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Edubiotik: Jurnal Pendidikan, Biologi dan Terapan
ISSN 2528-679X (print), ISSN 2597-9833 (online)
Vol. 7, No. 01, February 2022, pp. 63 – 78

Available online at:
http://ejurnal.budiutomomalang.ac.id/index.php/edubiotik

Research Article

Inventory of species and analysis of stomata characteristics of shade trees at UIN Walisongo Semarang

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Article Information
Submitted: 2021-12-22
Accepted: 2022-07-21
Published: 2022-07-21

ABSTRACT

The presence of shade trees has ecological function to reduce air pollution level. The part of leaves, stomata is responsible for the function. The study aimed to inventory species and analyze the characteristics of leaf stomata of shade trees at UIN Walisongo Semarang. This exploratory research was conducted in September-October 2021. Observation method throughout the campus area was carried out by using observation sheet. Some representative books and articles were used as references. For stomata observation, leaf samples were taken by purposive sampling. Paradermal preparations were made by wholemount method. All data were analyzed descriptively. The results showed that there were about 17 families, 37 species and 712 individual species of shade trees growing on campus 2-3. Then, there were about 8 families, 8 species and 138 individual species of shade trees growing on campus 1. The highest number of trees in both location was Glodogan Tiang. There were about 7 families, 7 species, and 194 individual species of shade trees recently planted on campus 2-3. Stomata characteristics (type, distribution, length and width, pore length and width, number, and density) differed in each species. The largest stomata size and pore were found in in abaxial leaves of Nyamplung whereas the highest stomata density was found in abaxial leaves of Mahagony. Pore size and density of stomata were related to the ability of leaves to reduce air pollution level. The shade tree data obtained in this study showed plant diversity in the campus.

Keywords: Inventory; shade trees; stomata

Publisher
Biology Education Department
IKIP Budi Utomo, Malang, Indonesia

How to Cite
Khasanah, R., & Na'ima, M. (2022). Inventory of species and analysis of stomata characteristics of shade trees at UIN Walisongo Semarang. *Edubiotik : Jurnal Pendidikan, Biologi Dan Terapan, 7*(01), 63-78. https://doi.org/10.33503/ebio.v7i01.1731

INTRODUCTION

UIN Walisongo Semarang is a state Islamic university located in Ngaliyan District, Semarang, Indonesia. The campus is located in two different locations. Campus 1 is located at Jalan Walisongo Number 3-5 Semarang while campus 2 and 3 are located at Jalan Professor Hamka, Ngaliyan, Semarang. Based on the latest data, in 2019, this campus has an area of ± 304,226 m² consisting of: campus 1

(20,715 m²), campus 2 (100,310 m²), campus 3 (174,146 m²), and student dormitories (9,055 m²) (Laporan Rektor UIN Walisongo, 2019). Many trees and other green plants have been planted there with the aim for reducing air pollution and increasing aesthetic value, in accordance with the program conducted by the campus, namely "Smart and Green Campus". The university has carried out reforestation activities in green open spaces, including in the yard or the environment around buildings and parks. Shade trees are also planted along the campus area roads.

Shade trees have function to provide shade and block the glare of the sun (DPU, 2012). As protective plants, they provide protection to road users underneath from the hot sun and rain (Dwiyani, 2013). In addition to having an aesthetic function, shade trees also have an ecological function for helping to reduce air pollution levels (Ismiyati et al., 2014; Putri et al., 2013; Santoso et al., 2012). Tree vegetation also can act as a microclimate controller (temperature and humidity) as well as sound absorbers (Pratama et al., 2021). Another function of shade trees is to provide oxygen as well as a habitat for insects and birds. There are various geometric requirements that need to be considered in the selection of the shade trees; including: having a good root system which grows without damaging road construction and public facilities; the branches are not easily broken; the leaves are not easy to fall off, and easy to care (DPU, 2012).

Plant organ directly related to the air is the leaves, especially in the stomata. Stomata are pores lined by two guard cells in the epidermal tissue. In plant metabolism, stomata play a role in gas exchange between carbon dioxide (CO_2) and oxygen (O_2) (Raven et al., 2011). Leaves of shade trees can help to reduce levels of CO_2 and lead (Pb) (waste from motor vehicles) in the air through stomata (Hamidah et al., 2020; Yudha et al., 2013). The particulate matter especially lead can penetrate in leaves through stomatal openings (Schreck et al., 2012). Gaseous and dust pollutants enters the leaves through stomata following the same diffusion pathway as CO_2 and can affect the structural and functional stomata properties (Kushwaha et al., 2018; Pourkhabbaz et al., 2010).

Stomata characteristics in each plant are different both between in taxa and in individuals (Susilowati et al., 2022). Thus, the stomata can be used as plant taxonomic tool (Song et al., 2020). The function of the stomata is directly related to their distribution pattern. All different divisions of plants have differences of stomata distribution pattern in which the distribution pattern is not only under control genetics, but also the environmental factors, such as light intensity, humidity, temperature, atmospheric carbon dioxide and nutrient availability (Croxdale, 2000; Khan et al., 2014; Kushwaha et al., 2018; Pourkhabbaz et al., 2010). Therefore, it is important for us to investigate the stomata properties related to the protective function of shade tree leaves.

