Morphological characterization of pachira (Pachira aquatica Aubl.)

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Abstract. Pachira is one of the plants that have a fairly high and promising selling value. Characterization of morphological properties is important so that the pachira (Pachira aquatica Aubl.) germplasm is more efficient. This study aims to study and characterize diversity and kinship in order to obtain information about the characteristics of pachira groupings. Pachira's characterization includes qualitative and quantitative characters. Analysis of kinship using the UPGMA method. The results showed that the level of diversity in the morphological characters of pachira 3 districts in East Java reached 0.33. The results of the kinship analysis obtained 4 clusters with a coefficient of 0.74. Group A consisted of samples P1, P3, P15, P4, and P12. Group B consisted of samples P2, P8, P7, P11, P5, P9, P18, P13. Group C consisted of samples P6, P10, and P14. Group D consisted of P16 and P17. The level of diversity of pachira morphological characters reached 0.33.

1. Introduction
Pachira (Pachira aquatica Aubl.) is a plant that has a fairly high and promising selling value. Pachira is well known as the Money tree and it is a type of wetland plant originating from Central and South America. The shape of the pachira plant when it is under one year old is similar to the cassava plant, especially in the leaves. This research was conducted because in Indonesia not so many people know about the diversity, characterization of benefits, and potential of pachira. Morphology of plants is the study of the shape and structure of the plant body. Morphological characterization of plants is very important to detect the specific traits that are desired to avoid duplication when identifying an accession in order to increase the efficiency of collection efforts and population arrangement for conservation purposes. Morphological characterization is widely used as the first step in finding kinship in an accession because of its easy and fast application.

Pachira propagation can be done generatively or vegetatively. Sexual reproduction is by seeds. A good planting medium used consists of a mixture of soil and manure in a ratio of 1:1. After being mixed evenly, the planting medium is then put into the pot until it is full. After the seeds have grown for about 3 months and are about 15 cm high, the pachira stems can start to be braided and traded. Vegetative propagation is stem cutting. The material needed is a pachira stick of about 25-30cm. In vitro pachira can also be propagated using explants of pachira stems, shoots, and leaves.
2. Material and method

This research was conducted from August to November 2020 in Kediri Regency (Kandat, Ngancar, Kras, and Ngadiluwih Districts), Blitar Regency (Sukorejo District), and Tulungagung Regency (Besuki District) East Java. This research used a survey method with exploratory descriptive technique. Total plants observed were 18 plants. Sample selection was done by purposive random sampling (deliberately) with the criteria that they are adults, have an age of more than 4 years, have a height of more than 3 m, are not in the same location and are based on recommendations from the surrounding community. Morphological identification was carried out using instructions based on the similarity of characteristics possessed by each plant species.

The primary data was in the form of plant morphology such as tree morphology, leaves, stems, and pachira fruit which are observed directly at the location where it grows. The secondary data observed were altitude above sea level, latitude, longitude, temperature, rainfall, and soil types at the research site. Data collection techniques included field observations, respondent interviews, documentation, and literature study. The results of the data obtained are scored according to the descriptor from the IBPGRI (International Board Plant Genetic Resources Institute) which has been modified for each variable, then grouped using the Unweighted Pair Group Method Arithmetic Average (UPGMA). The data obtained were processed using the NTSYS (Numerical Taxonomy and Multivariate Analysis System) program version 2.02i calculated through the SAHN and then put together in the form of a dendrogram based on similarity.

3. Result and discussion

3.1. General condition of research site

The research location is divided into 3 regencies, namely Kediri Regency, Blitar Regency and Tulungagung Regency. These three places have different geography. Kediri Regency is located between 111°47'05" - 112°18'20" east longitude and 7°36'12" - 8°0'32" south latitude with an average elevation of 67m above sea level and a slope of 0-40%. The air temperature ranges from 23°C to 31°C with an average rainfall of 1,652 mm per year. The research location in Kediri Regency is divided into 4 sub-districts, namely Kandat, Ngadiluwih, Ngancar and Kras. The soil type in Kandat and Ngancar sub-districts is gray-brown regosol with a pH value of around 6-7 while the soil type in Ngadiluwih and Kras sub-districts is gray-brown alluvial with a pH of around 5.3-5.8.

