Carbon absorption capability of single-leaf and compound-leaf plants in the BNI Urban Forest, Banda Aceh

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Abstract. The creation of Open Green Spaces is one of the options for mitigating the impact of global warming. In order to maximize the function of urban forests as carbon dioxide absorbers, plant species selection for urban forests must be considered. The goal of this study was to compare the ability of single-leaf and compound-leaved plants growing in urban forests to absorb carbon dioxide. Exploratory survey methods with purposive sampling were used. The single-leaf plant, B. asiatica (520 cm²), had the maximum leaf area, whereas the single-leaf species, M. elengi had the lowest leaf area (47.50 cm²). The plant with the highest water content in leaves was found in single-leaf plants, B. asiatica (ranging from 74.67 percent to 77.32 percent), while plant F.decipiens from the compound-leaf plant had the lowest water content (ranging from 44.34 percent to 46.14 percent). The plant with the highest percentage of carbohydrate mass at 06.00 am was M. elengi (531.63 percent), and the plant with the lowest percentage of carbohydrate mass was P.indicus (211.15 percent). At 11 am, the compound-leaf plant S.mahogani (496.76 percent) had the largest percentage of carbohydrate mass, B.asiatica had the lowest (289.29 percent). B.asiatica had the most carbon dioxide absorption per leaf area per hour (g/leaf/hour), whereas S. mahogany had the lowest. S.mahogani (32.514 Å) had the highest chlorophyll concentration in the 06.00 am sample, while P.indicus had the highest chlorophyll concentration in the 11.00 am sample (42.440 Å).

1. Introduction

1.1. Carbon sequestration

Carbon sequestration is the capture and storage of carbon dioxide (CO₂) from the atmosphere over a long period. Carbon sequestration can also refer to the process of removing carbon from the atmosphere and depositing it into reservoirs such as the ocean, land, and plants [1, 2]. The direct carbon reduction effect by urban forest trees is the most effective way to reduce carbon emission in terms of economy and technology [3]. Optimizing the number of trees and the tree species would increase the total carbon sequestration of the trees in the case area by 95% during 50 years [4]. Based on the research results, it is known that there is a relationship between the basal area and the absorption of green open spaces to
carbon dioxide. Tree vegetation has the ability to absorb carbon dioxide higher than saplings and shrubs. A tree with a large diameter will increase the capacity of carbon sequestration [5].

Research on carbon analysis balance between carbon dioxide emissions produced by human activities including respiration and use of motor vehicles and carbon sequestration by urban street trees was also carried out. The result showed that the trees in the Soekarno-Hatta area are able to absorb carbon dioxide six times higher than it emits. The palm tree (*Roystonea regia*) was able to store significantly more carbon dioxide than the other two sample species, the Ashoka tree (*Polyalthia longifolia*) and the Rain tree (*Samanea saman*) [6]. Meanwhile, *Ficus benjamina* has the highest annual CO₂ sequestrated from forty-five different species of tree were enumerated in Amity University campus Noida, Uttar Pradesh, India [7].

1.2. Urban forest

The value of urban trees is not only as ornamental and aesthetic plantations but also in mitigating the impacts of climate change at a local level [7]. Urban forests can play an important function as the most effective carbon sink, reducing carbon emissions in the atmosphere [8, 9]. Photosynthetic ability is a property of plants that requires carbon dioxide (CO₂) from the air and water (H₂O) from the soil as raw materials. Sunlight supplies the energy needed in plant cells to convert these raw ingredients into glucose (C₆H₁₂O₆) and oxygen molecules (O₂), which plants can then release into the environment [10, 11, 12]. In general, plants absorb carbon from the atmosphere (in CO₂) and transform it into biomass through photosynthesis. Biomass becomes part of the soil (in the form of humus) and part of CO₂ (via the respiration of microorganisms that process biomass) during the decomposition process [13]. To be able to absorb carbon dioxide, plants must have stomata that enable CO₂ to enter [12]. CO₂ diffuses from the intercellular air gap to the carboxylation in the leaf [14].