UIN Walisongo Semarang has completely built several new buildings of the Islamic Development Bank (IsDB) project on 2021. The development activities have created an arid environment. As green campus, UIN Walisongo Semarang has been concerned about the environment by managing the environment in a systematic and sustainable manner in order to provide the comfort for the academic community as well as help to reduce the impact of global warming. This concern was shown by the number of trees planted there, even several new tree cuttings from several species have been planted along the road to the new buildings and around them to provide the coolness. The information about plant or shade tree species in the campus has not been recorded and the inventory of them has not been carried out. In other campus, inventory activity of plant species has been carried out, not only on shade trees but also on shrubs and herbs (Wijaya et al., 2017) or focused on the medicinal plants (Hasan et al., 2020) and the mangroves (Al Syauqi and Purwani, 2017). This study just focused on the shade trees and its stomata characteristics related to the ecological functions. The studies of stomata characteristics were also carried out, but they are limited to a few plant species (Des et al., 2020, 2021; Kamaluddin et al., 2020). Therefore, the study aimed to inventory species and analyze the characteristics of stomata of shade trees at UIN Walisongo Semarang.

RESEARCH METHODS

The exploratory research was conducted at UIN Walisongo Semarang in September-October 2021. The identification of stomata characteristics was carried out at the Laboratory of Plant Structure and Development, Faculty of Science and Technology, UIN Walisongo Semarang. We divided the research location into 2 areas, namely campus 1 and campus 2-3. The inventory of shade tree species was carried out through observation methods using observation sheets. The population was all plant trees at the campus whereas the sample was the mature trees with the minimum height of 2 meters. Some books entitled "*Plant Systematics, An Integrated Appoarch, 3rd Edition*" (Singh, 2010), "*Plant Systematics (2nd Edition)*" (Simpson, 2010), and "*Mengenal Tanaman Pelindung di Sekitar Kita*" (Dwiyani, 2013) were used as references of plant species. The collected data consisted of: local names, scientific names, family names, number of individuals, and growing locations. A book entitled "*Anatomi Tumbuhan*" (Susilowati, 2006) and some articles entitled "*A classification of stomatal types*" (Cotthem, 1970) and "*Structure, delimitation, nomenclature and classification of stomata*" (Prabhakar, 2004) were used as references of stomata properties. Environmental factors such as air temperature, humidity, altitude, air pressure, and light intensity were also measured as supporting data.

Leaf samples were taken by purposive sampling, each with 3 replications. Mature leaves (5th position from each shoot) were taken in the morning (08.00–09.00 am). Leaf paradermal preparations were prepared by the wholemount method (Sass, 1958). Cleaned fresh leaf pieces (1x2) cm^2 were heated in 25% HNO_3 until the leaf colour became pale brown and the epidermal tissue appeared loose. The soft leaves were washed using distilled water in a petri dish. The epidermis was carefully separated. Then, the epidermis layer was dripped with 1% safranin dye for ± 1 minute. After that, the stained epidermis was rewashed with distilled water in a petri dish. The epidermis layer was carefully placed on a slide that had been dripped with water and then covered with a cover glass. The preparations were observed under a binocular microscope (MT-30 Meiji Tecno) with 100x and 400x magnification using optilab. Stomata characteristics were analysed using an image raster. The observed parameters were distribution, type, length and width of stomata, length and width of pores, number of stomata, and density of stomata, which were observed in the wide field of view (400x magnification). Determination of stomatal density was calculated by formula (1) from Willmer (1983) in Des et al. (2020).

$$\text{Stomata density} = \frac{\text{The number of stomata}}{\text{wide field of view (mm2)}} \quad \ldots\ldots\ldots\ldots (1)$$

The quantitative data were analysed using Microsoft Excel and IBM SPSS Statistics 21 software to obtain the mean and standard deviation of each measurement. All data were then analysed descriptively.

FINDING AND DISCUSSION

The observation area in this study was divided into 2 areas, namely: campus 2-3 and campus 1. Campus 2-3 included the main gate of campus 3, the language development center (PPB), mosque of campus 3, ICT, hall 2, library, student regiment building, Faculty of Social and Political Sciences (FISIP), Faculty of Psychology and Health (FPK), Faculty of Sharia and Law (FSH), Faculty of Da'wah and Communication (FDK), Faculty of Islamic Economics and Business (FEBI), connecting roads of campus 2-3, FUHUM, mosque of campus 2, Science laboratory, Faculty of Tarbiyah and Teacher Training (FITK), and along the main road of campus 2. The area also included several new IsDB buildings such as FSH, rectorate, FST (Faculty of Science and Technology), FUHUM (Faculty of Ushuluddin and Humanities), planetarium, and library. Furthermore, the inventory continued on campus 1. Environmental factors in each observation area were measured (Table 1).

Table 1. Environmental Factors of UIN Walisongo Semarang

No.	Parameters	Values
	Campus 3 (6° 59' 31.1362" S, 110° 20' 57.3252" E)	
1	Air temperature	24°C/34.5°C
2	Air humidity	(66-67) %
3	Altitude	(99-102) masl
4	Air pressure	(1000.1-1001.5) hPa
5	Light intensity	18.910 Lux
	Campus 2 (6° 59' 23.946" S, 110° 21' 12.0132" E)	
1	Air temperature	24°C/34.5°C
2	Air humidity	(66-67) %
3	Altitude	(99-102) masl
4	Air pressure	(1000.9-1001.3) hPa
5	Light intensity	17.450 Lux
	Campus 1 (6° 59' 14.2656" S, 110° 21' 33.6888" E)	
1	Air temperature	24°C/34.5°C
2	Air humidity	(66-67) %
3	Altitude	(57-61) masl
4	Air pressure	(1006.4-1006.7) hPa
5	Light intensity	19.570 Lux

The results showed that there were about 17 families with a total of 37 species and 712 individuals. (Table 2). The highest number of species was dominated by Fabaceae (7 species) with a total of 90 individuals. In addition, on campus 1 there are 8 families with a total of 8 species and 138 individuals (Table 3).