Tulungagung Regency is located between coordinates 111°43' - 112°07' east longitude and 7°51' – 8°18' latitude with an average altitude of 85 m above sea level and an air temperature of 21°C - 32°C. The average rainfall in this location is 1500 mm per year. The research location in Tulungagung Regency is located in Besuki District. The type of soil at the location is mixed gray alluvial and gray brown alluvial soil with soil pH values ranging from 6-7. The next research location is located in Blitar Regency. Blitar Regency is located between the coordinates of 112°14' - 112°28' East Longitude and 8°2’ – 8°10’ South Latitude with an altitude of 156m above sea level and an average temperature of 24°C - 34°C. The research location in Blitar Regency is located in Sukorejo District. The average rainfall in this location is 1478 mm per year. The type of soil in Sukorejo District is regosol which is associated with lithosol soil. The type of regosol soil comes from volcanic materials and limestone sedimentary rocks. Lithosol soil type has a loose consistency and good porosity and water absorption resistance.

3.2. Tree morphology

The results of the identification of the shape of the canopy on the observed pachira samples did not show any diversity. All samples of pachira trees have a spreading crown. According to Booth and Norman [1], the shape of the canopy is divided into seven types, namely globular (rounded), columnar (tall, slender), spreading (spreading), picturesque (interesting), weeping (draining), pyramidal (cone), and fastigiate (high), slender, tapered). The spreading type of canopy has an irregular (irregular) branch shape whose crown widens even at the top of the canopy so that it gives a broad impression.
3.3. **Leaf morphology**

3.3.1. **Leaf shape.** The results of the identification of leaf shapes in the observed pachira samples did not show diversity. All pachira leaf samples observed had orbicularis leaf shape. Leaf shape can be determined based on the ratio of the length and width of the leaf and the location of the leaf petiole. According to Tjitrosoepomo [2], round leaves (orbicularis) have the same leaf width and length ratio of 1:1 and the location of the widest part of the leaf is located in the middle of the leaf blade.

![Leaf shape orbicularis on the number of leaves 5 (A) and 7 (B)](image)

3.3.2. **Leaf edge.** The results of the identification of leaf edges in the observed pachira samples did not show any diversity. All samples of pachira leaves that were observed showed the results of shared leaf margins (palmatipartitus), namely leaves with shared leaf edges and had finger bone arrangement. Broadly speaking, leaf edges are divided into two types namely, flat leaf edges and incised ones. Pachira leaf margins are a type of incised leaf edge. The location of the incision depends on the arrangement of the leaf bones. Leaf margin sharing (partitus) is a type of leaf that has a notch more than half the length of the leaf bone on the right and left.

3.3.3. **Leaf tip.** The results of the identification of leaf tips in the observed pachira samples did not show diversity. All observed leaf tips showed the same results, namely pointed (acutus). The acutus leaf tip is the tip of the leaf when the two edges on the right and left of the mother's leaf blade gradually move upwards and they meet at the top of the leaf to form a sharp angle (smaller than 90°).

3.3.4. **Leaf base.** The results of the identification of the base of the leaves on the pachira leaf samples did not show any diversity. The bases of the pachira leaves all show pointed results (acutus) whose leaf edges are separated by the base of the mother bone. The shape of the acutus leaf base is one where the leaf edges at the base of the leaf meet at the petiole forming an angle that is less than 90°.
3.3.5. Leaf length. The identification results on the observed leaf length showed diversity. Based on Table 1, the leaf length with the largest value is shown at P6 with an average leaf length of 35 cm, while the leaf length with the smallest value is at P8 with an average leaf length value of 24 cm. Environmental factors are one of the causes of differences in pachira leaf length.

