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The Thickness Changes of Anatomical Ornamental Monocotyledon Plant Leaves Affected by the Interactions between Plant Types and Light Intensity

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ABSTRACT/ABSTRAK

Perubahan Ketebalan Anatomi Daun Tanaman Hias Monokotil akibat Interaksi antara Jenis Tanaman dan Intensitas Cahaya

Perbedaan intensitas cahaya memengaruhi ketebalan anatomi daun tanaman hias monokotil. Tujuan penelitian untuk mengetahui ketebalan anatomi daun beberapa tanaman hias monokotil pada intensitas cahaya yang berbeda. Penelitian menggunakan rancangan acak lengkap pola faktorial dengan dua faktor utama yaitu jenis tanaman dan intensitas cahaya yang berbeda, diulang tiga kali. Faktor pertama adalah jenis tanaman hias monokotil terdiri dari enam spesies tanaman, yaitu *Chlorophytum laxum, Dracaena refleksa, Rhoeo discolor, Aglaonema commutatum, Cordyline fruticosa* dan *Hymenocallis littoralis*. Faktor kedua adalah intensitas cahaya, yaitu intensitas cahaya tinggi (area terbuka) dan intensitas cahaya rendah (area naungan). Pengamatan dilakukan terhadap awetan anatomi daun yang dibuat dengan menggunakan metode paraffin yang dimodifikasi. Variabel pengamatan terdiri dari ketebalan total daun, epidermis atas dan bawah, mesofil (untuk jaringan tumbuhan yang belum berdiferensiasi), serta palisade dan bunga karang (untuk jaringan tumbuhan yang berdiferensiasi). Data dianalisis dengan analisis ragam dilanjutkan dengan uji LSD apabila perlakuan yang diuji signifikan. Uji korelasi dilakukan antara ketebalan total daun dengan masing-masing bagian anatomi daun pada kondisi intensitas cahaya tinggi dan rendah. Hasil penelitian menunjukkan bahwa interaksi antara jenis tanaman dan intensitas cahaya berpengaruh terhadap ketebalan total daun, epidermis atas dan bawah, dan palisade. Adapun pada mesofil dan bunga karang, faktor jenis tanaman berpengaruh secara mandiri, sedangkan faktor intensitas cahaya secara mandiri hanya berpengaruh pada mesofil tetapi tidak pada bunga karang. *Hymenocallis littoralis* merupakan satu-satunya tanaman yang bertambah tebal pada kondisi intensitas cahaya rendah dengan peningkatan pada tebal epidermis atas dan bawah. Perubahan ketebalan lebih dipengaruhi oleh palisade pada mesofil yang berdiferensiasi.

Kata Kunci:
Leaf tissue thickness, Light intensity, Monocotyledon, Ornamental plants

The different levels of light intensity affect the anatomical thickness of monocotyledon ornamental plant leaves. The aim of this research was to determine the anatomical thickness of several monocotyledon ornamental plant leaves under different light intensities. The research used a factorial complete randomized design with two main factors, namely plant type and different light intensity, repeated three times. The first factor was the plant type, which consisted of six plant species of monocotyledon ornamental plants which were *Chlorophytum laxum, Dracaena reflexa, Rhoeo discolor,*

Aglaonema commutatum, Cordyline fruticosa and *Hymenocallis littoralis*. The second factor was light intensity, which consisted of high light intensity (open areas) and low light intensity (shaded areas). The observation was carried out on preserved leaf anatomy made using the paraffin method with modification. The observation variables were the total thickness of the leaf, upper and lower epidermis, mesophyll (for undifferentiated mesophyll), and palisade and sponge (for differentiated mesophyll). Data were analyzed using analysis of variance followed by the LSD test if the treatment was significant. Correlation tests were carried out between total leaf thickness and each leaf anatomical part under conditions of high and low light intensity. The results showed that the interaction between plant types and light intensity influenced the total thickness of the leaves, upper and lower epidermis, and palisade. The plant types independently influenced the mesophyll and sponges, while the light intensity independently influenced only the mesophyll but not the sponge thickness. *Hymenocallis littoralis* was the only plant that showed thicker under low light intensity, with an increase in the thickness of the upper and lower epidermis. The palisade mainly influenced leaf thickness changes in the differentiated mesophyll.

INTRODUCTION

In selecting ornamental plants for cultivation, it is important to consider their aesthetic value, which comprises their beautiful leaves, flowers, and fruits (Evinola, 2019), as well as the environmental factors that affect them (Upadhyay *et al.,* 2022). The environmental factors that affect the plants' growth include, but are not limited to, light intensity, light quality, and the duration of irradiation (Son *et al.,* 2018; Paradiso *et al.,* 2022). According to Gao *et al.* (2019), light plays a vital role in plant growth, particularly due to its involvement in photosynthesis.

