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***Full Length Article***

# Morphological Characters and Phenetic Relationship of Pineapple (*Ananas comosus*) from Central Java and Riau Provinces, Indonesia

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## Abstract

Pineapple (*Ananas comosus* (L.) Merr.) is one of the agricultural commodities in Indonesia that were widely cultivated with a variety of cultivars. Riau and Central Java Provinces are among the two largest pineapple-producing provinces in Indonesia. This study aimed to identify morphological variations and determine the phenetic relationship of pineapple cultivars in Central Java and Riau Provinces. A total of 27 pineapple accessions were evaluated using 44 morphological characteristics. The pineapple accessions in Central Java and Riau Provinces belonged to three cultivars, which were 'Queen', 'Spanish' and 'Cayenne'. The highest variation in morphological characters was found in the leaves and fruit organs. Phenetic relationship produced two main clusters that separated 'Queen' and 'Spanish' from 'Cayenne'. Based on PCA scatter biplot, this study found eight new characters that can be distinguish 'Queen', 'Spanish' and 'Cayenne'. In 'Queen' and 'Spanish' clusters, the main contributing characters which were color of crown leaf spines, the spines on crown leaves, distribution of spines and sepal color. In the 'Cayenne' cluster from this study had four diagnostic characters, which were bracts color, leaf spine directions, fruit base leaf color and crown shape. This research will be encouraging several similar studies regarding pineapples both in Indonesia and in other largest pineapple-producing countries, such as Costa Rica, the Philippines and Brazil. 

**Keywords:** *Ananas comosus*; Cultivar; Morphology; Phenetic; PCA

## Introduction

Pineapple (*Ananas comosus* (L.) Merr.) is one of the fruits native to Southern Brazil and Paraguay and distributed in tropical and subtropical regions (Assumi and Jha 2021). Indonesia as a tropical country is one of the fourth largest pineapple-producing countries in the world after the Philippines, Costa Rica and Brazil (Statista 2022). The distribution of pineapple in Indonesia based on data from the Central Statistics Agency, has been distributed almost evenly throughout all regions in Indonesia. This is because the Indonesian region has agroclimatic diversity that can allow for the development of various types of plants, including pineapple (Budianingsih *et al.* 2017).

Indonesia as a tropical country has great potential in producing various agricultural commodities. Pineapple as one of the potential agricultural commodities in Indonesia, has a comparative advantage in the world export market (Wiranthi and Mubarok 2017). This made pineapple production centers in Indonesia further improve plant breeding development programs so that the great pineapple cultivation varieties can be produced as a supply of fruit export products in Indonesia. Central Java and Riau Provinces are pineapple centers in Indonesia with total production in Central Java Province 252.221.00 tons and Riau Province 214.277.00 tons (Central Statistics Agency (BPS) Riau Province 2020; Central Statistics Agency (BPS) Central Java Province 2021).

Based on the characteristics, pineapple cultivars are divided into five main groups, namely 'Spanish', 'Queen', 'Cayenne', Abacaxi and 'Maipure' (Assumi and Jha 2021). The most cultivated pineapple cultivars in Indonesia are 'Queen' and 'Cayenne'. The differences between these cultivars of pineapple can be identified through their morphological characters, such as the presence of spine on the leaves, the shape and size of the fruit, the eye profile of the fruit, the color of the fruit when ripe and the color of the fruit flesh (D'Eeckenbrugge *et al.* 2011, 2018; Assumi and Jha 2021). Based Rosmaina *et al.* (2021), pineapple cultivars identified in Riau Province consist of two groups, namely 'Queen' and 'Smooth Cayenne'.

Morphological character analysis is a classical approach used to distinguish plant cultivars and is the basis for identifying phenotypic and genotypic diversity, as well

as determining phenetic relationship in plants *(*Nisha and Radhamany 2016; Martiwi *et al.* 2020). Nisha and Radhamany (2016, 2018) reported that morphological characters in pineapple flowers and fruits can efficiently distinguish between pineapple cultivars from Kerala. Other study by Rodríguez-Alfonso *et al*. (2020) reported that 14 morphological characters of leaves, spines, fruits and crows in pineapples based on the IBPGR descriptor (1991) can be used to identify and distinguish between three pineapple cultivars in Cuba based on dendrogram results. Rosmaina *et al*. (2021) reported that 12 morphological characters of pineapple leaves, fruits and crowns were used to identify and classify two pineapple cultivars found in Riau peatlands. This is reinforced by Purnomo *et al.* (2015) which stated that morphological variability is important data describing genetic variation and can be used to identify the range of variation and morphological similarity between cultivars using cluster analysis.

