The potential of *Azadirachta excelsa* characteristics as urban trees in residential areas

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Abstract. Residential areas have the potential to conserve economically and ecologically important local tree species. However, local species to be planted in residential areas, including business and office districts, have to meet certain criteria in accordance mainly with the significant tree functions and services. This study was aimed at investigating the potential of *Kayu bawang* (*Azadirachta excelsa*) based on the desired characteristics for urban trees. The analysis of tree characteristics was based on their morphometrics which has been conducted in two planting systems, namely monoculture and polyculture, found on the private forests in Bengkulu Province. The two planting systems of *Kayu bawang* were reflected in the target location (e.g., roadside, park, and yard). Variables used for assessment included total height, the diameter of breast height, clear stem height, live crown height, the diameter of the crown, live crown ratio, crown projection area, and slenderness ratio. The results showed that the tree crown architecture is classified as decurrent, while the average live crown ratio (LCR) was moderate, which had an average live crown ratio (LCR) of 51-64 %, meaning not too dense appearance. The average slenderness ratio (SR) is generally moderate, where SR of *Kayu bawang* in monoculture system was 76, polyculture was 54 to 81. It can be concluded that this species does not really meet the criteria as urban trees on roadside because they have moderate LCR and SR values, but they can be used to enrich parks and other sites for promoting local tree identity.

1. Introduction

Trees planted in residential areas have many functions, such as absorbing carbon and other pollutants...
[1,2], lowering air temperature [3,4], providing beautiful scenery [5,6], providing habitat for birds and small mammals [7,8], providing fruit [9,10], reducing noise [11,12], and reducing erosion [13,14]. The presence of trees also increases the rental value of houses and offices [15,16]. Planting trees in streets, parks, and yards has some benefits, including improving the quality of air, making the enjoyable place and promoting the quality of people's life [17].

Planting trees in residential areas also has a conservation function if the species planted are local species. The kayu bawang is a local tree species in Bengkulu [18] that produces high-quality wood used for carpentry wood and furniture [19]. Kayu bawang has long been planted in monoculture and polyculture on private forests [20]. It is necessary to plant this species in residential areas to conserve it, so it does not become extinct. The use of these local species can also show regional identity. Local people and outsiders can easily find it and learn about the kayu bawang.

Planting trees in residential areas has been done in several locations, such as roadsides, yards, and parks. The selection of tree species to be planted in residential areas have to meet certain criteria according to the desired function. The trees planted on the roadside should have aesthetic value, ability to cope with harsh ecosystem conditions [21]; trees for the yard should have a medium-size crown [22]; trees for garden trees should be able to grow well with other species [17]. An arborist must understand the characteristics of species to be planted in these sites because the right tree species will grow well in the right place [23].

Since trees and residential structures are inseparable, it is important to understand how they are compatible with each other, especially based on their architectural growth. By planning effective afforestation, it is hoped that it will avoid damage to buildings and other plants. Morphological change is a crucial component in understanding the dynamics of tree characteristics. Because of the knowledge gained about the conformation and natural features of each species, morphometric indices serve as instruments to aid in the planning and management of afforestation. By this means, morphometrics is one of the crucial characteristics of trees [24].

Selecting a type of urban tree is not easy because it must meet many criteria: Urban trees must be of a type that has strong wood, dense leaves, branches that are not easily broken, resistant to the effects of extreme weather, and can adapt under different environmental conditions. The dynamic indicates a brief time frame; the amount and direction of the load, as well as the structural reaction, vary rapidly. The swinging of trees caused by the wind is an example of dynamic load and structural response. While trees must constantly battle their own weight, the most common cause of tree failure is wind [25].

Regarding the aforementioned explanation, it is important to investigate the potential of kayu bawang to be planted in residential areas based on the morphometrics of trees. Therefore, this study aimed to examine the morphometrics of kayu bawang and its potential as urban trees in residential areas. The results of this study are expected to provide information on the sustainability of kayu bawang that can become a regional identity in Bengkulu Province.

2. Material and method

2.1. Research site

The description of the kayu bawang performance in the two planting systems was used to evaluate its potential performance if planted in residential areas. The samples of this study were kayu bawang ± 20 years old, which were planted in private forests in Bengkulu Province. Private forests that were sampled consisted of two planting systems, namely monoculture, and polyculture. A monoculture system is a private forest that is planted with kayu bawang. In the polyculture system, kayu bawang is grown with other species, i.e., rubber or oil palm. The monoculture kayu bawang is located in Seluma District at -3°54′12.32″S 102°21′02.05″E. The polyculture kayu bawang is located in Muko-Muko District, which the ones planted with rubber are located at -2°48′36.84″S 101°24′25.01″E and with oil palm is located at -2°53′45.42″S 101°26′42.66″E. Those three sites are presented in figure 1.
2.2. Data collection
Each planting system was sampled using a 50mx 50m plot [26]. There were 32 trees of monoculture system, 16 trees of polyculture with rubber, and 20 trees of polyculture with oil palm. The total height (H), diameter at breast height (DBH), clear stem height (CSH), live crown height (LCH), and diameter of the crown (DC) of each kayu bawang having a diameter at breast height (DBH) ≥ 30 cm were measured. The morphometrics data is used to evaluate the potential of kayu bawang as urban trees in residential areas. The measurements of total height and clear stem height were done using a haga altimeter, and the measurement of DBH (1.3 m) was done using a phi-band. Live crown height was measured as the difference between total height and clear stem height [27]. DC was the average of the sum of two normal diameters of the crown against the four corners of the world [28].

