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EXPLORATION OF STOMATA TYPES OF SHADE TREES AT UIN RADEN MAS SAID: A CONTEXTUAL LEARNING RESOURCE ON PLANT STRUCTURE AND DEVELOPMENT

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Abstract. Stomata are important structures on the leaf surface that function to regulate gas exchange and water loss in plants. Students often experience misconceptions about the relationship between plant structure and function because the learning resources used tend to be text-based without the support of contextual examples or direct observation. This study aims to identify the types of stomata in three types of shade trees within the UIN Raden Mas Said environment, serving as contextual learning resources for plant structure and development. This type of research is descriptive qualitative. The materials used include ketapang leaves (*Terminalia catappa*), pulai leaves (*Alstonia scholaris*), and breadfruit leaves (*Artocarpus altilis*), as well as distilled water. Observations were made under a light microscope at 100× and 400× magnification. The observation data were analysed descriptively by comparing the characteristics of the stomata found in the three species with those of stomata types in the literature. Observations show that ketapang (*Terminalia catappa*) and breadfruit (*Artocarpus altilis*) leaves have anomocytic stomata, while pulai (*Alstonia scholaris*) leaves have anisocytic stomata. These findings provide stomatal morphology data that can be used as locally based teaching materials to enhance students' connections between botanical concepts and their environment.
Keywords: Contextual learning, Realia learning resources, Stomata types

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INTRODUCTION

Shade trees play a crucial role in maintaining the balance of urban environments, not only as pollutant absorbers, shading agents, and microclimate regulators, but also as part of an ecosystem that provides ecological benefits (Ramanan et al., 2021; Salmond et al., 2016). One physiological aspect that contributes to the significant role of shade trees is the presence of stomata on their leaves (Niinemets, 2010). Stomata function as the entry and exit points for gases, including the absorption of carbon dioxide for photosynthesis and the release of oxygen into the atmosphere (Aasamaa & Aphalo, 2017; Pareek, 2016). Furthermore, stomata regulate water evaporation (transpiration), which helps cool the surrounding temperature (Chaves et al., 2016). With their numerous leaves, shade trees possess an abundant number of stomata, making them highly effective in absorbing carbon dioxide, producing oxygen, and regulating air humidity (Valladares et al., 2016).

Stomata are microscopic structures on the leaf surface that play a crucial role in maintaining physiological balance (Oguchi et al., 2018). Stomata vary in type, characterised by differences in shape, arrangement of guard cells, and subsidiary cells. This variation is not only useful in plant taxonomy but also reflects adaptations to specific environmental conditions, such as light intensity, humidity, temperature, and water availability (Harrison et al., 2020). Each plant group generally has a distinctive pattern of stomatal arrangement and shape (Lehmann & Or, 2015), making them an accurate taxonomic marker. Furthermore, differences in stomatal morphology are often closely linked to environmental factors, influencing the size, number, and shape of stomata as part of the plant's physiological adaptation strategy to its habitat (Harrison et al., 2020). Therefore, observing stomatal types provides benefits as a reference for taxonomic identification and offers insights into a species' ecological adaptation.

UIN Raden Mas Said is a campus with a diverse range of shade trees in its surroundings, thus offering significant potential as a tangible learning resource for students to understand the relationship between plant structure, function, and adaptation to their environment. Commonly encountered shade trees include the ketapang (*Terminalia catappa*) (Panjaitan et al., 2022; Wahyuni & Afidah, 2022), pulai (*Alstonia scholaris*), and breadfruit (*Artocarpus altilis*) (Panjaitan et al., 2022). These trees not only play a vital role in maintaining the balance of the campus ecosystem but also provide learning materials based on local potential. Through observations of stomatal types, students can contextually relate the concept of plant developmental structure to environmental conditions.

Microscopic observation of leaves to identify stomata types can be used as a realia learning resource, presenting real objects for students to observe directly (Murida, 2018). However, in practice, problems often arise when the learning resources used are not contextual, relying solely on images from books or online media that do not represent the conditions of plants in the surrounding environment (Anggrella et al., 2025; Rahmadani et al., 2017). This mismatch reduces the relevance of learning to students' real lives, resulting in a less in-depth understanding of concepts and less optimal development of observation skills. These findings are reinforced by the results of botanical literacy tests in the Plant Anatomical Structure course, which indicated a low level of student understanding due to limited learning resources (Anggrella & Sudrajat, 2025).