Morphological identification can provide a description that can directly distinguish differences in character and superiority of a genotype (Rosmaina *et al.* 2021). According to Das *et al.* (2012), phenotypic variability in a plant population can be used as an initial estimator in determining genotypic variability in selection. Knowing the variation and phenetic relationships of plant populations can be useful for the purpose of breeding, managing, collecting, cultivating, and using in future germplasm improvement programs such as selection and hybridization (Nisha and Radhamany 2016). In addition, this research is one of the first steps in efforts to develop pineapple cultivation in Central Java and Riau Provinces which are the two largest pineapple-producing provinces in Indonesia. This study aims to identify morphological variations and determine the phenetic relationship of pineapple cultivars collected from different location in Indonesia (Central Java and Riau Provinces) and as the initial step of morphological characterization, taxonomic position and pineapple cultivar differences from different geographical areas.

## Materials and Methods

### Site and population study

Geographically, Central Java Province is located between 6° and 8° South Latitude and between 108° and 111° East Longitude, while Riau Province is between 01°31 – 02°25 South Latitude or between 100° – 105° East Longitude (Fig. 1). Central Java and Riau Provinces have a tropical climate with low to high rainfall intensity in Central Java Province with an average of 20–300 mm, while Riau Province has a low to moderate rainfall intensity with an average of 10–150 mm (BMKG 2022, 2023). Based on measurements of actual environmental factors, the air temperature in Central Java Province ranged from 24 to 30°C, 30–32°C into 30 to 32°C while in Riau Province it ranged from 30 to 32°C and the soil pH in both provinces was included in the acidic category, which ranged from 5 to 6.8.

The method used in this study was a purposive sampling method based on data from the Central Statistics Agency and information from the local community in determining the location of sampling. Observation of morphological character were conducted on 27 pineapple accessions in nine locations located in Central Java and Riau Provinces (Table 1).

### Plant materials

Sample collection was conducted in Central Java (Wonosobo, Pemalang and Magelang regencies) and Riau (Kampar and Siak regencies) Provinces (Fig. 1) for seven months, starting from October 2022 to April 2023. Sample observations were carried out in pineapple plantations owned by farmers with the criteria for pineapple plants to be sampled were 1–3 years old and were in a flowering state. A total of 27 pineapple accessions were identified based on their morphological characters (Table 1).

### Data collection

The observation were made on 44 qualitative and quantitative characters following the Pineapple Descriptor standard published by the International Board for Plant Genetic Resources (IBPGR 1991). The characters used included vegetative and generative morphological characters (Table 2).

### Data analysis

Analysis variance of quantitative characters was performed by Duncan's multiple range test ($P < 0.05$) using SPSS software. Analysis of phenetic variation and relationship based on morphological characters was performed by assigning a score to each of the observed characters based on Descriptor standard published by the International Board for Plant Genetic Resources (IBPGR 1991) and then standardized into binary data. Calculation of similarity matrix using Gower General similarity with using cluster analysis Unweighted Pair-Group Method with Arithmetic Averages (UPGMA). The results of cluster analysis are constructed in dendrogram. Principal Component Analysis (PCA) was also performed to determine the main morphological characters that contributed to distinguish each cluster. All analyses in construction of dendrogram and PCA used Multi Variate Statistical Package (MVSP) software version 3.2.