Different light intensities can cause changes in leaf anatomy and morphology during its development (Li *et al.,* 2014; Setyaningrum *et al*., 2021; Tang *et al.,* 2022) by changing the efficiency of the leaf to carry out photosynthesis (Ulinnuha *et al*., 2021). Plants that receive high intensity have thicker epidermal and mesophyll layers compared to those under low light intensity (Paluvi *et al.,* 2015). Saputri *et al.* (2019) explained the phenomenon happened due to the increase in the density of the palisades, which contain more chlorophyll to support photosynthesis. Meanwhile, Li *et al.* (2023) suggested that low light intensity can cause leaves to become thinner and the palisade layer to become shorter.

The ability of ornamental plants to adapt to different light conditions depends on morphology and anatomy, aiding in plant selection. Ornamental plants with thin and wide leaves can enable them to adapt to low light conditions (Supriyono *et al*., 2022). On the other hand, plants with thick and narrow leaves can adapt to high light intensity (Zwieniecki and Boyce, 2014; Febriyani *et al*., 2023). The differences in the response of these plants to light intensity are also different at different light intensities (Teixeira, 2020). For example, the *Rhoeo discolor* plant forms a thinner layer at low light intensity because it expands the size of the palisade to capture more sunlight, but when exposed to high light, the leaves reduce the size and thicken the leaf blades. This is related to the function of the palisade and epidermal tissue to prevent high transpiration and increase photosynthesis (Tihurua, 2020; Li & Mu, 2021). Understanding how different plant types respond to varying light intensities is essential for narrowing plant selection under different light conditions.

Ningsih & Daningsih (2022) have conducted research on six species of monocotyledon ornamental plants, which are commonly cultivated in Pontianak, West Kalimantan, Indonesia. Their research indicated the differences in the leaf thickness of the six species while they were placed in the open area. Daningsih *et al.* (2022) showed that the reduced anatomical thickness in the six dicotyledon ornamental plants was not due to transpiration. Differences in leaf tissue thickness due to shading are also important to consider for photosynthetic efficiency (Fan *et al.,* 2019).

It is important to investigate how ornamental plants respond to different light intensities, as this will help determine whether they should be placed in

open or shaded areas. This study aimed to determine the differences in leaf tissue thickness of monocotyledon ornamental plants in response to different light intensities for plant selection.

MATERIALS AND METHODS

Place and time of research

The study was carried out from February to September 2022. The plants were cultivated in the greenhouse of the Biology Education Laboratory, Faculty of Teacher Training and Education Universitas Tanjungpura, Pontianak City. The greenhouse is located on 00 02' 24" to 00 05' 37" (North to South Latitude) and 1090 16' 25" to 1090 23' 01" (West to East Longitude).

Experimental design

This experiment was arranged in a 6 x 2 factorial complete randomized design (CRD) and replicated three times. The first factor was monocotyledon plant types, and the second factor was the level of light intensity. The six species of monocotyledon plants were bichetii grass (*Chlorophytum laxum* R.Br.), song of india (*Dracaena reflexa* Lam.), boat lily (*Rhoeo discolor* (L'Her)), philippine evergreen (*Aglaonema commutatum* Schott.), cabbage palm (*Cordyline fruticosa* (L.). A. Chev.) and spider lily (*Hymenocallis littoralis* (Jacq.) Salisb.). The two levels of light intensity were obtained by placing the plants in the open area (high intensity) and in the shaded area (low intensity). The shaded area was created using a black paranet, which reduced the light intensities by 70%. Figure 1 shows the six monocotyledon ornamental plants used in the experiment.

Figure 1. Six monocot ornamental plants used in the experiment.
a. Boat lily (*Rhoeo discolor* (L'Her)), b. Spider lily (*Hymenocallis littoralis* (Jacq.) Salisb.), c. Cabbage palm (*Cordyline fruticosa* (L.). A. Chev.), d. Bichetii grass (*Chlorophytum laxum* R.Br.), e. Song of india (*Dracaena reflexa* Lam.), f. Philippine evergreen (*Aglaonema commutatum* Schott.).

Plant preparation

All the plants evaluated were obtained from the plant seller and were acclimated for two weeks before the study began. All plants were approximately 50 cm tall. The number of leaves varied by species, reflecting the plants' characteristics rather than their age. On average, there were 10 leaves for *C. fruticosa* and *A. commutatum*, 48 leaves for *D. reflexa*, 34 leaves for *C. laxum*, six leaves for *H. littoralis* and 28 leaves for *R. discolor*. Plants were cultivated in the 35x30 cm polybags filled with planting medium with a ratio of 2:1 for soil and sand and placed in the shading area (low light intensity using paranet 70%) and in the open area (high light intensity) for two weeks for acclimatization, and another two weeks for the experiment. At the start of the experiment, each plant was given 0.5 g of NPK fertilizer (16:16:16 ratio of nitrogen, phosphate, and potassium) dissolved in 100 ml of water. Plant watering was done daily during acclimatization and experiment, as much as 75 ml per polybag.