2.3. Data analysis
The variables of the kayu bawang that were measured included total height, DBH, tree crown architecture, live crown ratio (LCR), slenderness ratio (SR), and crown projection area (CPA). LCR is the ratio of crown height to total height or the percentage of a tree's total height that has foliage [27]. A healthy tree should have a LCR of close to 100%. Trees that have LCR below 70% are categorized as moderate, while trees that have less than 30% are considered as dead [29]. SR is the ratio of total height to DBH [30]. Low SR indicates high resistance to wind damage (good stand stability), while high SR indicates a low resistance to wind blows which could cause damage to trees. SR value > 99 means high, SR value: 70 - 99 means moderate, and SR value < 70 means low. CPA is defined as the horizontal projection of the crown (PCR). It is obtained by using this formula: CPA = ((DC)^2 x π) / 4 [28].

In this study, the potential of the kayu bawang in the targeted location included the roadside, yard, and park [23]. The basic considerations to analyze the potential of planting kayu bawang at the three locations were the area size and shape of the areas; the number of tree species at the sites; buildings; wires, and street lights [21].
3. Results and discussion

3.1. Kayu bawang characteristics

The decision to choose the species of trees planted in residential areas required careful consideration. It is necessary for the longevity of the trees. One important consideration is the morphometrics of the trees. In this study, the observed trees were ± 20 years old kayu bawang in monoculture and polyculture systems. Each system had a different kayu bawang performance according to the conditions in which they grow. The performance of kayu bawang in the two systems was used as an approach to describe the potential of kayu bawang planted in urban forests. Field observations showed that kayu bawang had a cylindrical stem and grey bark. The bark peels brown when the tree is old. The tree crown architecture belongs to the decurrent category. Decurrent is dominant, spreading multi-branched tree [27]. The trees produce edible fruits, which are liked by several species of animals. The characteristics of kayu bawang are presented in table 1.

| Variables | Monoculture | Polyculture | Rubber | Oil palm |
|-----------|-------------|-------------|--------|----------|
| Height (m) | Min 18    | Max 30      | Min 23 | Max 32   |
|           | Mean 27.3±2.7 |            | Mean 27.8±3 | Mean 23 |
| DBH (m)   | 0.3        | 0.6        | 0.4    | 0.6      |
|           | 0.4 ±0.1   | 0.7        | 0.5±0.1| 0.4 ±0.03|
| LCH (m)   | 4.2        | 20         | 7      | 22       |
|           | 14.9±4.1   |            | Mean 14.4±4.8 | Mean 8 |
| DC (m)    | 4.2        | 8.9        | 7      | 17       |
|           | 6.2±1.2    |            | 11.6±3.4 | 5.3      |
| LCR (%)   | 16         | 74         | 28     | 71       |
|           | 54±14      |            | 51±15  | 53±18    |
| CPA (m²)  | 13.8       | 62.2       | 38.5   | 226.9    |
|           | 31.4±11.7  |            | 114.5±62.7 | 56.7     |
| SR        | 50.2       | 96.1       | 38.6   | 85.2     |
|           | 76.2±12.3  |            | 54.4±12.4 | 62.8     |

Note: DBH (diameter at breast height), LCH (live crown height), DC (diameter of the crown), LCR (live crown ratio), CPA (crown projection area), SR (slenderness ratio).

Kayu bawang of ± 20 years old had an average height of 27-29 m, average diameter at breast height (DBH) of 0.4-0.5 m, average live crown height (LCH) of 14-18 m, and average diameter of the crown (DC) of 6-11 m. The height performance and diameter in the two planting systems had relatively the same range of values, but the average LCH and DC had different ranges in the two planting systems. It showed that the crown performance was more sensitive to where it grew. The average diameter of kayu bawang in polyculture systems with rubber was higher than that of kayu bawang in polyculture with oil palm and monoculture, where the diameter of the canopy of polyculture with rubber was also higher than that of other planting systems. An increase in stem diameter tends to have a larger diameter of the crown [28].

The data also showed that kayu bawang had an average live crown ratio (LCR) of 51-64 %, which means that the LCR was in the moderate category. The LCR value is related to the function of trees to reduce temperature [17]. A moderate LCR value can occur due to the ability of trees to do self-pruning, for instance, Douglas-fir and most pines. Another reason for low LCR is unhealthy trees, yet this can be treated by chemical treatment [29].