The urban forest is built as a forest to contribute to green open space in the city of Banda Aceh [15]. The urban forest was built in 2010 and inaugurated by President Susilo Bambang Yudhoyono. The area was previously a swamp area whose condition was exacerbated by the tsunami, the intrusion of seawater into the land, the salinity of groundwater was high enough that it was difficult to find freshwater. From 2010 until now, the urban forest has played an important role in ecology, research, and recreational facilities [16, 17].

2. Materials and methods

2.1. Study area

The sampling site was in BNI Urban Forest, Tibang, Banda Aceh. Six species of trees (3 species single-leaf plants and three species of compound-leaf plants) grown in the urban forest were selected. Samples were taken twice, at 06.00 am and 11.00 am from March to April 2017. The research was carried out at The Weed Laboratory of Agrotechnology Department and Soil Physics Laboratory of Soil Science Department, Agriculture Faculty of Syiah Kuala University, Herbarium and Basic Biology Laboratory of the Department of Biology and Instrumental Laboratory Chemistry Department of Mathematics Faculty, Syiah Kuala University.

2.2. Materials

The tools used in this research are Leaf Area Meter, Genesys 10 Series UV spectrophotometer, ring sample, hoe, 100 ml and 500 ml measuring flask, water bath, oven, 100 ml, and 250 ml glasses, volume pipes, 50 ml and 100 ml measuring cylinders, funnel, test tube, reaction tube shelf, digital scales with precision 0.01, scissors, 3 kg, and 5 kg plastic bags, rubber band, dark glass bottle, blender, spatula, ruler, aluminum foil, label paper, drop, filter paper, digital camera, laptop, software (Ms. Word and Ms. Excel), and stationery.

Materials used include leaf samples from six plant species in BNI Urban Forest Village (table 1), 70% alcohol, 80% acetone, HCl 0.7 N, alkaline copper tartrate reagent, arsenomolybdic acid reagent, aquades, carbohydrate solution (glucose).
2.3. Procedure

Purposive sampling was used in this study. The samples were taken from the dominant plants in the BNI Urban Forest (e.g., *Pterocarpus indicus*, *Swietenia mahagoni*, *Filicium decipiens*, and *Mimusops elengi*), as well as plants that are frequently and infrequently planted for reforestation in other green spaces (e.g., *Barringtonia asiatica* and *Terminalia catappa*). The leaf samples were selected from the leaves, and twigs are still reachable either by hand or a pole. Samples were taken from different individual trees of each plant species in two-time stages, i.e., before and after sunrise (between 06.00 - 07.00 am and 11.00 - 12.00 am). Photosynthesis did not occur at 06.00 a.m. because the plants did not receive sufficient sunlight intensity, whereas, at 11.00 a.m., it is estimated that plants received sufficient sunlight to carry out the photosynthesis process, which will produce carbohydrates as the final product.

Soil samples were taken using ring samples and tested in Soil Physics Laboratory. Leaf area measurement using Leaf Area Meter. CO$_2$ gas exchange rate measurements were carried out in two stages: sampling in the urban forest and measuring the mass of carbon dioxide by measuring carbohydrate mass in leaves. Measurement of reducing sugar using the Nelson-Somogyi method [18]. The data is shown in the figure and table.

3. Result and discussion

Banda Aceh's BNI urban forest is one of the city's green spaces. To test their ability to absorb carbon dioxide, three varieties of single-leaf plants and three compound-leaf plants were chosen. The species chosen for this research dominate the urban forest and are commonly planted in other greening regions (table 1). Lowland trees and coastal formation/Baringtonia vegetation, which comprises low, medium, and high trees, dominate the vegetation characteristics observed in BNI urban forests [15].

| Table 1. List of plants studied in BNI urban forest. |
|----------------------------------------------------|
| Single-leaf plant | Compound-leaf plant |
|-------------------|---------------------|
| *Barringtonia asiatica* | *Filicium decipiens* |
| *Mimusops elengi* | *Pterocarpus indicus* |
| *Terminalia catappa* | *Swietenia mahagoni* |