Preparation of cross-section of leaf anatomy

Samples were a third leaf from the bottom. They were collected by cutting in the base of the lamina part and avoiding the midvein of the leaf. All samples in the open and shading areas were collected at 10 a.m. The preservation of samples followed the paraffin method of Johansen (1940) with some modifications. Modifications to Johansen (1940) included the softening process (Orchard et al., 2008), the thickness of the incision, gluing, and coloring (Berlyn & Miksche, 1976). The softening process was carried out by immersing the sample block in a fabric softener containing diethyl ester dimethyl ammonium chloride for 15 minutes and then putting it in the refrigerator for 15 minutes. Process slices were made with a thickness of 12-14 μm. The gluing process was carried out using Haupt's Adhesive, which was made by dissolving 1 gram of gelatine in 100 ml of water and then adding 0.5 gram of sodium benzoate. The coloring process used double staining, namely safranin-fast green.

Measurement of leaf tissue thickness and external factors

The leaf tissue was observed under a microscope with 10x10 magnification attached to Optilab Advance. Leaf tissue thickness was measured using Image Raster3 software. The measured leaf tissue included the upper and lower epidermal tissues, mesophyll (palisade and sponge), and total leaf tissue thickness.

External factors measured were light intensity using a digital lux meter AS803, humidity using a digital thermo-hygrometer max/min AZ-HT-02, and wind speed using a digital anemometer GM816. All environmental data were measured twice a week as supporting data.

Data analysis

Leaf tissue thickness data was analyzed using a factorial complete randomized design ANOVA model in SAS. Prior to ANOVA, the normality and homogeneity of the data were checked using SPSS version 24. If the treatment factor showed significant results, further analysis was obtained using the least significant difference test (LSD) at $\alpha = 0.05$. Pearson correlation analysis was also carried out between total leaf thickness and tissue thickness in different light areas. The category of correlation coefficient referred to Amruddin *et al*. (2022).

RESULTS AND DISCUSSION

Description of leaf anatomical tissue in monocotyl ornamental plants

Different tissue thicknesses of the upper and lower epidermis, mesophyll (palisade and sponge) and the total thickness of six types of monocotyledon ornamental plants were observed. Figure 1 to Figure 6 show the measurement results of the ornamental monocotyledon plants evaluated. Among the six plant types, *R. discolor*, *C. laxum*, *D. reflexa*, and *A. commutatum* showed a differentiated mesophyll to palisade and sponges, while *H. littoralis* and *C. fructicosa* had undifferentiated mesophyll. Although most monocotyledon plants have a differentiated mesophyll, for some plants, the mesophyll is not differentiated into palisade tissue and sponge (Hasanah *et al*., 2021).

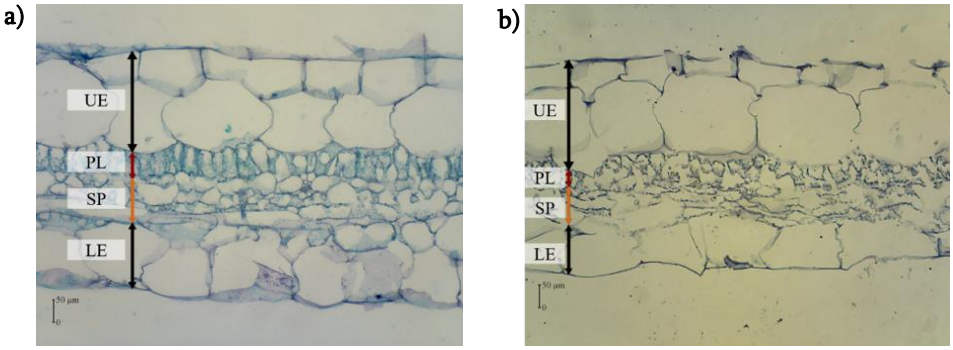

Figure 1. Anatomy of *R. discolor* open area (a) and shading area (b) cross-section. UE (Upper epidermis), PL (Palisade), SP (Sponge), LE (Lower epidermis).

