The palm leaves falling periods and characteristics of royal palm (*Roystonea regia* (Kunth) F.Cook) at IPB Dramaga Campus, Bogor, Indonesia

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Abstract. Royal palm is widely planted as an ornamental plant and becomes part of parks and open landscapes in urban areas, especially on the roadside and in an urban forest. The leaves have a large size that can potentially cause harm to people or property under or around the tree. Information regarding the falling period and the weight of palm leaves was necessary in terms of risk mitigation of tree management. The study was conducted on ten royal palm trees by observing the incidence of leaf fall every three days during the period of September 2019 to March 2020. The palm leaves comprise the leaf sheath and the petiole. The results showed that the number of royal palm leaves was about 12 leaves per tree. Royal palm at IPB Dramaga campus has a tree height of about 12 m and a diameter of 40 cm. The period of fall of palm leaves is 30 to 40 days; although it may not fall every period, it can even fall once in 6 months. The average weight of the fallen leaves is about 8.2 kg, with a moisture content of 85.2%. Information on the period and weight of royal palm leaf fall are very important as information on risk mitigation activities in plant management in the urban landscape.

1. Introduction
Palm trees are monocotyledonous plant species whose abundance in the world has about 184 genera and more than 2400 species [1]. Among these species, there are 576 species in Indonesia, including 29 endemic genera. Some palm species are also imported as exotic from various regions of the world that entered Indonesia with a specific purpose. One of the imported types is Royal palm (*Roystonea regia* (Kunth) F.Cook) and is originated from the West Indies [2]. This palm is categorized as an ornamental plant that is widely planted as a component of parks or landscapes and in the open land of urban areas, especially in the roadside and urban forests [3]. This palm is commonly found in the city of Bandung, Bogor, and Pontianak and planted as roadside ornamental plants [4, 5]. The shape of a tree with a
towering sturdy trunk and large leaves [3] is the main attraction of the king palm. A royal palm tree trunk can reach a diameter of more than 40 cm, a height of more than 25 m, a leaf weight of more than 22.7 kg, and a leaf length of 3–4.5 m [6].

A growth cycle also includes a period of natural leaf fall. The leaves of this type of palm plant are known as fronds. The royal palm leaf itself consists of the sheath, petiole, and leaflets. When falling, the big size of the frond is considered to be dangerous and can cause harm to people and also property under it. The cause of leaf fall is generally due to the reduced water content so that the leaves become dry and no longer strong enough to withstand the weight of the leaves. Knowing the period of falling leaves can minimize the risk of losses caused by the fall of this leaf. To the best of our knowledge, information regarding the period of the fall of the royal palm leaves is still limited, especially in Indonesia. Therefore, this study was conducted with aims to determine the time window of the fall of royal palm leaves and the characteristics of the weight and moisture content of fallen king palm leaves.

2. Methodology

2.1. Characterization of royal palm
The royal palm trees chosen in this study are located on the university campus. All plantations are in uniform appearance condition showing almost the same age. Detailed data regarding planting or age was not available. Therefore, in this study, the approach was carried out based on tree height and diameter characteristics. The characteristics of the royal palm tree that were observed and measured consisted of its height and diameter. Height was divided by the shiny green part (crownshaft) at the top and the brown part at the trunk base [6]. Meanwhile, the diameter measurement is the diameter breast to height (dbh) or about 130 cm from the ground.

2.2. The palm leaves falling periods
Data collection on the fall of royal palm leaves used observation and recording methods. Observations were made for six months, starting from September 2019 until March 2020. The observation was conducted on ten trees royal palm trees that are distributed on the Campus IPB Landscape. The observation is carried out every three days during the study period. There were five periods during six months. Fallen leaves can consist of green leaves and brown leaves. Green leaves are categorized if they are from fresh fellings, while brown leaves are from dry fellings. In calculating the falling period, the value for each falling period has to be averaged.

2.3. Moisture content
The moisture content of royal palm leaves was measured from leaf sheath and petiole. The Sample size was 2.5 cm in length and conditional thickness was depended on leaf sheath and petiole thickness. Samples were balanced in wet and dry conditions. The wet condition means that the leaf is fresh or just fallen, while the dry condition is obtained by putting samples in an oven with 103±2 °C temperature for 24 hours. Moisture content means the water contained in the material, which is expressed as a percentage (%) [7] and measured with the following equation (1):

\[ MC \, (\%) = \frac{w - d}{d} \times 100\% \] (1)

where:
MC = Moisture content (%)
w = wet weight condition (g)
d = oven-dry weight condition (g)
2.4. Weight of royal palm leaf

The weight of the royal palm leaves was measured by digital hanging scales as total weight. The leaves were separated on some parts like leaf-sheath, petiole, and leaf sheet. The weight of each part was measured.