One alternative solution is to utilise local potential (Sari et al., 2025) and use realia media to encourage students to observe the stomata on the leaves of plants growing in the surrounding environment, such as shade trees. This condition makes learning more meaningful, contextual, and fosters environmental awareness (Yunilasari, 2018). The use of realia not only enriches the learning experience but also fosters curiosity and observation skills (Prokop et al., 2016). Realia media encourages more meaningful learning (Aziza, 2024) because students can see, analyse, and draw conclusions from real objects (Azizah et al., 2021), rather than simply from images or text in textbooks.

This research is important because the use of shade trees can address the limitations of learning resources that currently rely solely on images or descriptions in textbooks, making the learning process more meaningful and applicable. The research objects can serve as authentic, easily accessible, and relevant realia learning resources. The results of this research can be used as teaching materials and as a practical tool, encouraging students to observe real-world objects on campus directly. Utilising these research findings provides a contextual learning experience, allowing students to connect the theories learned in class with the phenomena they observe themselves.

METHOD

Research design

This qualitative descriptive study aims to identify and describe stomatal types based on microscopic observations. This study focuses on describing the morphological characteristics of stomatal cells without any treatment or variable manipulation. The research was conducted in February 2025 at the Biology Laboratory of the Biology Education Study Program, UIN Raden Mas Said Surakarta. Leaf specimens were obtained from the campus environment and surrounding residential areas.

Research Object

The materials used in this study included ketapang leaves (*Terminalia catappa*), pulai leaves (*Alstonia scholaris*), breadfruit leaves (*Artocarpus altilis*), and distilled water. These three tree species were selected based on their status as dominant shade trees in the UIN Raden Mas Said campus environment, making them representative for local studies. Furthermore, the number of species was limited to three to ensure practical, efficient, and controlled research. The tools used included a light microscope, slides, coverslips, tweezers, razor blades, droppers, and a digital camera to document the observations.

Research Procedures

Research Object Selection

Ketapang, pulai, and breadfruit leaves are harvested from healthy trees with nearly the same level of leaf maturity (young to semi-old leaves) to minimise differences in epidermal structure resulting from leaf age.

Preparation of epidermis preparations

The leaf epidermis was taken by thinly incising the underside (abaxial) surface of the leaf with a razor blade. The epidermis was placed on a glass slide, stained with distilled water, and stained with safranin to clarify the cell structure.

Installation of preparations

The stained epidermis section is gently covered with a coverslip to prevent air bubbles from forming. The slide is then ready to be observed under a microscope.

Microscopic observation

The preparations were observed using a light microscope at 100× and 400× magnification. Stomatal structure was documented using a digital camera attached to the microscope. Stomatal type was identified based on the morphological characteristics of the guard cells and their surrounding subsidiary cells, as described in the plant anatomy literature.

Data analysis

Observation data were analysed descriptively by comparing the stomatal characteristics found in the three species with reference stomatal types available in the literature. The results of the observations were then presented in the form of descriptions and microscopic photographic documentation. The classification of stomatal types was based on the schemes by Dilcher (1974) and Metcalfe (1973), as outlined in Stace (1989), which served as the basis for defining the various stomatal forms encountered in this study. Most of the stomatal types cited by Stace (shown in Figure 1; A - R).

RESULTS AND DISCUSSION

Stomata are one of the main structures in leaves that play a crucial role in helping higher plants adapt to various terrestrial environmental conditions, through adjustments in size, number, and distribution patterns (Hetherington & Woodward, 2003). Changes in the number of stomata in leaves can serve as a marker of environmental change (Casson & Grey, 2008). Previous research has shown that stomatal density can be influenced by genetic and environmental factors (Doheny-Adams et al., 2012), light intensity (Idris et al., 2019), water availability and temperature (Fraser et al., 2009), and atmospheric CO_2 levels (Rogers et al., 2011). Furthermore, identifying stomatal types is also important because it can provide taxonomic information (Khan et al., 2014), facilitate an understanding of plant adaptation strategies, and serve as ecological indicators that help reveal plant physiological responses to environmental changes (Hetherington & Woodward, 2003).