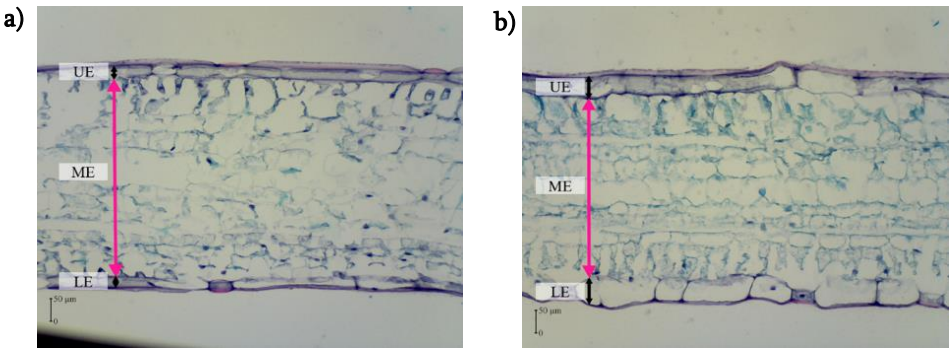

Figure 2. Anatomy of *H. littoralis* open area (a) and shading area (b) cross-section. UE (Upper epidermis), ME (Mesophyll), LE (Lower epidermis).

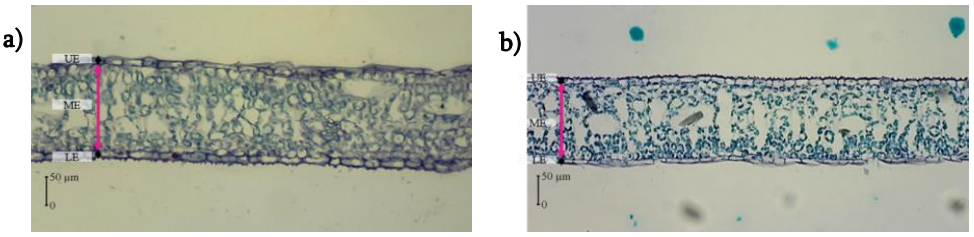

Figure 3. Anatomy of *C. fruticosa* open area (a) and shading area (b) cross-section. UE (Upper epidermis), ME (Mesophyll), LE (Lower epidermis).

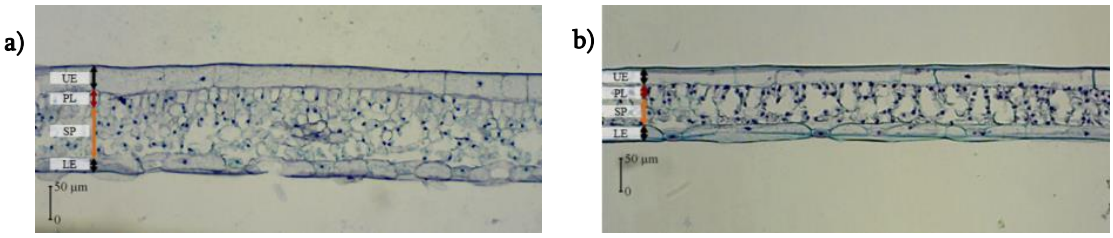

Figure 4. Anatomy of *C. laxum* open area (a) and shading area (b) cross-section. UE (Upper epidermis), PL (Palisade), SP (Sponge), LE (Lower epidermis).

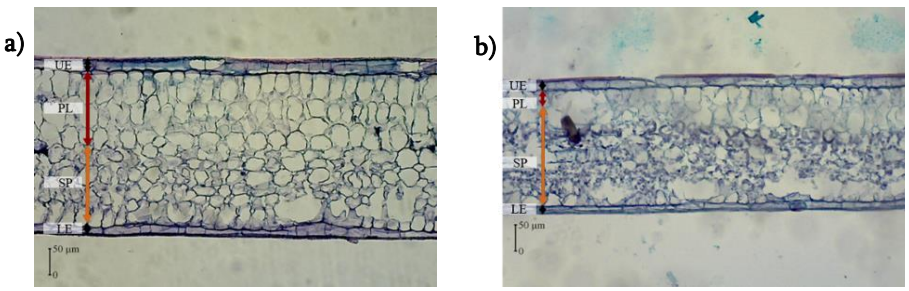

Figure 5. Anatomy of *D. reflexa* open area (a) and shading area (b) cross-section. UE (Upper epidermis), PL (Palisade), SP (Sponge), LE (Lower epidermis).

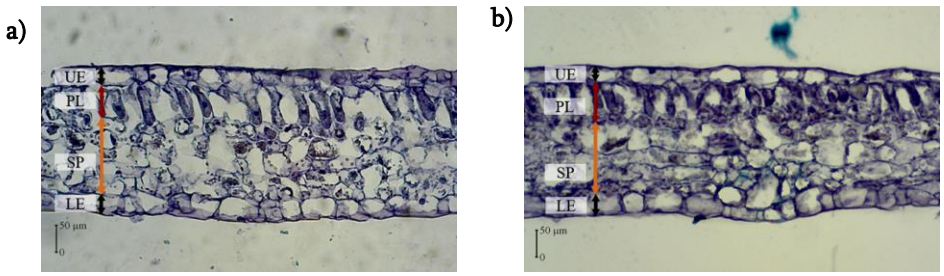

Figure 6. Anatomy of *A. commutatum* open area (a) and shading area (b) cross-section. UE (Upper epidermis), PL (Palisade), SP (Sponge), LE (Lower epidermis).