Table 2. Data on Shade Tree Species on Campus 2 and Campus 3

No	Local Name	Scientific Name	Family	Total	Location
1	Akasia	*Acacia auriculiformis*	Fabaceae	6	FISIP, FDK, FUHUM
2	Angsana	*Pterocarpus indicus* Willd.	Fabaceae	20	Main road of campus 3, library, hall 2, FDK, FISIP, mosque of campus 2
3	Belimbing	*Averrhoa carambola*	Oxalidaceae	2	PPB, connecting road of campus 2-3
4	Belimbing wuluh	*Averrhoa bilimbi*	Oxalidaceae	1	PPB
5	Beringin (Banyan)	*Ficus benjamina* L.	Moraceae	11	PPB, hall 2, FEBI, FUHUM, FITK
6	Bintaro	*Cerbera manghas*	Apocynaceae	1	FUHUM
7	Bunga Merak	*Caesalpinia pulcherrima*	Fabaceae	1	FDK
8	Durian	*Durio zibethinus*	Malvaceae	1	FDK
9	Glodogan Tiang	*Polyalthia longifolia* Sonn.	Annonaceae	106	Main road of campus 2-3; mosque of campus 3, hall 2, FSH, FISIP, planetarium, FEBI, connecting road of

No	Local Name	Scientific Name	Family	Total	Location
					campus 2-3, FUHUM, FITK
10	Jambu Biji	*Psidium guajava* L.	Myrtaceae	4	FDK, FEBI
11	Jambu Bol	*Syzygium malacense*	Myrtaceae	4	FPK, FUHUM
12	Jati (Teak)	*Tectona grandis* L.	Lamiaceae	40	FISIP, FDK, FEBI, connecting road of campus 2-3, main road of campus 2, FITK
13	Kamboja	*Plumeria sp.*	Apocynaceae	8	Mosque of campus 2-3, FDK, main road of campus 2
14	Kapas Hantu	*Abroma augusta* L.	Malvaceae	2	Science laboratory
15	Karet Kebo	*Ficus elastica* L.	Moraceae	9	FUHUM
16	Kersen	*Muntingia calabura* L.	Elaeocarpaceae	26	FUHUM, FISIP, FDK, FEBI, connecting road of campus 2-3, main road of campus 2
17	Ketapang	*Terminalia catappa* L.	Combretaceae	83	Main road of campus 2-3, hall 2, FSH, FDK, FUHUM, Mosque of campus 2, FITK, Science laboratory
18	Ketapang Biola Cantik	*Ficus lyrata*	Moraceae	6	Hall 2
19	Ketapang Kencana	*Terminalia mentaly*	Combretaceae	13	FDK, FISIP, FPK, main road of campus 2
20	Johar	*Senna siamea*	Fabaceae	7	FUHUM
21	Kiara Payung	*Filicium decipiens*	Sapindaceae	7	Hall 2, FSH, FUHUM
22	Kupu-kupu	*Bahunia purpurea*	Fabaceae	9	FITK
23	Mahagony	*Swietenia macrophylla*	Meliaceae	92	Main road of campus 2-3, Hall 2, FSH, FISIP, FPK, FDK, FEBI, FUHUM
24	Mango	*Mangifera indica* L.	Anacardiaceae	87	PPB, main road campus 2-3, Hall 2, student regiment building, FSH, FPK, FDK, FEBI, coonecting road of campus 2-3, FUHUM, mosque of campus 2, Science laboratory, FITK
25	Matoa	*Pometia pinnata*	Sapindaceae	7	PPB, FSH, FDK, FEBI
26	Nangka	*Artocarpus heterophyllus*	Moraceae	4	FDK, FEBI
27	Nyamplung	*Calophyllum inophyllum* L.	Calophyllaceae	3	FDK, FUHUM
28	Pucuk Merah	*Syzygium myrtifolium*	Myrtaceae	25	Library, FDK, FUHUM, connecting road of campus 2-3, FITK
29	Pulai	*Alstonia scholaris*	Apocynaceae	16	connecting road of campus 2-3, FUHUM,

No	Local Name	Scientific Name	Family	Total	Location
					mosque of campus 2, FITK
30	Rambutan	*Nephelium lappaceum* L.	Sapindaceae	4	FDK
31	Sawo Kecik	*Manilkara kauki* (L.) Dubard.	Sapotaceae	14	Mosque of campus 3, FDK, FEBI, main road of campus 2
32	Sengon	*Albizia chinensis* (Osbeck) Merr.	Fabaceae	24	Mosque of campus 3, and FISIP
33	Sirihan	*Piper aduncum* L.	Piperaceae	1	Science Laboratory
34	Spathodea	*Spathodea campanulata*	Bignoniaceae	1	FUHUM park
35	Sukun	*Artocarpus communis*	Moraceae	2	FUHUM
36	Tanjung	*Mimusops elengi* L.	Sapotaceae	41	Mosque of campus 2-3, Hall 2, student regiment building, FISIP, planetarium, main road of campus 2-3
37	Trembesi	*Samanea saman* (Jacq.) Merr.	Fabaceae	23	FDK, planetarium, main road of campus 2, and FITK
	Total of individuals			**712**	