2.5. Total number of leaves

The whole palm leaves, including shoots, were counted manually using drone technology. The drone captured the entire angle of palm leaves and counted the leaves from the picture. The observation was conducted at the early and end of data collection.

3. Results and discussion

3.1. Characterization of royal palm at IPB campus

Royal palm at IPB Dramaga campus has a wide distribution of height and diameters. General information of coordinate position, height, diameter, as well as number of palm leaves tree before and after fallen shows in table 1.

Table 1. General information of royal palm plantation at IPB Dramaga campus.

| ID | Coordinates         | Height (m) | DBH (cm) | Number of Leaves          |
|----|---------------------|------------|----------|---------------------------|
|    |                      | BT | GT | TH | Early or initial obv. | End obv. | Fall leaves | New leaves |
| R02 | S 6° 33.343 E 106° 43.497 | 8.2 | 1.9 | 10.1 | 34.0 | 11 | 10 | 3 | 2 |
| R03 | S 6° 33.277 E 106° 43.446 | 8.2 | 2.4 | 10.6 | 39.2 | 11 | 12 | 2 | 3 |
| R04 | S 6° 33.263 E 106° 43.440 | 8.2 | 3.5 | 11.7 | 44.9 | 12 | 11 | 1 | 0 |
| R05 | S 6° 33.231 E 106° 43.396 | 7.0 | 2.6 | 9.6 | 35.7 | 14 | 16 | 5 | 7 |
| R07 | S 6° 33.226 E 106° 43.368 | 8.3 | 2.3 | 10.6 | 40.4 | 8 | 8 | 2 | 2 |
| R11 | S 6° 33.482 E 106° 43.184 | 14.6 | 2.8 | 17.4 | 43.6 | 14 | 13 | 1 | 0 |
| R12 | S 6° 33.498 E 106° 43.209 | 12.5 | 2.0 | 14.5 | 39.2 | 13 | 14 | 2 | 3 |
| R13 | S 6° 33.499 E 106° 43.212 | 11.9 | 1.9 | 13.8 | 38.8 | 15 | 16 | 4 | 7 |
| R19 | S 6° 33.639 E 106° 43.649 | 14.7 | 2.6 | 17.3 | 42.8 | 13 | 12 | 3 | 2 |
| R20 | S 6° 33.423 E 106° 43.953 | 8.5 | 2.3 | 10.8 | 40.4 | 12 | 12 | 1 | 1 |

Average: 10.2, 2.4, 12.6, 39.9, 12, 12, 2, 2
Deviation standard: 2.9, 0.5, 2.9, 3.4
Coefficient variation (%): 28.6, 20.2, 23.3, 8.4

Note: identity (ID), brown trunk (BT), green trunk (crownshaft) (GT), total height (TH), diameter breast to high (DBH), observation (obv.), fall leaves based on observation every three days during the study period, new leaves during the study period as calculation from initial obv. minus fall leaves on the final existence number of leaves based on end obv.

The average total height of the royal palm at the IPB Dramaga campus was 12.6 m. The total height comprised the brown (BT) and green (crownshaft, GT) trunk. Meanwhile, the average diameter was 43.6 cm which the distribution of BT was wider than GT. The range of BT was in a range of 7.0 to 14.7 m, while BT was between 1.9 to 3.5 m. The data distribution of diameter and height is shown in figure 1. It is almost no scientific paper reported the maximal age of the royal palm tree. Generally, the information only mentions the average height and diameter that can be achieved, which is about 40 cm in diameter and up to 25 m in height [6]. Referring to this information, the royal palm tree on the IPB Dramaga campus will still be able to grow taller.
3.2. Total number of leaves

According to observation, the number of leaves is shown in Table 1. An average number of a royal palm was about twelve leaves. At the first observation the number of leaves at the first observation had the fewest palm leaves of eight, owned by palm R07, while palm R13 had the most palm leaves, i.e., fifteen leaves. On average, the number of palm leaves was twelve leaves for the royal palm trees.