Figure 1 shows that *R. discolor* had a unique hypodermic layer, which originated from the ground tissue meristem (Mulyani, 2019) to store water (Rocha *et al.,* 2013). Therefore, this plant has the potential to store more water. Usually, the upper epidermis is denser and more rigid to reduce water evaporation. Thus, with the availability of hypodermal storing water, even the thickness decreases of epidermal tissue did not much affect the water level stored in the leaf (Madail *et al.,* 2022).

Analysis of variance of leaf thicknesses

The normality and homogeneity test of the data prior to ANOVA showed that total leaf and mesophyll, including palisade and sponge, were normally distributed ($p \leq 0.05$). However, this was not the case for the upper and lower epidermis. The latter data were transformed using Log_{10} method to get a normal distribution. The result of the ANOVA test is presented in Table 2. There were significant interactions between light intensity (area) and plant types on total leaf, upper epidermis, lower epidermis, and palisade (Table 2). Afzal *et al.* (2017) reported

that the leaf thickness was determined by the anatomy of the leaf, including the number, size, and different arrangement of leaf cells between species. The variations in the cell and tissue structure depend on taxonomy, environment, and genetics. The interaction between plant types and light intensity was significantly different in terms of total thickness, upper and lower epidermis, and palisade (Table 2).

The analysis of variance was conducted twice: the first was for all plant types, which included the thickness of total leaf, upper and lower epidermis, and mesophyll (Table 2), and the second was the ANOVA was run only for differentiated mesophyll, namely palisade and sponge thickness. The undifferentiated mesophyll monocotyledon plants (*H. littoralis* and *C. fruticosa*) were not included in the ANOVA.

Table 2. The interaction between light intensity and plant types on the thickness of total leaf, upper epidermis, lower epidermis, and palisade of differentiated monocotyledon leaf anatomy.

Light Intensity (Area)	Plant Species					
	H. littoralis	*R. discolor*	*D. reflexa*	*A. commutatum*	*C. fruticosa*	*C. laxum*
a. Total leaf thickness (µm)						
Open	485.77^{b}	490.19^{b}	332.98^{d}	270.76^{e}	180.24^{f}	168.90^{f}
Shading	539.95^{a}	439.42^{c}	259. 84^{e}	261.78^{e}	145.18^{g}	101.56^{h}
b. Upper epidermis (µm)						
Open	24.87^{e}	186.29^{a}	29.39^{d}	29.59^{d}	12.20^{g}	42.45^{b}
Shading	37.50^{c}	199.84^{a}	19.93^{f}	29.26^{d}	12.09^{g}	24.89^{e}
c. Lower epidermis (µm)						
Open	25.57^{d}	140.31^{a}	21.41^{f}	28.31^{d}	12.91^{h}	25.31^{de}
Shading	45.37^{c}	88.61^{b}	15.31^{g}	25.81^{d}	7.51^{i}	22.81^{ef}
d. Palisade (µm)						
Open	-	49.94^{d}	126.76^{a}	78.92^{b}	-	32.95^{e}
Shading	-	40.03^{e}	69.19^{c}	62.12^{c}	-	22.26^{f}

Note: O = Open, S = Shading. Different letters behind show a significant difference when tested with LSD α=0.05. - = Undifferentiated mesophyll (part of the plant anatomy did not exist).

All plant types, except *H. littoralis*, had thinner total leaf thickness in shading area (low light intensity). The thinning of leaf thickness under low light intensity was also reported in spinach (Nguyen *et al.*, 2019). Plants were thinning in the dark or shading area in order to get more light by changing the shape from vertical to horizontal, especially palisade cells (Oliveira *et al.*, 2018). The changes in palisade shape showed elasticity of the palisade (Laplaud *et al.*, 2023) to add leaf surface to get more light penetration per area. In another study, Ekawati & Saputri (2020) also reported thinner leaves with wider areas. *H. littoralis,* however, had thicker total leaf thickness in low light intensity (shading area). The thicker total leaf thickness was due to the thicker lower epidermis in *H. littoralis* (Table 2). *H. littoralis* has a wide spread of growing conditions from wet to dry areas (Singh and Saxena, 2016). Prajapati *et al.* (2023) explain *H. littoralis* prefers partial shade to open areas. The capability of *H. littoralis to live in shading areas could be associated with preserved water in the lower epidermis close to stomata, which in turn provides* water for photosynthesis (Tan *et al.,* 2009).