The average crown projection area (CPA) of kayu bawang ranged between 31-114m². CPA describes the extent of the crown closure, which will affect the area of the shadow formed [31]. The average slenderness ratio (SR) of kayu bawang in the monoculture system was 76, polyculture with oil palm was around 81, and polyculture with rubber was 54. The SR values for monoculture and polyculture with oil palm were in the moderate category, but the SR value for polyculture with rubber was in a low category. The low SR value of polyculture kayu bawang with rubber showed high resistance to wind blows compared to polyculture with oil palm and monoculture. SR is the stability index of the tree or the ratio of tree height to DBH. The lowest SR values occurred in trees with larger diameters [26]. The SR value is used to determine the stability of the tree against damage caused by
the wind. Windthrows can cause branches or crowns to break and trees to fall. This stability greatly affects the potential of trees in urban forests due to harsh environmental conditions.

Kayu bawang crown characteristics are important information needed in considering its potential as urban trees. One of the characteristics of urban trees is that they have a dense crown. This crown functions to produce oxygen, to become a habitat for several animals, to filter dust and some pollutants, to provide tree aesthetic, and to produce shadows [31]. Crown density is the main determinant of the main effect of heat reduction [32], so open areas require species with high crown density to provide coolness. From figure 2, the kayu bawang crown of the two planting systems does not appear to be very dense, so this species is not suitable for shade trees.

![Figure 2. Kayu bawang (A) Monoculture system; (B) Polyculture system with rubber; (C) Polyculture system with oil palm; (D) Bearing fruit; (E) Fruit eaten by animals.](image)

3.2. The potential of planting kayu bawang in residential areas

This study was aimed at investigating the suitability of the morphometries of kayu bawang planted in residential areas, such as roadsides, yards, and parks. There are several things to consider before deciding to plant the trees. This consideration is used to select the species of trees planted to meet the criteria for the need for the survival of the trees to last longer. These considerations are in the form of function, size, form, crown shape, and tree height.

The roadside has harsh ecosystem conditions. The trees planted by the roadside are intended to absorb carbon and other pollutants, lower the air temperature, and provide aesthetic value. In addition, this location has a narrow and elongated tree growing space. Species of trees suitable for planting in this location generally were not varied but had aesthetic value. The yard is the land around the house building. This location requires the character of trees that beautify the appearance of the house building and provide coolness for the residents [4]. Finally, the park has a large enough land area so that it can accommodate various species of trees in that location. Therefore, parks need trees that have tree characteristics that are able to grow well even when combined with other species [17].

Residential areas also have many elements that need to be considered, such as buildings, wires, and street lights. There are many wires and street lights on the side of the road. Trees suitable for planting in this location should have a height that does not extend beyond wires and street lights [21]. It is intended so as not to interfere with their function and cause high tree pruning costs. The same
condition was also occurred in the yard. Because the yard has a larger area, what needs to be considered is that the planting location does not interfere with the house and building. The problem of wires and lights is not too significant in the park because the park has many alternative places to plant trees so as not to interfere with wires, street lights, and buildings.

![Figure 3. Kayu bawang trees were planted (A) in a roadside; (B) in a yard.](image)

Mature kayu bawang can grow up to 30 m with a diameter of 0.7 m. It means that the kayu bawang can be categorized as a large tree. In addition, the LCR value is the moderate category with a crown that is not too dense. The average SR value also shows the moderate category. Therefore, kayu bawang does not meet for planting on roadsides because it will interfere with wires and street lights. In addition, the crown does not provide maximum benefit as a shade and is not aesthetically useful, as can be seen from figure 3. The moderate SR value also indicates that the trees have moderate resistance to wind, so they can be damaged or broken and endanger road users. Kayu bawang can be planted in the yard in small quantities and consider the distance between the plant and the building.

Based on the characteristics and elements in residential areas, kayu bawang is more suitable for planting in the parks. Buildings and wires are easy to avoid in the parks because they have a landscape and wide areas. In addition, kayu bawang is able to grow well with other species to form multi strata and multi-species. Since kayu bawang is a local tree species that produces edible fruit, it is hoped that these trees will not only be beautiful but also provide home and feed for local animals [8]. The park also provides sites for community social activities. Kayu bawang in parks can show a regional identity. Both local people and immigrants can easily recognize Bengkulu's superior tree so that they can learn and be more aware of conserving kayu bawang.

4. Conclusion
Based on the results, it can be concluded that the characteristics of trees are the main criteria in choosing potential urban trees for residential areas. It is important to consider elements (wires, street lights, and buildings) on-site for the tree's survival or ability to survive on site. Kayu bawang does not really meet the criteria as urban trees on the roadside, but it can be used as species enrichment of urban forest, especially in parks. Kayu bawang has moderate LCR and SR values which means that there is a possibility of broken trees from windthrow, and it will be harmful to road users. Tree planting in residential areas is expected to last for a long time. Kayu bawang can be planted in yards by considering the distance from buildings and wires. Therefore, arborists must be able to predict changes that might occur for the sustainability of kayu bawang in residential areas.

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