Table 3. Data on Shade Tree Species on Campus 1

No.	Local Name	Scientific Name	Family	Total	Location
1	Beringin (Banyan)	*Ficus benjamina* L.	Moraceae	4	Campus 1
2	Glodogan Tiang	*Polyalthia longifolia* Sonn.	Annonaceae	86	Campus 1
3	Jambu Bol	*Syzygium malaccense*	Myrtaceae	1	Campus 1
4	Kamboja	*Plumeria* sp.	Apocynaceae	9	Campus 1
5	Kelengkeng	*Dimocarpus longan* Lour.	Sapindaceae	10	Campus 1
6	Ketapang	*Terminalia catappa* L.	Combretaceae	12	Campus 1
7	Mahogany	*Swietenia macrophylla*	Meliaceae	13	Campus 1
8	Sawo Kecik	*Manilkara kauki* (L.) Dubard.	Sapotaceae	3	Campus 1
	Total of individuals			**138**	

The results showed that the highest total number of shade trees in the university was Glodogan Tiang, about 192 individuals, then followed by Mahogany, Ketapang, Mango, Tanjung, and Teak (Jati) (Tables 2 and 3). Some tree cuttings intentionally planted as shade at UIN Walisongo Semarang along with the construction of the new IsDB building with an area of 26,400 m^2 (Table 4). The new trees included Bungur, Spathodea, Flamboyant, Pulai, Sawo Kecik, Trembesi, and Ketapang Kencana. It is possible that additional number of new trees will be planted there in the coming year.

The shade trees growing at UIN Walisongo showed diverse. Based on Table 1, it was seemed no differences of the environmental factors in the campus. The altitude between the two areas (campus 1 and 2-3) differed slightly. The environmental factor values in the areas were almost same and showed tropical environment condition. The air temperature (24°C/34.5°C) was suitable for the growth of tropical plants. Therefore, all of shade trees could grow well there. The optimum watering was needed by plants for their growth.

Table 4. Data on New Shade Tree Species on Campus 2-3

No.	Local name	Scientific name	Family	Total	Location
1	Bungur	*Lagerstroemia speciosa*	Lythraceae	17	Connecting road of campus 2-3
2	Spathodea	*Spathodea campanulata*	Bignoniaceae	17	Connecting road of campus 2-3
3	Flamboyant	*Delonix regia*	Fabaceae	37	Main road of campus 3, FST
4	Pulai	*Alstonia scholaris*	Apocynaceae	65	Rectorate building
5	Sawo Kecik	*Manilkara kauki* (L.) Dubard	Sapotaceae	15	FSH
6	Trembesi	*Samanea saman* (Jacq.) Merr.	Fabaceae	3	Main road of campus 3
7	Ketapang Kencana	*Terminalia mentaly*	Combretaceae	40	Main road of campus 3, FST
	Total of individuals			194	

The shade trees had certain morphological appearances such as the shape of the canopy, branching, root system, shape, area, and color of the leaves as well as the shape and color of flowers. These various elements, a tree provided a certain function in a landscape. Some functions of them were as 1) shade; 2) pollutant absorber; 3) noise absorber; 4) wind breaker; 5) sight barrier; and 6) blocking vehicle headlight glare (Damayanto et al., 2017; DPU, 2012). Some shade trees at UIN Walisongo could be classified into the category. For example, Kiara Payung, Tanjung, and Angsana trees had functions as pollutant absorbers, noise absorbers, and wind breakers. Santoso et al. (2012) also recommended several shade trees having the ability to absorb metals such as Glodogan Tiang, Angsana, Kiara Payung, Ketapang, Banyan, Butterfly trees, and several other species.

The combination of the functions of the shade tree would increase the comfort for road users (The academic community of UIN Walisongo Semarang). This comfort could be related to the function of road shade trees in controlling the microclimate (temperature and humidity) (Rada et al., 2019). As reported by Mariski et al. (2017) that climatological comforts such as temperature and humidity in parks/green open spaces were the preferences of visitors at Menteng Park and Honda Tebet Park, Jakarta. Yasmine and Wicaksono (2018) also reported that the comfort index in Taman Singha Merjosari, Malang, East Java, could be seen from the role of trees in controlling these microclimate. According to Pratama et al. (2021), in addition to temperature and humidity, the comfort index was also seen from the noise factor, especially in traffic-heavy urban areas such as Jakarta.

A shade tree had certain requirements in order to carry out their functions optimally (Dwiyani, 2013). The leaves had thick and lush canopy to provide shade and withstand the glare of the sun. However, the erection and inclination of the canopy needed to be considered. Overleaned canopy toward a building could reduce its aesthetic value and increased the risk of buiding damage meanwhile overinclined canopy to the road could increase the risk of danger to road users, both pedestrians and motorists (Suripto and Aksari, 2021). There were no shade trees at UIN Walisongo leaning towards the building. Regular trimming some tree branches has been done to avoid this. On the other hand, Glodogan Tiang had a conical canopy so that the branches did not reach the building. Then, the leaves of shade trees were not easy to fall off because the over fallen leaves quickly caused dirty road and also the stems or branches were not easily broken when blown by the wind. The shade trees had roots which were relatively strong and grew inward, did not spread to the side or to the road, and did not cause road infrastructure damage

(Zayadi and Hayati, 2017). Based on observations, road damage caused by tree roots was rare in the campus.