The similarity of thinning leaves in five monocotyledon plants was not found in the upper epidermis thickness. Upper epidermis functions to protect the leaf from sun exposure to prevent high transpiration as the plant is exposed closely to light (Anu *et al.*, 2017; Febriyani *et al.*, 2023). The structure of the upper epidermis cell sometimes gets thicker in the cell wall (Rakhimov *et al.*, 2021). In this study, as shown in Table 2, the response of upper epidermis thickness varied. *H. littoralis* had thinner upper epidermis leaf thickness in the open area. On the other side, *C. laxum* and *D. reflexa* had thicker thickness of upper epidermis. *R. discolor, A. commutatum,* and *C. fruticosa* had the same thickness between open and shading areas. Varied responses of thickening are divided into: 1) not change (*R. discolor, A. commutatum,* and *C. fruticosa*), 2) thicker in the open area (*D. reflexa* and *C. laxum*), and 3) thinner in the open area (*H. littoralis*). The change in upper epidermis thickness

due to light exposure indicates the plants are adapted to open areas (Liu *et al.,* 2020).

In terms of higher thickness in the lower epidermis, some plants (*A. commutatum* and *C. laxum*) have similar thicknesses in open and shading areas, while others (*R. discolor*, *D. reflexa*, *C. fruticose*) have higher thicknesses in the lower epidermis. Nonetheless, *H. littoralis* excided the thickness of all plants in lower epidermis thickness (45.37 µm) in the shading area. On the other hand, *H. littoralis* had thicker lower epidermis in shading areas than in open areas (Table 2). This thickness adds up to the total thickness of the leaf.

The interaction effects between light intensity and plant types were not significant on the thickness of mesophyll and sponge. Therefore, the main effects, which were plant types or light intensity, were analyzed. Plant types significantly affected the thickness of mesophyll and sponge (Table 3). However, the light intensity only affected mesophyll, not the sponge.

Table 3. Effect of the main factors (light intensity and plant types) on mesophyll and sponge thickness.

Factors	Average leaf thickness (µm)	
	ME	SP
Plant types	*	*
Spider lily (*Hymenocallis littoralis*)	446.20[a]	-
Boat lily (*Rhoeo discolor*)	157.28[d]	112.29[b]
Song of india (*Dracaena reflexa*)	263.39[b]	155.41[a]
Philippine evergreen (*Aglaonema commutatum*)	209.79[c]	139.26[a]
Cabbage palm (*Cordyline fruticosa*)	140.37[d]	-
Bichetii grass (*Chlorophytum laxum*)	77.50[e]	49.90[c]
Areas (Light Intensity)	*	ns
Open (High light intensity)	229.04[a]	117. 80
Shading (Low light intensity)	203.14[b]	110.63

Note: * = significant at α = 0.05, ns = nonsignificant, ME = Mesophyll, SP = Sponge. Different letters behind the mean in the same column show a significant difference when tested with LSD α=0.05. - = Undifferentiated mesophyll (part of the plant anatomy did not exist).

Four monocotyledon plants have differentiated mesophyll form palisade and sponge. When four differentiated mesophyll plants were run for ANOVA, the result showed that the thickness of sponge were affected by plant type but not the light intensity (Table 3). The different thickness of sponges amongst plants is more indication of different characteristics in plants (Khasanah *et al*., 2022).

H. littoralis showed the thickest mesophyll followed by *R. discolor*, *D. reflexa, A. commutatum, C. fruticosa, C. laxum* (Table 3). *H. littoralis* was the only plant having thicker total leaf thickness in the shading area (low intensity) (Table 2). Furthermore, *H. littoralis* also showed the thickest mesophyll among other plants. Seemingly, the total thickness of the leaf was due to *H. littoralis* characteristics with mesophyll thickness (data not shown).

Mesophyll for undifferentiated plants contains many chlorophylls (Kuntjoro & Rachmadiarti, 2018) that function for photosynthesis. The thicker mesophyll facilitates more water and light capture for photosynthesis (Zhang *et al.,* 2014; Baillie & Fleming, 2019). This benefits *H. littoralis* to adapt in the shading area as reported by Tan *et al.* (2009). On the other hand, *C. fruticosa,* the other undifferentiated plant, had only one-third of mesophyll thickness of of *H. littoralis.*

Sponge and palisade are formed from differentiated mesophyll plants. For undifferentiated mesophyll, sponges exist to facilitate photosynthesis. Once the mesophyll differentiates into spongy and palisade tissues, the palisade contains more concentrated chlorophyll than the spongy tissue, thereby having a greater impact on the rate of photosynthesis (Gotoh et al., 2018). The sponge was relatively stable in terms of structure (Kubatsch and Gruneberg, 2007). The different thicknesses amongst plant types are characteristics of each plant. Therefore, it can be used as a basis for classification (Khasanah *et al*., 2022).