Broschart [6] mentioned that royal palm leaves tend to self-cleaning of dying old leaves naturally. It was reported for about one leaf per month, the leaves drop off by themselves. Our study found an initial condition as the starting point in measuring the number of palm leaves, the leaves in a tree were about twelve. During the period of study for six months, the fall leaves naturally were reached about two leaves, with the new leaves as captured from the drone being about two leaves (Table 1). It seems there is a different ability in dropping off the leaves. Our study revealed that it was not every month for the royal palm tree to fall the leaves. It is presumably related to the environment site, especially in the difference of soil condition, rainfall, sunlight, etc. Although the royal palm is a tropical tree, the environment factor becomes a defining factor in site adaption. It is also related to the new shoot development promoted by abundant sunlight that may stimulate the auxin hormone system. This auxin functions to promote new shoots, thereby increasing the number of leaves [8]. These young leaves approximately take more than 30 days to become mature leaves which metamorphose to dark green color. For that reason, also the weight of royal palm leaves can be different.

3.3. Leaves falling periods

The patterns of the fall period of the royal palm leaf are shown in Figure 2. During the study period, there was a royal palm tree that shed its leaves only once. Since the observation started, palm ID R04 and R07 shed their leaves only on the day 13th, while for R11 and R20 fell their leaves more than 40 days, R11 on day 95th and R20 on day 47th, respectively. There were three royal palms that had two falling periods, i.e., R03, R12, and R19 while having for three periods falling was owned by the tree of R02 only, and for four periods was R13 only. The palm R05 had five palm leaves falling periods during six months of observation, the first period on day 13th, the second period after day 46th, the third period on day 75th, the fourth period on day 136th, and the fifth period after day 171st. The leaves were falling in September, October, November, January, and March. Furthermore, the average of falling periods is
shown in figure 3. From our study, it can be explained that not every royal palm tree drops off the palm leaves in each period during six months of observation. It seemed at the end of observation of December to February becoming the extensive period in dropping of the leaves. It can be understood that in those months are in the rainy season which the raindrop was driving the leaf fall.

Figure 2. Falling periods of each individual of royal palm trees.

Figure 3 shows the timely of falling leaves which not every tree can drop off leaves each period. Our observation found the royal palm tree which fell the leaves in once period was in 39th day, the tree had fallen in twice period dropped off the leaves for eighty days, and the tree which fallen the palm leaves in the fifth period, the total number days reached 160 days. It meant, on average, it will drop off the leaves every 40 days for each period. However, not all royal palm trees have the ability to fall the leaves every 40 days. Broschat [6] mentioned that the R. regia plant in the Florida area drops off its leaves about once a month or more or less every 30 days. The fall of royal palm leaves is closely related to the adaptability of the tree to the sites where it grows. Our study revealed that it can find the royal palm trees, which fall every period about 30 to 40 days, or trees can drop off their leaves longer even in 5 to 6 months only drop off once.

Figure 3. Average of royal palm falling periods.
The royal palms at the IPB Dramaga campus were generally planted on the roadside, which means getting irradiation all day. Around the palm, grass growth covers the ground. Soil fertility at IPB Darmaga Campus contains a pH of around 5.5-6.5 [9], meaning that the soil is classified as slightly acidic. The fertility is sufficient but not too high so that it still supports the growth of royal palms [10]. In addition, the growth of royal palms is also influenced by the air temperature. Royal palm could grow at temperatures ranging from 25-33 °C where the air temperature around the campus already supports the place to grow royal palm which can be seen on the climate graph [11]. The average temperature in the Bogor Regency area is 27.4 °C and the monthly rainfall for a period of 5 years (2015-2019 period) is 3609 mm. According to Bogor Climatology Station, the Bogor district has an average annual rainfall of 3500 to 4000 mm [11].

3.4. Moisture content
The palm leaves that have just fallen are immediately taken in order to separate the palm sheath, petiole, and leaf blades. Table 2 shows the results of measuring the moisture content of the fallen sheath and petiole.