The other requirement was shade trees should have a high tolerance level or easily adapted to environmental factor changes. Futhermore, shade trees had the ability to absorb dust particles and gaseous pollutants, playing role as a biomonitor for air pollution levels (Samsoedin et al., 2015). Some of the shade trees found appeared to have potential as pollutant absorbers. Angsana, Mahogany, and Tembresi have been investigated to absorb excess carbon dioxide (Mansur and Pratama, 2014). Tanjung, Glodogan Tiang, and Mahagoni trees have also been studied to have the ability to absorb dust (Rahmadhani et al., 2019).

The shade tree had a beautiful canopy with attractive colorful flowers. Aesthetic value could be obtained from a combination of several aspects such as color (stems, leaves, and flowers) and morphological characters (stem shape, branching, and crown shape). Most of the shade trees at UIN Walisongo belonged to a group of flowering plants that produced flowers in season. The shade trees that had beautiful flowers, for example, were Angsana, Butterfly flowers, Spathodea, Bungur, Trembesi, etc. No less important was the shade trees had resistance to pests and diseases. In addition to endangering the survival of trees, the presence of pests such as caterpillars could increase the risk of danger for road users because of making itchy.

In this study, The leaf stomata characteristics were observed only on the leaf epidermis of 15 shade tree species growing on locations along the main road of campus 3 and along the connecting road 2 and campus 3. Our results showed that most shade tree species had stomata distribution only on the lower epidermis (leaf abaxial surface) or hypostomatic types, except for the leaves of Ketapang and Ketapang Kencana (Combretaceae). Raven et al. (2011) explained that mostly the number of stomata was found on the leaf abaxial surface as a mechanism for adaptation of trees to environments with high temperatures to reduce overtranspiration. Des et al. (2020) confirmed the presence of Mahogany leaf stomata which were only on the leaf abaxial side. Alege & Shaibu (2015) also confirmed that the stomata of Flamboyant (*Delonix regia*) as well as other members of Fabaceae such as *Parkia biglobosa*, *Senna siamea* (Johar), *Daniella oliveriand*, and *Caesalpinia pulcherrima* were only found on the abaxial surface. An interesting finding from this study was the presence of stomata on the leaf adaxial and abaxial surfaces of Ketapang and Ketapang Kencana (amphistomatic type). Our finding was different from the results of Des et al. (2021) who reported that in Ketapang leaves, stomata were only found on the abaxial surface, therefore they were classified as hypostomatic type. However, Ekeke & Agbagwa (2015) reported that the distribution of stomata on Ketapang leaves between cotyledon leaves and mature leaves was different. In cotyledon leaves, stomata were found on both adaxial and abaxial surfaces while in mature leaves, stomata were found only on the abaxial surface. Thus, the distribution of stomata was influenced by leaf growth and development.

The results showed that each species of shade trees had different stomata types (Figures 2 and 3). Members of Fabaceae such as Angsana, Trembesi, and Flamboyant had paracytic stomata types. Paracytic stomata in Fabaceae were also mentioned by Obembe (2015) espesially in *Berlinia grandiflora* (Vahl.) Hutch. and Dalz. leaf and Silva et al. (2012). Stomata of *Pterocarpus indicus* (Angsana) were also observed having a paracytic type (Humami et al., 2020). Paracytic stomata were also found in Pucuk Merah leaves (Myrtaceae). Paracytic stomata were defined as possessing one or more pairs of lateral subsidiary cells oriented parallel with the guard cells (Ekeke & Agbagwa, 2015). Anomocytic stomata were found on several other species leaf such as Mahogany, Glodogan Tiang, Ketapang, Ketapang Kencana, Nyamplung, Bungur, Beringin, Ketapang Biola Cantik, and Sawo Kecik. Anomocytic stomata were stomata in which the guard cells remained surrounded by several subsidiary cells whose size and shape cannot be distinguished from other epidermal cells (Ekeke & Agbagwa, 2015). There were only one type of anisocytic stomata found in Tanjung leaves. Anisocytic stomata (unequal celled) were stomata in which the guard cells were surrounded by three subsidiary cells (two larger subsidiary cells and one distinctly smaller (Ekeke & Agbagwa, 2015). Cyclocytic stomata were found on Kiara Payung leaves. Cyclocytic stomata were stomata in which the guard cells are surrounded by several circular subsidiary cells. Different results were reported by Kamaluddin et al. (2020) who states that the type of stomata on Kiara Payung leaves were paracytic.