Thickness correlation amongst parts of leaf anatomical tissue

Pearson correlation between total leaf tissue thickness and the thickness of the lower epidermis, mesophyll, and palisade are presented in Table 4. A

thinner leaf thickness in shading areas indicated plant adaptation. The shading leaves tend to be thinner and wider than their counterpart in the open area. Mostly, this is caused by the decrease of mesophyll cells, palisade layer, and lower epidermis (Samsuri, 2013; Wu *et al.,* 2017; Nguyen et al., 2019; Han *et al.,* 2020; Rebecca *et al*., 2021). This was indicated by a very strong correlation between mesophyll and total leaf thickness (Table 4). In addition, palisade tissue correlated very strongly to total leaf thickness in the differentiated mesophyll of *R. discolor* and *A. commutatum*.

A shorter palisade cell size was due to the modification to the low light intensity, as shown in *R. discolor*, *A. commutatum*, *C. laxum*, and *D. reflexa* (Table 4). More modification to the low light intensity was found in *D. reflexa*, which also had a reduced palisade cell layer from three to a single layer (Figure 5). This finding is consistent with Setiawati *et al.* (2018), who stated that plants in a shading area show a decrease in the palisade cell layer, forming only one or two layers.

Table 4. Correlation of total leaf tissue thickness with the lower epidermis, mesophyll, and palisade in monocotyledon ornamental plants.

Plant species	Areas	Coefficient Correlation*					
		LE		ME		PL	
		r	Category	r	Category	r	Category
Boat lily	O	0.72	Strong	0.99	Very strong	0.8	Very strong
(*Rhoeo discolor*)	S	0.96	Very strong	0.83	Very strong	-0.94	Very strong
Spider lily	O	0.66	Strong	1	Very strong	-	
(*Hymenocallis littoralis*)	S	-0.17	Very low	0.69	Strong	-	
Cabbage palm	O	0.54	Strong enough	1	Very strong	-	
(*Cordyline fruticosa*)	S	0.18	Very low	1	Very strong	-	
Bichetii grass	O	-0.09	Very low	0.77	Strong	0.15	Very low
(*Chlorophytum laxum*)	S	0.99	Very strong	0.89	Very strong	0.50	Strong enough
Song of india	O	0.44	Strong enough	0.99	Very strong	0.36	Low
(*Dracaena reflexa*)	S	-0.99	Very strong	0.98	Very strong	0.77	Strong
Philippine evergreen	O	-0.14	Very low	0.59	Strong enough	0.91	Very strong
(*Aglaonema commutatum*)	S	0.72	Strong	0.57	Strong enough	0.99	Very strong

Note: r = Correlation coefficient, O = Open/High Light Intensity, S = Shading/Low Light Intensity, LE = Lower epidermis, ME = Mesophyll, PL = Palisade, SP = Sponge. *Correlation category was based on Amruddin *et al.* (2022) classification.

The widening of the leaves allows the plant to absorb more sunlight (Buntoro *et al.,* 2014) and it can maximize light absorption to carry out photosynthesis (Yustiningsih, 2019; Ekawati & Saputri 2020). An increase in leaf width allows for leaves to increase the area of the captured light (Munawaroh *et al*., 2018; Poorter *et al.,* 2019). In addition, thinning of the leaves in shading areas caused chloroplasts to be concentrated to spread to the upper surface of the leaf so that it can optimize light capture and photosynthetic use (Ekawati & Aziz, 2016). In this study, the decrease in the thickness of the total leaf occurred due to a reduction in palisade tissue (Table 1), as was also found by Lestari *et al*. (2019).

Environmental factors in open and shading areas

Changes in leaf thickness can be caused by environmental factors, including differences in light intensity, humidity, and altitude (Karyati *et al*., 2017). The presence of shading can affect the microclimate of plants, such as humidity (Hamdani *et al*., 2016) and wind movement (Chambers, 1978 in Sitohang, 2017). Based on the observation of environmental factors, there were differences in the light intensity, humidity, and wind speed between the open area (O) and the shading area (S), as follows: the average light intensities were 484 W.m-2 (O) and 101 $W.m^{-2}$ (S); the average humidities were 65% (O) and 67% (S); and the average wind speeds were 0.6 $m.s^{-1}$ (O) and 0 $m.s^{-1}$ (S). In this study, shading resulted in lower light intensity and wind speed compared to the open area. Usually, low light intensity causes a reduction in humidity. However, in this study, the reduction in humidity in the shading area was only 2% lower than in the open area.