A plant's growth medium is soil. The top soil layer is the one that is taken and tested. The soil texture of the BNI Urban Forest varies, including sandy, loamy, and clayey loam with an average soil pH of 6.57, according to the results of a physical investigation of soil samples at the Soil Science Laboratory (acidic soil). The growth and development of plants planted in the BNI Urban Forest are also influenced by soil conditions. Table 2 shows the physical soil data for the BNI urban forest. Plants obtain their nutrition from the soil and the atmosphere. Plants use sunlight as a source of energy to build organic material by converting carbon dioxide to sugar via photosynthesis [19]. The quantity of topsoil correlates with the potential for carbon sinkage, both in trees and biochar, and thus yards with a thick soil layer should be preferred [4].

| Table 2. Data of physical soil in BNI Urban Forest. |
|----------------------------------------------------|
| Physical Soil data                                  |
| The average groundwater content is 13.25%          |
| The average soil permeability is 62.91%            |
| The average soil porosity is 33.12%                |
| The average aggregate stability index is 37.34     |

Not all plants in the BNI Urban Forest can thrive [15]. This is due to the soil's lack of topsoil due to the area's previous status as a marsh that was filled with landfills. This supports assertions that urban forest land is landfill land [16, 17]. The area was previously a marsh, whose state was compounded by the tsunami, seawater incursion into the land, groundwater salinity high enough that finding fresh water was difficult, and soil pH was 4.72 (acidic).
3.1. Leaf surface area and water content

Plants carry out the process of photosynthesis in leaf organs. Water molecules (H₂O) are absorbed by plants from the soil together with CO₂ gases taken from the air and converted into sugar through photosynthesis.

Table 3. The average leaf surface area per leaf.

| Plant Type          | Average leaf surface area per leaf (cm²) |
|---------------------|----------------------------------------|
| Single-leaf plant   |                                        |
| Barringtonia asiatica | 520                                    |
| Mimusops elengi     | 47.50                                  |
| Terminalia catappa  | 354.89                                 |
| Compound-leaf plant |                                        |
| Filicium decipiens  | 67.55                                  |
| Pterocarpus indicus | 317.6                                  |
| Swietenia mahagoni  | 339.08                                 |

Table 3 shows the results of the leaf measurement. The highest leaf area was found in a single-leaf plant, *B. asiatica* (520 cm²), while the lowest leaf area was also found in a single-leaf plant, *M. elengi* (47.50 cm²).

Not all plants in the BNI Urban Forest can grow [15]. This is due to a lack of topsoil in the soil as a result of the area's previous status as a landfill-filled marsh. This validates that landfill land is urban forest land [16, 17]. The area was once a marsh, and the tsunami, seawater intrusion into the land, groundwater salinity high enough to make locating fresh water difficult, and soil pH of 4.72 worsened the situation (acidic). This study found that the highest water content in leaves was found in single-leaf plants, *B. asiatica* (ranging from 74.67% – 77.32%), while *F. decipiens* from the compound-leaf group plant had the lowest water content in the range of 44.34% - 46.14% (figure 1).

Figure 1. The range of water content in observed plant species

The plant absorbs the water molecules from the soil using the root tip. Water is also needed by plants as one of the raw materials for the process of photosynthesis. The raw material for photosynthesis is carbon dioxide (CO₂) taken from the air and water (H₂O) absorbed from the soil. In-plant cells, sunlight
provides energy to convert these raw materials into sugars called glucose (C₆H₁₂O₆) and oxygen molecule (O₂), a product that plants can release into the environment [10, 11, 12].

3.2. Mass of carbohydrate and mass of carbon dioxide
Carbohydrates are the main product of the photosynthesis process. The carbohydrate analysis method uses a spectrophotometer to determine the percentage of carbohydrates can determine the mass of carbon dioxide absorbed by plants. Table 4 shows the different carbohydrate masses formed in each type of plant. Not all plants have an increase in the number of carbohydrates. This is presumably because each plant has a different rate of the photosynthesis process.