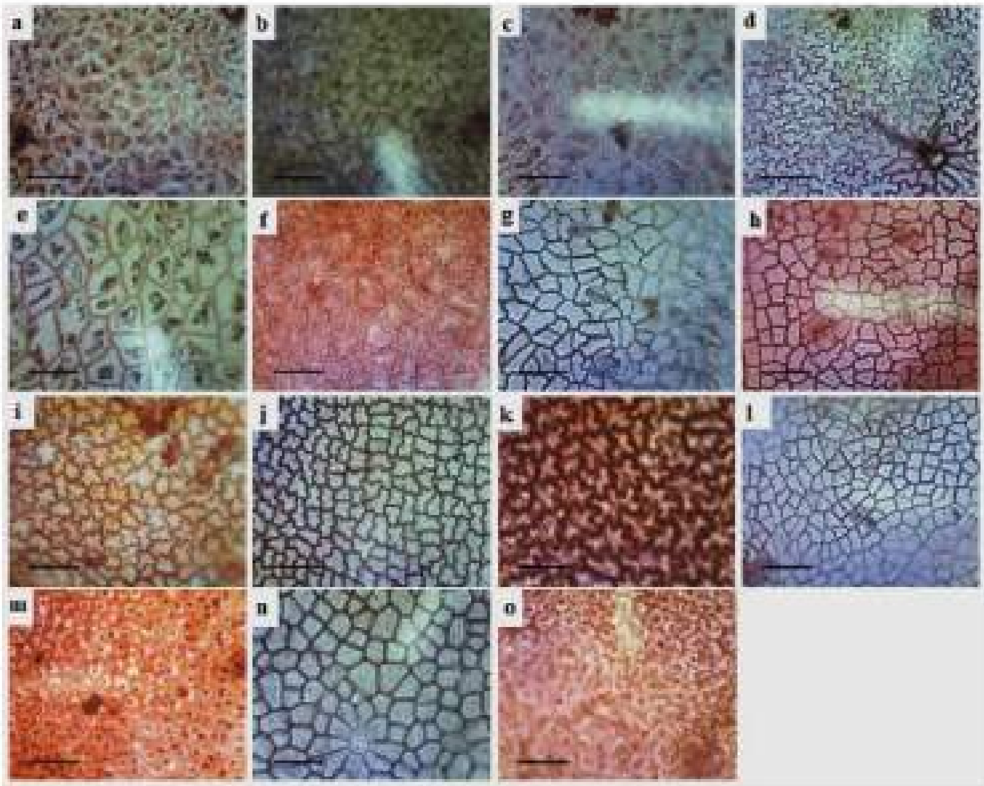

Figure 1. Upper Epidermis (Adaxial): (a) Mahogany; (b) Glodogan Tiang; (c) Angsana; (d) Trembesi; (e) Flamboyant; (f) Tanjung (g) Ketapang; (h) Ketapang Kencana; (i) Kiara Payung; (j) Pucuk Merah; (k) Nyamplung; (l) Banyan (Beringin); (m) Ketapang Biola Cantik; (n) Bungur; and (o) Sawo Kecik. (400x Magnification; Bar Scale: 50µm)

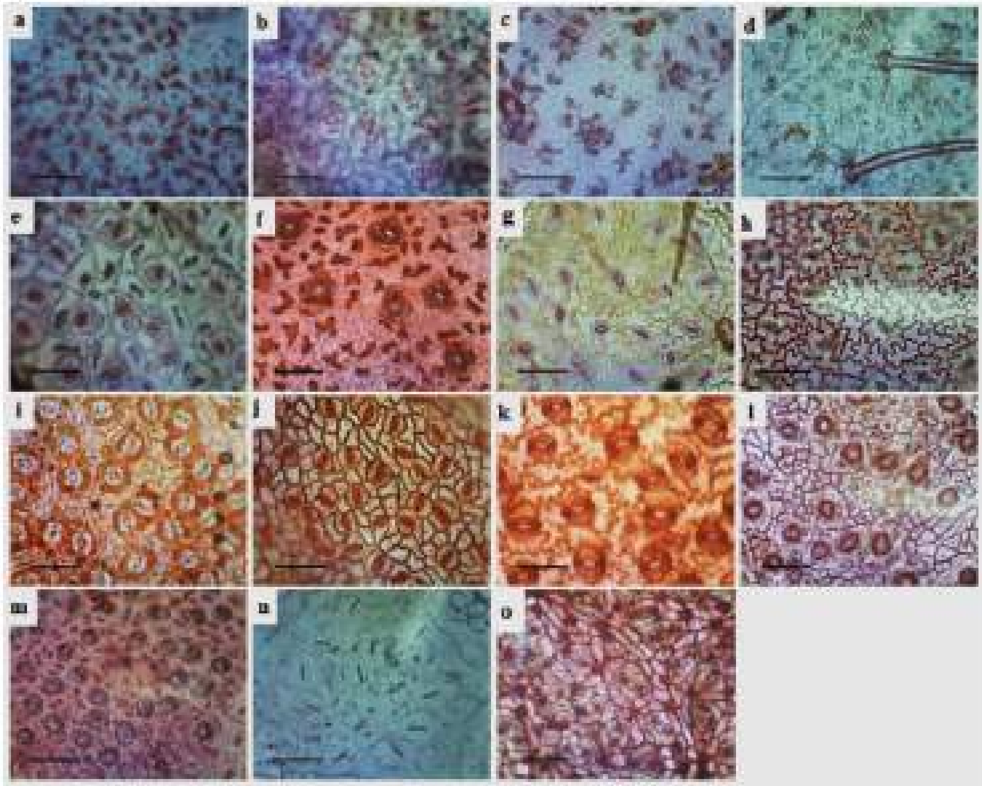

Figure 2. Lower Epidermis (adaxial): (a) Mahogany; (b) Glodogan Tiang; (c) Angsana; (d) Trembesi; (e) Flamboyant; (f) Tanjung (g) Ketapang; (h) Ketapang Kencana; (i) Kiara Payung; (j) Pucuk Merah; (k) Nyamplung; (l) Banyan (Beringin); (m) Ketapang Biola Cantik; (n) Bungur; and (o) Sawo Kecik. (400x Magnification; Bar Scale: 50μm)