| ID  | MC of leaf sheath (%) | Average (%) | MC of the petiole (%) | Average (%) |
|-----|-----------------------|-------------|-----------------------|-------------|
|     | 1         | 2     | 3     | 4     | 5     | 1     | 2     | 3     | 4     | 5     |
| R02 | 105.3     | 34.8  | 38.6  |      |      | 59.6  | 111.5 | 83.9  | 89.5  | 95.0  |
| R03 | 118.9     | 59.2  |      |      |      | 89.1  | 36.5  | 173.  |      | 105.1 |
| R04 | 20.3      |      |      |      |      | 7     | 20.3  | 54.7  |      | 54.7  |
| R05 | 19.5      | 38.0  | 30.4  | 13.8 | 25.  | 25.4  | 70.8  | 121.  | 172.  | 229.  | 150.  | 149.0 |
|     | 3         | 6     | 4     | 8     | 2     |       |       |       |       |       |
| R07 | 17.2      | 13.4  |      |      |      | 15.3  | 84.8  | 16.2  |      | 50.5  |
| R11 | 15.4      |      |      |      |      | 15.4  | 24.2  |      |      | 24.2  |
| R12 | 13.4      | 14.6  |      |      |      | 14.0  | 16.6  | 17.1  |      | 16.9  |
| R13 | 16.2      | 13.5  | 11.4  | 12.5 |      | 13.4  | 92.6  | 18.6  | 13.5  | 14.6  | 34.8  |
| R19 | 16.5      | 14.3  | 23.2  |      |      | 18.0  | 17.9  | 15.7  | 27.2  |      | 20.3  |
| R20 | 13.7      |      |      |      |      | 13.7  | 17.8  |      |      |      | 17.8  |
|     |           |       |       |       |       | 28.4  |       |       |       |       | 56.8  |
|     |           |       |       |       |       |       | 25.4  |       |       |       | 45.1  |
|     |           |       |       |       |       |       |       |       |       |       | 71    |

Compared to the palm leaf sheath, the average moisture content in the petiole was higher (MC = ±56.8%) than the leaf sheath (MC = ±28.4%). It was presumably due to the storage capacity of the petiole being larger than the leaf sheath.

This moisture content affects the weight of royal palm leaves. The higher the moisture content, the heavier the palm leaf. Table 3 shows the weight of the leaf sheath and the combination of petiole and leaflets. The average weight of royal palm sheath can reach about 8.2 kg. It should be considered when this royal palm part fall in a public area and can be fatal on the people or other public asset below the tree since this plant species need enough light as well as suitable as ornament plant [12, 13].
Table 3. Weight of royal palm leaf.

| ID  | Weight of leaf sheath (kg) | Average (kg) | Weight of petiole + leaflets (kg) | Average (kg) |
|-----|---------------------------|--------------|----------------------------------|--------------|
|     | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| R02 | 3.3 | 3.7 |     |     |     | 3.5 |     |     |     |     | 5.7 |     |     |     |     |     | 5.7 |     |
| R03 | 4.8 | 5.4 |     |     |     | 5.1 |     |     |     |     | 6.3 |     |     |     |     |     | 9.7 |     |
| R05 | 3.5 | 4.6 | 3.7 | 3.9 | 4.2 | 3.9 |     |     |     |     | 5.9 |     | 4.7 | 7.9 | 7.8 | 7.6 | 8.0 | 6.8 |
| R07 | 2.3 | 2.3 |     |     |     | 2.3 |     |     |     |     | 5.2 |     | 5.2 |     |     |     | 5.2 |     |
| R11 | 3.1 |     |     |     |     | 3.1 |     |     |     |     |     |     | 4.6 |     |     |     | 4.6 |     |
| R12 | 3.6 | 3.2 |     |     |     | 3.4 |     |     |     |     | 4.3 |     | 4.6 |     |     |     | 4.5 |     |
| R13 | 2.9 | 2.6 | 2.9 |     |     | 2.8 |     |     |     |     | 4.0 |     | 3.3 | 3.3 |     |     | 3.5 |     |
| R19 | 3.5 | 3.5 | 3.5 |     |     | 3.5 |     |     |     |     | 3.7 |     | 3.7 | 3.8 |     |     | 3.8 |     |
| R20 | 3.5 |     |     |     |     | 3.5 |     |     |     |     | 3.8 |     |     |     |     |     | 3.8 |     |
|     | Average |     |     |     |     | 3.1 |     |     |     |     |     |     |     |     |     |     | 3.1 | 5.1 |
|     | Standard Deviation |     |     |     |     | 0.77 |     |     |     |     |     |     |     |     |     |     | 1.50 |
|     | Coefficient of Variation (%) |     |     |     |     | 22 |     |     |     |     |     |     |     |     |     |     |     | 29 |

4. Conclusions

Our study reported that the royal palm (*Rostenia regia*) had a height of about 12.6 m and a diameter of about 39.9 cm, and revealed the average weight of fallen leaf was about 8.2 kg with moisture content condition of 85.2%. The average number of royal palm leaves was about twelve leaves. The period of royal palm leaves drop off was 30 to 40 days, although it did not always fall for every period. Even our study found the royal palm, which drops off its leaves once in six months. The rainy season becomes a period that royal palm leaves can easy to fall. By knowing the information on the period and weight of fallen royal palm leaves, risk mitigation can be anticipated through maintenance actions such as pruning. Further study is needed in determining the characteristics of the leaves that are about to fall.

5. References

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