Table 1. Leaf and stem variable

| Sample | Leaf Length (cm) | Leaf Width (cm) | Number of Leaves |
|--------|-----------------|-----------------|-----------------|
| P1     | 29              | 30              | 5               |
| P2     | 34              | 35              | 5               |
| P3     | 32              | 28              | 5               |
| P4     | 29              | 32              | 5               |
| P5     | 26              | 28              | 7               |
| P6     | 35              | 38              | 7               |
| P7     | 28              | 35              | 5               |
| P8     | 24              | 22              | 5               |
| P9     | 27              | 28              | 5               |
| P10    | 34              | 36              | 7               |
| P11    | 31              | 34              | 5               |
| P12    | 26              | 27              | 5               |
| P13    | 26              | 29              | 5               |
| P14    | 27              | 32              | 7               |
| P15    | 28              | 26              | 5               |
| P16    | 31              | 34              | 7               |
| P17    | 33              | 35              | 7               |
| P18    | 29              | 27              | 5               |
According to Kastono and Istiawan [3], differences in altitude will affect the distribution of available light. The higher a place is, the less light that reaches the surface. The pachira sample number 6 shows the leaf length with the largest value because the pachira grows in the highlands, namely the Kelud mountain area in Ngancar District, while the leaf length with the smallest value is the pachira sample number 8 which is located in a lowland area, namely Besuki District, Tulungagung Regency. This is in accordance with the results of research by Haryanti [4], plants that grow at low to sufficient light intensity will show a larger leaf area.

3.3.6. Leaf width. The results of morphological characterization of the observed pachira samples are shown in Table 1, showing the diversity of leaf widths. Measurement of leaf width was carried out by measuring the width of 3 leaf samples taken from each sample of pachira trees observed and then calculating the average. The leaf width with the largest value is shown in sample P6 which grows in the highlands, with an average leaf length of 38 cm, while the leaf width with the smallest value is in sample P8 with an average leaf length value of 22 cm which grows in the lowlands. As quoted by Suci and Heddy [5], the wide leaves of plants that receive less light intensity is a form of expression of environmental adaptation by the leaves used so that the leaves are able to absorb more light.

3.3.7. Leaf color. The results of the morphological characterization of the observed pachira samples showed that there was no variation in the color of the leaves on the upper surface and lower surface of the pachira leaves. All leaf colors on the upper surface were observed the same, namely dark green and for the low surface of the leaves are light green. Leaf color was observed using the Munsell color chart and then scored according to the color results that showed similarities.

![Figure 4. Leaf top surface color (A) munsell color chart 2.5G (B)](image)

![Figure 5. Leaf underside color (A) munsell color chart 2.5GY L3 (B)](image)

The difference in the green color of the leaves is caused by the difference in the amount of green leaf substance (chlorophyll). Leaf color that shows dark green results indicates that the chlorophyll content is high. In accordance with the opinion by Biber [6] that leaf age and physiological stages of a plant are factors that can determine the chlorophyll content in leaves. According to Susanto [7], the process of photosynthesis is influenced by the age of the leaves and this will affect the change in leaf color, because in photosynthesis there are pigments associated with leaf color.

3.3.8. Number of leaves. The results of the morphological characterization of the observed pachira samples are shown in Table 1, indicating the diversity of the number of leaves. Pachira leaves are compound leaves whose leaves are arranged in a circle consisting of 5 to 7 per petiole. From 18 tree samples, there were 12 trees with 5 leaves on each pachira leaf stalk, and 6 trees with 7 leaves on each leaf stalk.
The difference in the number of leaves on pachira is caused by genetic factors. This can be proven because in the same growing environment, there are differences in the number of leaves on the pachira tree. Genes are factors that carry heredity. Gene traits in plants that are usually passed on to new plants include leaf shape, stem, flower color, and fruit taste. Genes stored in DNA that will later regulate the nature of the plant.