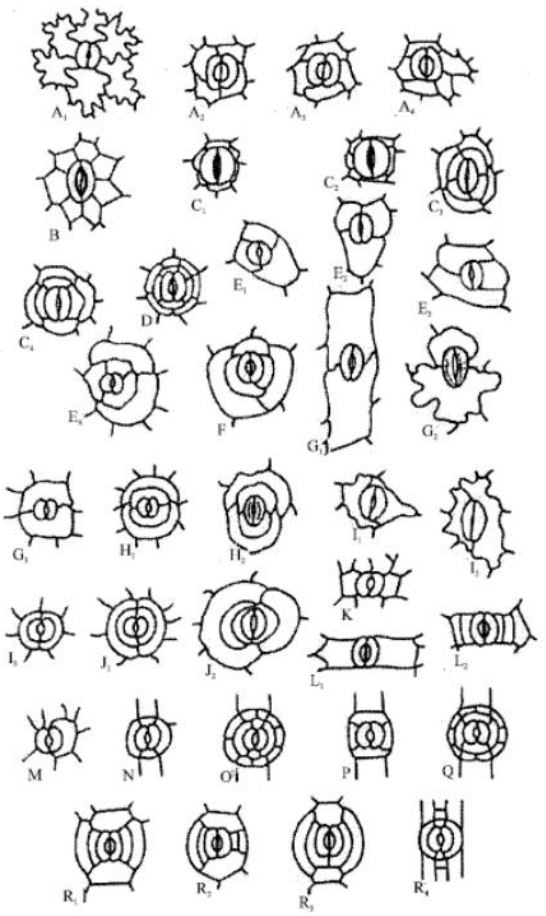

Figure 1. Stomata type: A1, Anomocytic; A (2,3,4), Staurocytic; B, actinocytic; C, (1,2), cyclocytic; C(3,4), tetracytic; D, amphycyclocytic, E, (1,2,3), anisocytic; E4, amphianisocytic; F, helicocytic; G, (1,2,3), diacytic; H, (1,2), amphianisocytic; I, (1,2), laterocyclic; I3, parasitic; J, (1,2), amphiparasitic; K, brachyphacytic; L, (1,2), amphibracyphacytic; M, hemiparasitic; N, paratetracitic; O, amphiparatetracytic; P, bracuparatetracitic; Q, amphibrachyparatetrasitic, R(1,2,3) paratetrasitic-monopolar; R4, parahexasitic-dipolar

Identification of leaf morphology and microscopic structure is a crucial initial step in understanding the physiological characteristics and ecological potential of plants, including the types of stomata. This study aims to explore the types of stomata in various shade trees found in the UIN Raden Mas Said environment, providing contextual learning resources for the Plant Structure and Development course. Data on stomata observations were obtained through the preparation of leaf epidermis slices, microscopic observations, and the identification of stomata types based on the morphological characteristics of guard cells and subsidiary cells. Shade trees found around UIN Raden Mas Said include ketapang (*Terminalia catappa*) and pulai leaves (*Alstonia scholaris*). Based on the results of observations of Ketapang (*Terminalia Catappa*) shade trees around UIN Raden Mas Said, are shown in Figure 2.

Based on the observation results in Figure 2, the epidermis preparation of ketapang leaves (*Terminalia catappa*) under the microscope shows stomata with kidney-shaped guard cells typical of dicotyledonous plants. The stomatal pore is located in the centre of the guard cell. It is surrounded by surrounding epidermal cells that cannot be clearly distinguished as special subsidiary cells, both in terms of size and shape. This arrangement indicates that the type of stomata in Ketapang leaves is anomocytic (*ranunculaceous*), characterised by stomata surrounded by a number of ordinary epidermal cells without a special pattern in the number or size of subsidiary cells (Stace, 1989).

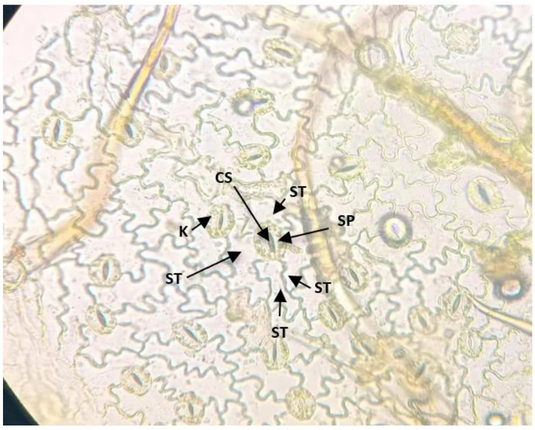

Figure 2. Stomata of ketapang leaves (*Terminalia catappa*), SP = Guard Cells, ST = Subsidiary Cells, CS = Stomatal Pore, K = Chloroplasts

Observations reveal that the leaf epidermal cells are irregularly polygonal in shape, with interlocking, sinuous walls, which provide mechanical strength to the leaf surface. The fairly even distribution of stomata across the leaf surface supports efficient photosynthesis and transpiration. This adaptation enables the ketapang leaf to survive in tropical environments with high light intensity, allowing the plant to optimise CO_2 uptake while regulating water loss (Wahyuni & Afidah, 2022).