Table 5. Qualitative Data of Leaf Stomata Characteristics of Several Shade Tree Species

No.	Local name	Scientific Name	Distribution	Type
1	Mahogany	*Swietenia macrophylla*	Abaxial	Anomocytic
2	Glodogan tiang	*Polyalthia longifolia* Sonn.	Abaxial	Anomocytic
3	Angsana	*Pterocarpus indicus* Willd.	Abaxial	Paracytic
4	Trembesi	*Samanea saman* (Jacq.) Merr.	Abaxial	Paracytic
5	Flamboyant	*Delonix regia*	Abaxial	Paracytic
6	Tanjung	*Mimusops elengi* L.	Abaxial	Anisocytic
7	Ketapang	*Terminalia catappa* L.	Adaxial, abaxial	Anomocytic, Tetracytic, Isotricytic
8	Ketapang Kencana	*Terminalia mantaly*	Adaxial, abaxial	Anomocytic, Tetracytic, Isotricytic
9	Kiara payung	*Filicium decipiens*	Abaxial	Cyclocytic
10	Pucuk merah	*Syzygium myrtifolium*	Abaxial	Paracytic
11	Nyamplung	*Calophyllum inophyllum* L.	Abaxial	Anomocytic
12	Banyan (Beringin)	*Ficus benjamina* L.	Abaxial	Anomocytic
13	Ketapang Biola Cantik	*Ficus lyrata*	Abaxial	Anomocytic
14	Bungur	*Lagerstroemia speciosa*	Abaxial	Anomocytic
15	Sawo Kecik	*Manilkara kauki* (L.) Dubard.	Abaxial	Anomocytic

Table 6. Quantitative data of Leaf Stomata Characteristics of Several Shade Tree Species

No.	Local Name	The Length (µm)	The Width (µm)	The Pore Length (µm)	The Pore Width (µm)	Number of Stomata	Density (Number of Stomata/mm²)
		Abaxial leaves					
1	Mahoni	14.26 ± 0.49	12.51 ± 0.16	7.18 ± 0.59	4.05 ± 0.33	43-44	970.37 ± 12.83
2	Glodogan Tiang	26.03 ± 0.28	21.87 ± 2.38	13.42 ± 1.48	8.53 ± 0.75	13-15	311.11 ± 22.22
3	Angsana	20.78 ± 1.85	18.87 ± 1.19	16.79 ± 1.40	5.77 ± 0.66	5-7	133.33 ± 22.22
4	Trembesi	20.80 ± 0.98	12.15 ± 0.55	12.87 ± 1.09	3.11 ± 0.14	22-30	548.15 ± 102.64
5	Flamboyan	21.45 ± 0.68	13.29 ± 0.45	14.37 ± 1.01	4.69 ± 0.27	15-16	340.74 ± 12.83
6	Tanjung	25.81 ± 0.94	21.88 ± 1.12	16.54 ± 0.32	6.25 ± 0.26	5-8	140.74 ± 33.95
7	Ketapang	21.53 ± 0.16	17.41 ± 0.35	14.96 ± 0.79	5.05 ± 0.45	18-19	407.41 ± 12.83
8	Ketapang Kencana	22.33 ± 0.46	16.75 ± 0.45	12.02 ± 0.23	5.15 ± 0.18	18-20	422.20 ± 22.20
9	Kiara Payung	19.84 ± 0.51	20.36 ± 0.08	12.26 ± 0.23	7.37 ± 0.17	25-29	600.00 ± 44.44
10	Pucuk Merah	16.19 ± 0.25	14.05 ± 0.40	7.33 ± 0.25	4.05 ± 0.08	31-36	755.56 ± 58.79
11	Nyamplung	32.99 ± 0.96	24.25 ± 0.35	14.90 ± 0.55	10.68 ± 0.83	14-15	318.52 ± 12.83
12	Beringin	20.23 ± 0.36	20.30 ± 0.11	10.22 ± 0.51	6.78 ± 0.14	19-22	444.43 + 38.50
13	Ketapang Biola Cantik	17.55 ± 0.11	15.70 ± 1.37	10.38 ± 0.25	6.48 ± 0.37	31-35	725.93 ± 46.26
14	Bungur	22.27 ± 0.19	15.06 ± 0.54	17.64 ± 0.25	4.53 ± 0.18	17-22	429.63 ± 55.92
15	Sawo Kecik	32.19 ± 0.04	26.92 ± 0.54	11.06 ± 0.02	7.52 ± 0.25	15-17	355.57 ± 22.25
		Adaxial leaves					
1	Ketapang	23.43 ± 1.93	17.43 ± 1.76	14.37 ± 0.01	4.42 ± 0.20	3-5	81.48 ± 25.66
2	Ketapang Kencana	25.48 ± 0.54	18.45 ± 0.10	13.40 ± 1.48	4.91 ± 0.16	5-7	133.33 ± 22.22

Notes: n=3

The results indicated that the leaves of Ketapang and Ketapang Kencana (Combretaceae) had various types of stomata, including: anomocytic, tetracytic, and isotricytic stomata (Figures 1g-h and 2g-h). Tetracytic stomata were stomata in which the guard cells were surrounded by only four subsidiary cells whose varying size and shape, of which two subsidiary cells were at the poles and the other two were in a lateral position (Prabhakar, 2004). Meanwhile, isotricytic stomata were stomata in which the guard cells were surrounded by only three subsidiary cells, which vary in position and shape but were approximately the same size (Prabhakar, 2004). As reported by Ekeke & Agbagwa (2015) that there were 5 types of stomata on abaxial leaf of Ketapang, consisting of: anomocytic, tetracytic, staurocytic, anisocytic, and isotricytic. Anomocytic, tetracytic, and isotricytic stomata were predominant while anisocytic and staurocytic stomata were rare. Stomata development was influenced by genetic and environmental factors so that the stomata characteristics between taxa were different (Casson and Gray, 2008; Zhang et al., 2012).