![Figure 6. Number of leaves 5 (A) and 7 (B)](image)

3.4. **Stem morphology**

3.4.1. **Rod shape.** The results of the morphological characterization of the observed pachira samples showed that there was no variation in the shape of the stems, all had a round stem shape. The uniformity of the pachira stem shape character can be determined by each gene. The results of the observations show that the genes that make up the same phenotype give rise to the same character even though the environmental conditions are different. This corresponds to Dartius [8] states that adaptation to different environments can produce the same growth and phenotypic characteristics if they come from the same gene.

3.4.2. **Branching pattern.** The results of the morphological characterization of the pachira samples did not show diversity in the pachira branching pattern. The branching patterns observed in the pachira all have a monopodial branching pattern. This is in accordance with the results of research by Ospina [9] that pachira has a monopodial branching pattern. According to Tjitrosoepomo [10], monopodial branching pattern is a branching pattern in which the main stem and branching stems can be clearly distinguished. The main stem on the pachira looks bigger and longer than the branching trunk.

![Figure 7. Round rod shape (A) Monopodial branching pattern (B)](image)
3.4.3. **Stem circumference.** The results of the morphological characterization of the observed pachira samples are shown in Table 2 showing that there is a variation. The pachira stem circumference was measured using the DBH (Diameter at Breast High) measurement method. The stem circumference with the largest value is shown in sample P12, with a stem circumference of 57 cm, while the stem circumference with the smallest value is in sample P1, which is 30 cm.

The higher the level of light intensity, the diameter of the plant stem also increases. As quoted by Marjenah [11] the growth of stem diameter will be faster in open places with high light intensity. The longer the photosynthesis process takes place, the more carbohydrates are produced.

3.5. **Fruit morphology**

3.5.1. **Fruit shape.** The results of the morphological characterization of the observed pachira samples are shown in Table 2 which shows that there is a diversity in the shape of the pachira fruit. There is a diversity of fruit shape characteristics, namely ovoid (Figure 8) in 13 trees and elliptic in 2 pachira trees. According to research of Robyns [12], the shape of the pachira fruit varies from sub-globose, elliptic, and oblong. The different fruit shapes are thought to be caused by genetic factors, cultivation techniques, and environmental factors.

| Sample | Fruit Shape | Fruit Weight (gr) | Fruit Circumference | Number of Fruit per tree | Stem Circumference (cm) |
|--------|-------------|-------------------|---------------------|-------------------------|------------------------|
| P1     | Ovoid       | 226               | 16                  | 13                      | 30                     |
| P2     | Ovoid       | 270               | 22                  | 18                      | 40                     |
| P3     | Ovoid       | 186               | 18                  | 16                      | 41                     |
| P4     | elliptic    | 187               | 17                  | 9                       | 32                     |
| P5     | Ovoid       | 271               | 22                  | 28                      | 44                     |
| P6     | Ovoid       | 210               | 23                  | 4                       | 39                     |
| P7     | Ovoid       | 188               | 21                  | 23                      | 45                     |
| P8     | Ovoid       | 275               | 24                  | 17                      | 47                     |
| P9     | Ovoid       | 268               | 22                  | 6                       | 53                     |
| P10    | -           | 0                 | 0                   | 0                       | 44                     |
| P11    | Ovoid       | 186               | 21                  | 27                      | 31                     |
| P12    | elliptic    | 175               | 15                  | 5                       | 57                     |
| P13    | -           | 0                 | 0                   | 0                       | 38                     |
| P14    | -           | 0                 | 0                   | 0                       | 36                     |
| P15    | Ovoid       | 181               | 19                  | 11                      | 35                     |
| P16    | Ovoid       | 289               | 23                  | 16                      | 27                     |
| P17    | Ovoid       | 184               | 17                  | 12                      | 38                     |
| P18    | Ovoid       | 193               | 20                  | 9                       | 36                     |

![Figure 8. Fruit shape ovoid (A) and elliptic (B)](image_url)
3.5.2. **Fruit skin color.** The results of morphological characterization of the observed pachira samples showed that there was no diversity in the color of the pachira fruit skin. The skin color of the pachira fruit that was observed all had a dark green color (Figure 9). The color of the fruit skin on the observed pachira samples showed uniformity of results. According to observations, it can be concluded that the emergence of the same character between varieties may be caused by the presence of genes that make up the same phenotype despite different environments. Differences in phenotypic characters can occur due to each gene which also involves the influence of the existing environment.