Table 4. Mass of Carbohydrate.

| Plant Name                        | Mass of carbohydrate (%) (06.00 am) | Mass of carbohydrate (%) (11.00 am) |
|----------------------------------|------------------------------------|------------------------------------|
| Barringtonia asiatica            | 223.68                             | 289.29                             |
| Mimusops elengi                  | 531.63                             | 441.51                             |
| Terminalia catappa               | 214.10                             | 351.86                             |
| Filicium decipiens               |                                    |                                    |
| Pterocarpus indicus              | 211.15                             | 298.39                             |
| Swietenia mahagoni               | 512.42                             | 496.76                             |

The plant that had the highest percentage of the mass of carbohydrate at 06.00 am was found in the single-leaf plant, M. elengi (531.63%), and the lowest percentage of the mass of carbohydrate was found in the compound-leaf plant, P. indicus (211.15%). In sampling at 11.00 is, the highest percentage of the mass of carbohydrate was found in the compound-leaf plant, S. mahogani (496.76%), and the lowest was in the single-leaf plant, B. asiatica (289.29%) (table 4). M. elengi and F. decipiens had a decrease in the amount of mass of carbohydrates at 11.00 am. This is presumably because not all photosynthetic products are stored in the form of carbohydrates, some of which are reused by plants for other metabolic processes such as respiration.

Table 5. Mass of Carbon Dioxide.

| Plant Name                        | Mass of Carbon Dioxide (06.00 am) | Mass of Carbon Dioxide (11.00 am) | Carbon Dioxide absorption per leaf area per hour (g/leaf/hour) |
|----------------------------------|-----------------------------------|-----------------------------------|---------------------------------------------------------------|
| Barringtonia asiatica            | 329.10                            | 425.25                            | 1.35                                                          |
| Mimusops elengi                  | 781.19                            | 649.02                            | -0.09                                                         |
| Terminalia catappa               | 314.72                            | 517.23                            | 0.14                                                          |
| Filicium decipiens               | 649.38                            | 590.48                            | -0.29                                                         |
| Pterocarpus indicus              | 310.39                            | 438.63                            | 0.62                                                          |
| Swietenia mahagoni               | 753.26                            | 730.23                            | -3.68                                                         |

Table 5 shows that the highest carbon dioxide absorption per leaf area per hour was found in B. asiatica, while S.mahogani had the lowest carbon dioxide absorption. The decrease in the mass of carbon dioxide is suspected that at that time, the plants take and break down carbohydrates and using them in
other metabolisms processes. Plants, through photosynthesis, extract carbon from the atmosphere (in the form of CO$_2$) and convert it into biomass. In the decomposition process, biomass becomes part of the soil (in the form of humus) and part of CO$_2$ (through the respiration of microorganisms that process biomass [13].

3.3. Chlorophyll concentration
In this study, chlorophyll levels were tested at two different times; at 06.00 am before sunrise and at 11 am after sunrise.

![Figure 2. Chlorophyll concentration in samples at 06.00 am.](image1.png)

The result showed that the highest and lowest chlorophylls concentration at 6.00 is found in compound leaves. *S. mahagoni* had the highest chlorophyll concentration, 32,514 Å (chlorophyll a 22,012 Å and chlorophyll b 12,565 Å), while *F. decipiens* had the lowest chlorophyll concentration, which was 11.660 Å (chlorophyll a 7.809 Å and chlorophyll b 3.851 Å) (figure 2).

![Figure 3. Chlorophyll concentration in samples at 11 am.](image2.png)

Furthermore, on sampling at 11.00 am, almost all plant species observed showed an increase in chlorophyll concentration. Chlorophyll (both chlorophyll a and chlorophyll b), except in the *M. elengi* plant. The highest chlorophyll concentration, which increased more than doubled chlorophyll level, was
found in *P. indicus* with a compound leaf, 42,440 Å (chlorophyll a 25,124 Å and chlorophyll b 17,316 Å). Otherwise, the lowest chlorophyll concentration was found in a single leaf plant, *M. elengi* which decreased to 12,837 Å (chlorophyll a 7,824 Å and chlorophyll b 5,013 Å) (figure 3). The increase in the amount of chlorophyll in leaves increases with increasing sunlight intensity [20]. At the same time, the decrease in leaf chlorophyll concentration is a plant response to water shortages [21].

4. Conclusion

Each plant has a distinct capacity for absorbing carbon. To assess carbon absorption by plants in a day for each plant species analyzed, leaf samples must be taken at different intervals to determine the mass of carbohydrates regularly during the photosynthetic process. It is also necessary to conduct research on different types of plants in order to provide more comprehensive data to be used as a guide in selecting species for use as reforestation plants in urban forests.

5. References

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