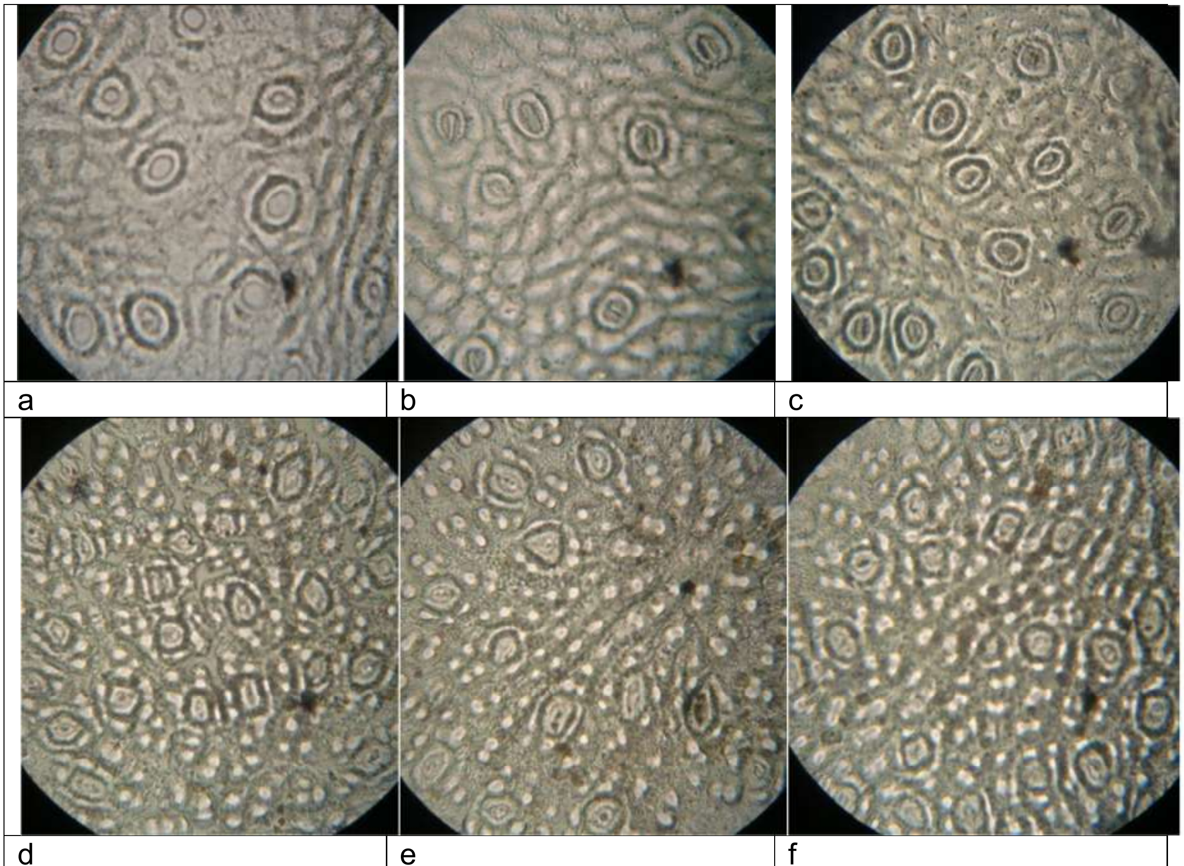

Figure 2. Detail of 400X microscopic observation of stomata in a *Eucalyptus microthica* L. leaf adaxial surface (a) stomata in basal leaves for trees grown in shady condition (b) stomata in middle leaves for trees grown in shady condition (c) stomata in apical leaves for trees grown in shady condition (d) stomata in basal leaves for trees grown in light condition (e) stomata in middle leaves for trees grown in light condition (f) stomata in apical leaves for trees grown in light condition.