![Fruit skin color](image)

**Figure 9.** Pachira fruit skin color (A) and munsell color chart 2.5G (B)

3.5.3. **Fruit weight.** The results of the morphological characterization of the observed pachira samples are shown in Table 2 which shows the diversity in the weight of the pachira fruit. The weight of the fruit with the largest value was shown by sample P16, which was 289 grams, while the weight of the fruit with the smallest value was shown by sample P12, which was 175 grams. According to Armaini et al [13], fruit weight can be influenced by the availability of macro and micro nutrients that are needed by plants for plant physiological processes. According to Salisbury and Ross [14], the increase in cell size results in an increase in the size of tissues and organs thereby increasing fruit size.

3.5.4. **Fruit circumference.** The results of the morphological characterization of the observed pachira samples are shown in Table 2 showing the diversity in the circumference of the pachira fruit. Pachira fruit circumference is measured with the help of a tape measure. The fruit circumference with the largest value is shown in sample P8, which is 24cm, while the fruit circumference with the smallest value is shown by sample P12, which is 15cm. In general, the initial increase in size depends on the multiplication of cells that begins before the flower blooms and continues after fertilization.

3.5.5. **Number of fruit per tree.** The results of the morphological characterization of the observed pachira samples are shown in Table 2, indicating that there is diversity in the number of fruits per tree. The highest number of fruits is shown in sample P5, which is 28 fruits in one tree, while the number of fruits with the smallest value is shown in sample P6, which is 4 fruits in one tree. Sufficient nutrients are one of the factors that support plant metabolic processes related to the production of productive branches. The number of productive branches produced by the plant will ultimately determine the total number of fruit formed.

3.6. **Diversity and classification of Pachira**

Information on genetic diversity is very necessary to obtain new varieties. The grouping of plant diversity was based on the level of similarity in the morphological characteristics of the observed pachira samples. Herawati et al [15] explained that the selection will be more effective if the character that is the target of selection has a high diversity. Based on the results of group analysis (cluster analysis), the results of the grouping of pachira in East Java can be seen in the dendrogram image below.
Based on the results of the morphological character dendrogram on 18 pachira trees in East Java show there is diversity in the morphological characters of trees, leaves, stems, and fruit. The 18 samples found were located in several different locations. The highest similarity coefficient value of 0.94 (coefficient of diversity 0.6) was shown in samples P3 with P15, while the lowest similarity coefficient value was 0.67 (coefficient of diversity 0.33). At the similarity coefficient value of 0.74 (coefficient of diversity 0.26) grouped into 4 groups, namely groups A, B, C, and D.

Group A consisted of samples P1, P3, P15, P4, and P12. The highest similarity coefficient value of pachira morphological characters is 0.94, namely in samples number 3 and 15. Sample P1 tends to have similarities with P3 and P15. Sample P4 tends to have similarities with P12.

Group B consisted of samples P2, P8, P7, P11, P5, P9, P18, and P13. Samples P7 with P11 and P9 with P18 have the highest similarity coefficient value in group B, which is 0.88. Samples P13 tend to have similarities with P9 and P18. Samples P2 and P8 had a lower similarity coefficient value of 0.83. Sample P5 had the most similarity in group B with distinguishing morphological characters in the number of leaves, stem circumference, fruit weight, fruit circumference, and number of fruit per tree.

Group C consisted of P6, P10, and P14. P6 and P10 had the highest similarity coefficient in this group, which was 0.83. P14 has a similarity coefficient value of 0.76 with P6 and P10. The distinguishing morphological characters were shown in leaf length, leaf width, fruit weight, and fruit circumference.