Quantitative data such as the length, width, pore length and width, number, and density of stomata were also measured using image raster (Table 6). The results showed that Nyamplung leaf had stomata with (32.99 ± 0.96) µm in length and (24.25 ± 0.35) µm in width, and they were the highest among others. Likewise, the pore length and width of the Nyamplung leaf were (14.90 ± 0.55) µm and (10.68 ± 0.83) µm, respectively, and they were the highest among others. The stomata size and large leaf area allowed the Nyamplung tree to play an ecological function in absorbing pollutants. Nyamplung's ability to absorb dust has been reported by Sutrisno et al. (2020). In addition to stomata on Nyamplung leaf, stomata on Sawo Kecik leaf also had large stomata sizes with (32.19 ± 0.04) µm in length and (26.92 ± 0.54) µm in width. The smallest stomata size was owned by Mahogany leaf with (14.26 ± 0.49) µm in length and (12.51 ± 0.16) µm in width. Likewise, the pore length and width on Mahogany leaf had the smallest size among others, namely (7.18 ± 0.59) µm and (4.05 ± 0.33) µm, respectively. The size of the pores stomata generally varied on each plant. According to Chichiriccò & Poma (2015), the pore length and width of stomata could range from (3-12) µm and (10-30) µm, respectively. The pore size was related to the ecological function of a plant, namely the ability to accumulate pollutant substances (dust, CO_2, heavy metals, nanoparticles) from the air into the leaf tissue either through adsorption or absorption mechanisms. There were two main mechanisms that might contribute to the absorption of heavy metal particulates, especially Pb by leaves, namely internalization through the cuticle and penetration through the stomata pores (Schreck et al., 2012).

The high and low stomata density depends on the number of stomata on the wide field of view of observation. Our study measured a wide field of view with 400x magnification at optilab of 0.045 mm^2. The more the stomata number in the wide field of view, the higher the stomata density. The results showed that the leaves with the highest number and density of stomata were found in abaxial leaves of Mahogany with the stomata number of 43-44 and stomata density of (970.37 ± 12.8) per mm^2 (Table 6). The leaves with the lowest number and density of stomata were found in the adaxial leaves of Ketapang with the stomata number of 3-5 and the stomata density of (81.48 ± 25.66) per mm^2. Furthermore, other relatively low densities were found in the Ketapang Kencana's adaxial and Angsana's abaxial leaves. Stomatal density on abaxial leaves in both Ketapang and Ketapang Kencana species was higher than that on adaxial leaves. Generally, in land plants, stomatal density on abaxial leaves was higher than that on adaxial leaves. As reported by Megia et al. (2015) that the stomatal density on the abaxial leaves of five cultivars of *Sansevieria trifasciata* (air pollution absorber plant) was higher than that of the adaxial leaves.

The physiological function of the stomata was related to the number, density, distribution pattern, and morphological properties (Harrison et al., 2020; Khan et al., 2014).The high density of stomata supported leaves with a broad surface in order to get sufficient CO_2 intake for the photosynthesis process and to help the leaves to carry out the transpiration process quickly (Raven et al., 2011). The aim was to reduce the temperature in the mesophyll tissue (cooling down process). Futhermore, plants having a high stomata number and stomata density were good plants to use in the absorption of pollutant substances. Stomatal density can be used as a bioindicator and biomonitoring of air quality (Balasooriya et al., 2009). It could be shown by a decrease in stomata size and an increase in stomata density in plants grown in poor quality habitats due to air pollution (Balasooriya et al., 2009). In other words, the high stomatal density was one way of structural adaptation of plants to air pollutants.

CONCLUSION

Various types of shade trees have been planted on the UIN Walisongo Semarang campus in order to realize the smart and green campus program. There were about 17 families, 37 species and 712 individual species of shade trees growing on campus 2-3 and also 8 families, 8 species and 138 individual species of shade trees growing on campus 1. The highest number of trees in both location was Glodogan Tiang. There were about 7 families, 7 species, and 194 individual species of shade trees recently planted on campus 2-3. Stomata characteristics (type, distribution, length and width, pore length and width, number, and density) differed in each species. The largest stomata size and pore were found in in abaxial leaves of Nyamplung whereas the highest stomata density was found in abaxial leaves of Mahogany. Pore size and density of stomata were related to the ability of leaves to reduce air pollution level. The shade tree data obtained in this study showed plant diversity in the campus. They could be a source of data in order to stakeholders could take proper steps in the management of shade trees in accordance with the green campus program.

ACKNOWLEDMENT

The authors thank to The Rector of UIN Walisongo Semarang and The Dean of the Faculty of Science and Technology, UIN Walisongo Semarang who has provided material support in the form of grant funds through DIPA BLU FST (SK. No. B-3042/Un.10.08/D/TA.00.01/08/2021) for this research.

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