Plants that can adapt to shading environmental areas will undergo changes in its anatomy and morphology. Shading allows plants to capture and use light more efficiently (Mathur et al., 2018). In this study, *C. laxum*, *D. reflexa*, *R. discolor*, *A. commutatum*, and *C. fruticosa* adapted to shaded areas by thinning their leaves. (Table 4). Ismaya & Saraswati (2006) also reported that the *C. laxum*, *R.*

discolor, and *C. fruticosa* plants survived in moderate light areas, while D. reflexa and A. commutatum can be tolerant in low light areas (Matjik, 2010). However, *H. littoralis* adapted unusually to shading areas by increasing the thickness of the leaves. This thickening was associated with an increase in the lower epidermis and mesophyll tissue.

Potential pattern between total leaf thickness and other tissue parts of the leave

The potential relationship pattern between the total tissue thickness of leaves and the three anatomical parts of the leaves of six types of monocotyledon ornamental plants is presented in Table 5. In general, the total thickness of the leaves is thinner in the shading area than in the open area (Wu *et al.,* 2017), but the thickening and thinning of the sixth leaf monocotyledon ornamental plant types showed more variations in leaf anatomy amongst species. Coneva & Chitwood (2018) suggested the variation in leaf thickness was due to genetic variation. Each type has a different pattern to determine the thick or thinness of the leaves (Table 5). It can be shown as a potential relationship between total leaf thickness and the thickness of the lower epidermis, mesophyll, or palisade. In spider lily, the total leaf thickness was more related to the thickness of the lower epidermis and mesophyll. While on the boat lily, the thickness of the lower epidermis was more related to the total leaf thickness. However, this relationship is not always the same as the other four types of ornamental plants. Thus, the pattern of leaf thickness associated with the lower epidermis and mesophyll, including palisade variation, greatly on monocotyledon ornamental plants.

Table 5. The pattern of the relationship between total leaf thickness and thickening of the lower epidermal tissue, mesophyll, and palisade of six types of monocotyledon ornamental plants.

Species	Spider lily (*Hymenocallis littoralis)*		Boat lily (*Rhoeo discolor)*		Song of india (*Dracaena reflexa*)		Philippine evergreen (*Aglaonema commutatum*)		Cabbage palm (*Cordyline fruticose*)		Bichetii grass (*Chlorophytum laxum*)	
Total thickness	Thick → Thin											
Area	O	S	O	S	O	S	O	S	O	S	O	S
Tissue												
LE	II	III	III	III	II	I	II	II	I	I	II	II
PL	-	-	II	I	III	II	III	II	-	-	I	I
ME	III	III	I	I	II	II	II	II	I	I	I	I

Note: O = Open/High Light Intensity, S = Shading/Low Light Intensity, LE = Lower epidermis, ME = Mesophyll, PL = Palisade, I = Thin thickness, II = Moderate thickness, III = Thick thickness, - = Undifferentiated mesophyll (part of the plant anatomy did not exist). Category: for LE: Thin = 7-15µm, Moderate = 21-28µm, Thick = 45-140µm; for PL: Thin = 20-40µm, Moderate = 48-70µm, Thick = 78-127µm; for ME: Thin = 50-165µm, Moderate = 205-285µm, Thick = 400-550µm.

CONCLUSIONS

The interaction between plant types and light intensity significantly influenced the thickness of the total leaf, upper and lower epidermis, and palisade tissue but had no effect on the thickness of mesophyll and spongy tissues. Plants with differentiated mesophyll, such as *R. discolor*, *C. laxum*, *D. reflexa*, *and A. commutatum*, were better adapted to varying light conditions. Plant type significantly impacted all tissue thicknesses, including the total leaf, upper and lower epidermis, mesophyll, spongy tissue, and palisade, for both differentiated and undifferentiated mesophyll. Different light intensities notably affected the thickness of the total leaf, lower epidermis, mesophyll, and palisade in plants with differentiated mesophyll. A reduction in light intensity led to a decrease in total leaf thickness, which corresponded with a reduction in mesophyll thickness in undifferentiated mesophyll plants and palisade thickness in differentiated mesophyll plants. Six monocotyledonous ornamental plants adapted to both low and high light intensities. However, five of them (*C. laxum*, *D. reflexa*, *R. discolor*, *A. commutatum*, and *C. fruticose*) exhibited reduced leaf thickness under low light conditions. In contrast, *H. littoralis* showed an unusual increase in leaf thickness in shaded areas. For plants with differentiated mesophyll, the palisade layer was most responsive to environmental changes, while the spongy tissue thickness remained constant. The patterns of thickening or thinning of the total leaf

thickness were associated with changes in the lower epidermis and mesophyll for undifferentiated plants and with the palisade layer for differentiated mesophyll plants. These patterns varied among the six types of monocotyledonous ornamental plants.

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