In comparison, observations of stomata in other shade tree species revealed distinct morphological characteristics. Observations of pulai (*Alstonia scholaris*) leaves are shown in Figure 3.

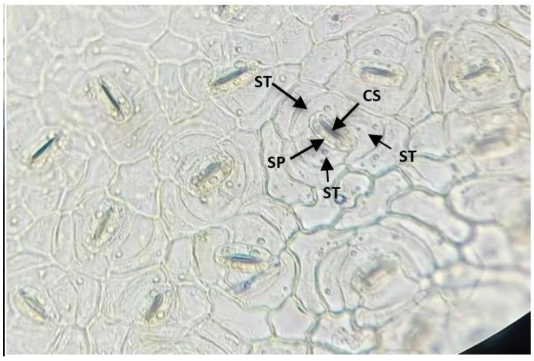

Figure 3. Stomata of pulai leaves (*Alstonia scholaris*), SP = Guard Cells, ST = Subsidiary Cells, CS = Stomatal Pore

Based on observations in Figure 3, an epidermal preparation of a pulai (*Alstonia scholaris*) leaf shows stomata surrounded by three subsidiary cells of unequal size, with one being smaller than the other two. This arrangement is characteristic of the anisocytic stomata type, commonly found in dicotyledonous plants (Stace, 1989). Observations show kidney-shaped guard cells with a central stomatal pore. The surrounding epidermal cells are polygonal in shape, with slightly indented cell walls, which helps to strengthen the leaf surface tissue.

Meanwhile, in breadfruit (*Artocarpus altilis*) leaves, microscopic observations reveal distinct stomatal characteristics compared to the previous species. Identification of these observations is presented in Figure 4.

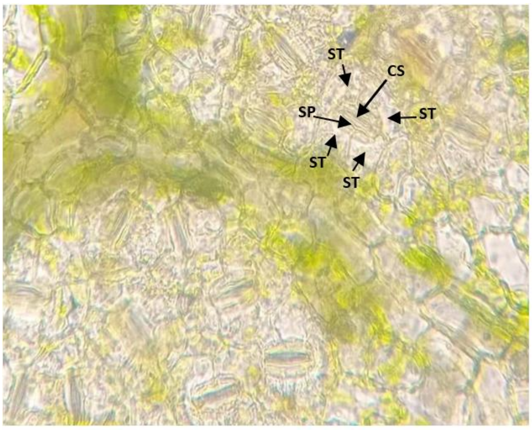

Figure 4. Stomata of breadfruit leaves (*Artocarpus altilis*), SP = Guard Cell, ST = Subsidiary Cell, CS = Stomatal Pore

Based on observations in Figure 4 of a breadfruit (*Artocarpus altilis*) leaf epidermis preparation under a microscope, the stomata are kidney-shaped and surrounded by epidermal cells that do not differ significantly in size or shape from the other epidermal cells. This pattern indicates that the stomata in the observed sample are anomocytic, meaning they lack specialised subsidiary cells and are irregularly arranged (Stace, 1989).

The anomocytic type is commonly found in various dicotyledonous plants (Perveen et al., 2007), including breadfruit (Iswahyudi et al., 2015). According to Palupi et al. (2021), the size and density of breadfruit (*Artocarpus altilis*) stomata vary based on the growing altitude. At altitudes <350 meters above sea level, stomata have the largest average length and width (18.90 µm × 7.4 µm) but the lowest density (37 stomata/unit area). At altitudes >700 meters above sea level, stomata are smaller (14.55 µm × 6.65 µm) but have the highest density (44.04 stomata/unit area). The stomatal structure is similar at all altitudes.

However, in a study by Sá et al. (2019), the types found are actinocytic and anomocytic in the abaxial region. The first pattern is the actinocytic type, where the stomata are surrounded by 5–7 subsidiary cells arranged in a radial circle resembling a crown. This arrangement provides mechanical protection and allows for more efficient control of stomatal opening. The second pattern is the anomocytic type, in which the stomata are surrounded by epidermal cells similar in shape and size to the other epidermal cells, without any specific arrangement pattern. These two stomata types demonstrate that breadfruit leaves have a variety of adaptations to support optimal gas exchange and transpiration.

Based on microscopic observations, ketapang (*Terminalia catappa*) and breadfruit (*Artocarpus altilis*) leaves have anomocytic stomata, while pulai (*Alstonia scholaris*) leaves have anisocytic stomata. The anisocytic type is characterised by the presence of three subsidiary cells surrounding a guard cell, with one being smaller than the other two. Meanwhile, the anomocytic type is characterised by kidney-shaped guard cells surrounded by epidermal cells of similar shape and size, without any specific arrangement or orientation. These observations confirm that the same stomatal type can be found in several different species, despite variations in habitats and leaf morphology.