Group D consisted of P16 and P17. The two samples had similar morphological characters of 0.83 with distinguishing morphological characters, namely stem circumference, fruit weight, and fruit circumference. Efendi et al [16] stated that the greater the coefficient of genetic similarity, the greater the chances of kinship. The diversity that occurs in the variables of the research conducted can be caused by genetic factors and environmental factors. According to Aharizad et al [17], morphological diversity does not always occur due to genetic diversity, but the interaction between genetic factors and environmental factors. Environmental conditions that can affect plant diversity, namely, cultivation techniques and agroecology such as planting locations and competition with plants that grow around staple crops.

According to Utami et al [18], grouping plants based on morphological characters has brought many benefits in plant breeding activities in particular to see variations in germplasm and accession relationships between plants. The use of germplasm can be considered successful if from these results it can be identified as sources of genes which can then be useful in breeding programs that will later produce new superior varieties.
4. Conclusion
Pachira aquatica observed in East Java has a spreading canopy shape, leaf shape orbicularis, leaf margins palmatipartitus, tips and bases of acutus leaves, leaf length 24-35cm, leaf width 22-38cm, leaf color on the upper surface dark green, leaf color on lower surface green. young, number of leaves 5 and 7, stem shape is round, branching pattern is monopodial, stem circumference is 30 - 57cm, fruit shape is ovoid and elliptic, fruit skin color is dark green, fruit weight is 175 – 289 gram, fruit circumference is 15 – 24 cm, and number of fruits per fruit. tree 4 - 28 pieces. Based on the similarity of morphological characteristics consisting of tree morphology, leaves, stems, and fruit on 18 samples of pachira show results diversity of 0.33. At the coefficient of similarity 0.74 sampel pachira in East Java is divided into 4 groups A, B, C, and D. The division of these groups is a mixed result where in the same group not all tree samples are located in the same location. All samples in groups A and C are located in Kediri Regency. Pachira in group B are located in Kediri, Blitar, and Tulungagung districts, while group D is located in Blitar districts. The distribution of genetic diversity characters is based on their morphology. The diversity that occurs is not affected by the planting location.

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References
[1] Booth and Norman K 1983 Basic elements of landscape architectural design. (Illinois: Waveland Press)
[2] Tjitrosoepomo G 2005 Printed Plant Morphology (Yogyakarta: UGM Press)
[3] Kastono D and Istiawan N D 2019 J. Vegetalika 8 27–41
[4] Haryanti S 2010 Buletin Anotomi and Fisiologi 18 41–8
[5] Suci C W and Heddy S 2018 Jurnal Produksi Tanaman 6 161–9
[6] Biber P D 2007 J. of Agricultural, Food, and Environmental Science 1 1–12
[7] Susanto A 2008 Chlorophyll content in various plants of different ages (Surabaya: Surabaya State University Press)
[8] Dartius 2008 Basic plant physiology II (Medan: UISU Press)
[9] Ospina J A 2016 Agriculture handbook issue 721 (Columbia: Centro Internacional de Agricultura Tropical)
[10] Tjitrosoepomo G 2011 Plant morphology (Yogyakarta: Gajah Mada University Press)
[11] Marjenah 2001 J. Forestry Science “Kalimantan Jungle” 6 2
[12] Robyns A 1963 Bulletin Botanica 33 1–144
[13] Armaini, Zuhri E and Sahyoga G 2007 Applications of various applications of 2006 plant catalyst fertilizers and gibberellins on tomato plants (Licopersicum esculentum Mill) (Riau: Riau University Press)
[14] Salisbury F B and Ross C W 1995 Plant physiology (Bandung: ITB Press)
[15] Herawati R, Purwoko B S and Dewi I S 2009 J. Agron Indonesia 37 87–94
[16] Efendi R, Musa Y, Farid B M, Rahim M D, Azrai M and Pabendon M 2014 Journal Penelitian Tanaman Pangan 34 43–53
[17] Aharizad S, Rahimi M H, Moghadam M and Mohebalipour N 2012 Annals of Biological Research 3 5748–53
[18] Utami D F F, Nihayati E, Roviq M and Djumali 2019 Jurnal Produksi Tanaman 7 1617–25