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پوختە

کاریگەری بارودۆخی ڕوناکی وشوێنی گەڵای کالبتۆس (*Eucalyptus microtheca* L.) لەسەر چالاکی رۆژە پێکهاتە

دوو کۆمەڵەی درەختی کالبتۆس هەڵبژێردرا کەوا لە ناوەندی کۆمەڵگای زانکۆی کۆیە چێنرابوون، یەکەمیان گەشەیان کردبوو لە شوێنێکی کراوە، وە دووەمیان گەشەیان کردبوو لەنێوان باڵەخانەی بەرز وە بارودۆخی سێبەر. چەند لقێ لە هەر کۆمەڵێ هەڵبژێردرا وە گەڵاکانی خوارەوە و ناوەڕاست وسەرەوەی لقەکان هەڵبژێردرا لە مانگی کانونی دووەمی ٢٠١٤ بەمەبەستی زانینی کاریگەری سێبەر وشوێنی گەڵا لەسەر بۆیەکانی رۆژە پێکهاتە وەخەسلەتەکانی دەمیلە. ئەنجامەکان دەریان خست کەوا زیادبوونێکی بەرچاو دیاری دا لەڕێژەی مادەی وشك لە گەڵای ئەو درەختانەی لە هەتاو گەشەیان کردبوو بە بەراوەرد بەوانەی لەسێبەر گەشەیان کردبوو، بەڵام بارودۆخی سێبەر کاریگەری نەبوو لەسەر ڕووبەری گەڵا، لەوکاتەی شوێنی گەڵاکان کاریگەریان هەبوو لە سەر ئەم خەسلەتە. هەروەها ئەنجامەکان دەریان خست کەوا بارودۆخی ڕووناکی کاریگەری نەبوو لەسەر پێکهاتەی کلۆرۆفیل ا وە ب وە کۆی کلوروفیل، بەڵام ڕێژەی ئەم بۆیانە زیادیان کرد لەناو گەڵاکانی خوارەوە بە بەراورد لەگەڵ گەڵاکانی ناوەڕاست وسەرەوەی لق. ئەنجامەکان دەریان خست کەوا ژمارەی دەمیلەکان /ملم^2 زیادیانکرد لەسەر ڕووی سەرەوەی گەڵای درەختەکان کەوا لە هەتاو گەشەیان کردبوو، بەڵام ژمارەی دەمیلەکان لە ڕووی خوارەوە کاریگەرنەبوون. ژمارەی دەمیلەکان/ملم^2 کەمیان کردەوە لەسەر ڕووی خوارەوەی گەڵاکانی خوارەوە بە بەراوەرد بە گەڵاکانی ناوەڕاست، بەڵام شوێنی گەڵاکان کارگەریان نەبوو لەسەر ژمارەی دەمیلەکان لە ڕووی خوارەوەی گەڵاکان.

الملخص

تأثير ظروف الاضاءة وموقع أوراق اليوكالبتوس (*Eucalyptus microtheca* L.) في كفاءة التركيب الضوئي

نفذت هذه الدراسة في مجمع جامعة كوية، حيث أختيرت مجموعتين من أشجار اليوكالبتوس، كانت المجموعة الأولى نامية في مساحة مفتوحة بينما المجموعة الثانية نامية بين مباني عالية وظروف تظليل. اختيرت افرع من اشجار كلتا المجموعتين واخذت اوراق قاعدية ووسطية وقمية من كل فرع في كانون الأول 2014، بهدف معرفة تاثير التظليل وموقع الورقة في صبغات التركيب الضوئي وصفات الثغور. أظهرت النتائج ازدياد معنوي في النسبة المئوية للمادة الجافة في أوراق الأشجار النامية في ظروف مشمسة مقارنة بالنامية في ظروف الظل. لم يكن لظروف التظليل تاثيراً معنوياً في المساحة الورقية في حين اثر موقع الورقة على الفرع على هذه الصفة. كما أظهرت النتائج عدم وجود فرق معنوي بين معاملتيي الإضاءة في محتوى الأوراق من كلوروفيل ا و ب والكلوروفيل الكلي ، في حين ازداد محتوى الأوراق من هذه الصبغات في الأوراق القاعدية مقارنة بالأوراق الوسطية والقمية، وكذلك زيادة عدد الثغور/ملم^2 في السطح العلوي للأوراق في الظروف المشمسة وعدم تأثره في السطح السفلي للورقة. انخفض عدد الثغور في السطح السفلي للأوراق القاعدية مقارنة بالأوراق الوسطية، في حين لم يكن لموقع الورقة تاثير معنوي في عدد الثغور في السطح العلوي للورقة.