From a learning perspective, these observations are highly relevant as contextual learning resources because they connect theoretical concepts with real-world phenomena in students' environments. A contextual approach has been shown to improve learning outcomes in plant structure and function (Kinasih, 2011), while fostering environmental stewardship through hands-on experience in understanding biological phenomena (Yani et al., 2021). Direct microscopic observation of stomata types can encourage students to connect theories learned in plant anatomy with real-world phenomena in their surroundings (Algita, 2021). Previous research has shown that direct microscopic observation encourages students to practice science process skills such as observing, identifying, and classifying (Al-Farisi et al., 2022). This activity strengthens conceptual understanding (Evagorou et al., 2015) while providing students with authentic learning experiences that enhance analytical thinking skills regarding the diversity of plant adaptations to their environments.

Observing stomatal behaviour has been shown to facilitate understanding of abstract concepts in plant physiology, such as transpiration and photosynthesis, making them more concrete and understandable (Gibbs & Burgess, 2024; Thompson et al., 2023). These findings suggest that contextual learning resources are effective in encouraging students to connect scientific concepts to their surrounding environment, fostering curiosity, and enhancing scientific literacy (Suryawati & Osman, 2018). Consequently, students not only understand the material conceptually but also develop scientific process skills such as observing, analysing, and inferring, making learning more meaningful and oriented toward developing 21st-century competencies (Özay Köse & Çam Tosun, 2013). These findings are relevant to research by Irwandi & Fajeriadi (2020), which shows that utilising the environment as a direct learning resource can increase interest and cognitive learning outcomes. Through environment-based contextual learning, students are more productive because they are directly exposed to the objects being studied, thereby simultaneously developing their motivation, curiosity, and conceptual understanding.

Plants in the surrounding environment can be used as realia media in the form of preparations, allowing students to directly observe the types and shapes of stomata of various species. This observation also emphasises the role of realia media in contextual learning, as it encourages students to learn from real objects around them (Sari et al., 2025; Yunilasari, 2018). The use of realia media not only enriches the learning experience but also fosters observation skills and scientific curiosity (Prokop et al., 2016). Furthermore, realia media encourages more meaningful learning (Aziza, 2024) because students can observe, analyse, and draw conclusions from real objects, rather than simply through pictorial representations or text in textbooks (Azizah et al., 2021). Observing stomata through realia media not only strengthens understanding of plant anatomy concepts but also fosters environmental awareness and supports the creation of relevant, contextual science learning that is oriented toward developing students' scientific literacy. This research has important implications in the field of plant anatomy learning, particularly in the Plant Development Structure practicum. Students can connect theories from the literature with the results of direct observations on local plant specimens that are readily available in the surrounding environment, making the learning process more relevant and meaningful. In addition, the use of these local specimens simplifies the implementation of practicums because the materials can be obtained easily and at low cost, while also providing insight into the biodiversity of the surrounding environment. Through this research, scientific skills can be developed, including making microscopic preparations, identifying stomata types, and compiling scientific reports. These findings also open up opportunities for further research to examine the relationship between stomata types and environmental factors, inter-individual variation, and physiological adaptation, thereby making a broader contribution to biological science and education.

CONCLUSION

Based on microscopic observations, the leaves of ketapang (*Terminalia catappa*) and breadfruit (*Artocarpus altilis*) exhibit anomocytic stomata, characterised by guard cells surrounded by regular epidermal cells of similar size and shape, without any specific arrangement pattern. Meanwhile, pulai (*Alstonia scholaris*) leaves exhibit anisocytic stomata, characterised by the presence of three subsidiary cells, one of which is smaller than the other two. These results emphasise the importance of direct observation in verifying theories and providing relevant contextual learning resources for students studying plant structure and development.

This study was limited by its relatively small sample size, so the results may not accurately represent the overall population variation. Furthermore, technical factors such as the quality of the slides, the sharpness of the microscope lens, and lighting can affect the clarity of the observations. This study also did not compare specimens from various environmental conditions, which could potentially influence stomatal type or morphology.

For future research, it is recommended to use a larger sample size and include individuals from different locations and environmental conditions to map variations in stomatal type more accurately. The use of specialised staining methods or higher-resolution microscopes can also help improve the quality of observations. Furthermore, research can be expanded to examine the relationship between stomatal type and physiological factors, such as transpiration rate, photosynthetic efficiency, or adaptation to specific environments, thereby yielding results that are not only descriptive but also analytical and applicable.

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