## Results

### Identification of pineapple accession from Central Java and Riau Provinces based on morphological characters

Based on the results of morphological character

**Table 1:** Accession of *Ananas comosus* (L.) Merr. found in Central Java and Riau Provinces

| Province | Accession location | Local Name | Accession Code |
|---|---|---|---|
| Central Java | Duren Sawit, Wonosobo | kopyor pineapple | JW01 |
| | Duren Sawit, Wonosobo | kopyor pineapple | JW02 |
| | Duren Sawit, Wonosobo | kopyor pineapple | JW03 |
| | Duren Sawit, Wonosobo | kopyor pineapple | JW04 |
| | Duren Sawit, Wonosobo | kopyor pineapple | JW05 |
| | Duren Sawit, Wonosobo | kopyor pineapple | JW06 |
| | Kembang Limus, Magelang | benggolo pinaepple | JM01 |
| | Kembang Limus, Magelang | benggolo pinaepple | JM02 |
| | Kembang Limus, Magelang | benggolo pinaepple | JM03 |
| | Kembang Limus, Magelang | benggolo pinaepple | JM04 |
| | Kembang Limus, Magelang | benggolo pinaepple | JM05 |
| | Kembang Limus, Magelang | benggolo pinaepple | JM06 |
| | Beluk, Pemalang | madu pineapple | JP01 |
| | Beluk, Pemalang | madu pineapple | JP02 |
| | Beluk, Pemalang | madu pineapple | JP03 |
| Riau | Kualu, Kampar | kualu pineapple | RK01 |
| | Kualu, Kampar | kualu pineapple | RK02 |
| | Kualu, Kampar | kualu pineapple | RK03 |
| | Pagaruyung, Kampar | moris pineapple | RK04 |
| | Pagaruyung, Kampar | moris pineapple | RK05 |
| | Pagaruyung, Kampar | moris pineapple | RK06 |
| | Pagaruyung, Kampar | madu pineapple | RK07 |
| | Pagaruyung, Kampar | madu pineapple | RK08 |
| | Pagaruyung, Kampar | madu pineapple | RK09 |
| | Sungai Apit, Siak | moris pineapple | RS01 |
| | Sungai Apit, Siak | moris pineapple | RS02 |
| | Sungai Apit, Siak | moris pineapple | RS03 |

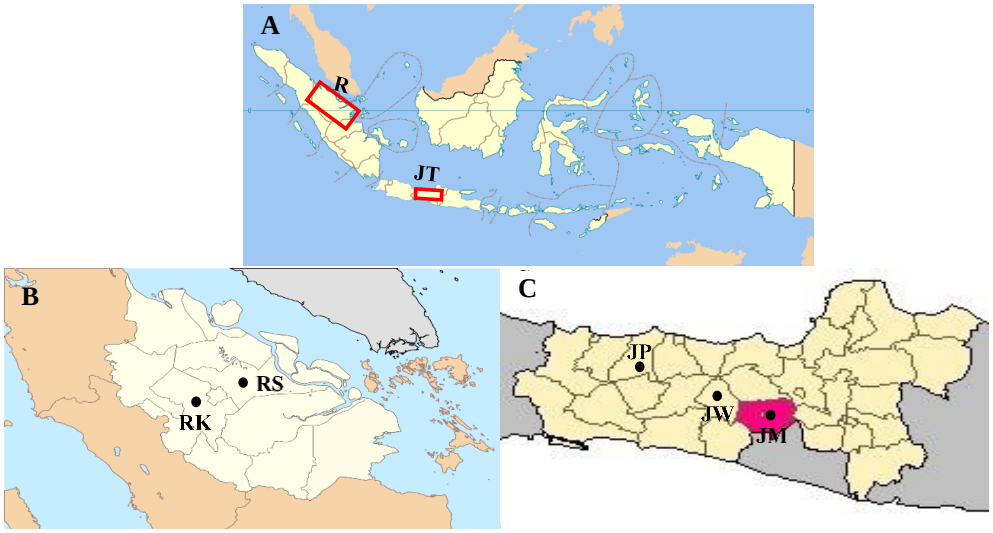


**Fig. 1:** Pineapple sampling locations in Central Java and Riau Provinces: A. Indonesia (R= Riau Province; JT= Central Java Province); B. Riau Province (RK= Kampar; 00 17' – 07.04'' LS dan 1000 - 09'58.0" BT) (RS= Siak; 10 16' 30"- 00 20' 49" LU dan 100 54' 21" 102° 10' 59" BT); C. Central Java Province (JW = Wonosobo; 70.11'.20"-70.36'.24"LS dan 1090.44'.08"-1100.04'.32" BT) (JM = Magelang; 110001'51"-110026'58" BT dan 7019'13"-7042'16" LS) (JP = Pemalang; 109°17'30"-109°40'30" BT dan 6°52'30"-7°20'11" LS)

identification analysis conducted on 27 accessions of pineapple in Central Java and Riau Provinces, it was found that there were three cultivar groups, namely 'Cayenne', 'Queen' and 'Spanish'. Of the total 15 accessions in Central Java Province, there were 12 accessions belonged to 'Cayenne' with the local names kopyor pineapple and benggolo pineapple and three accessions of 'Queen' with the local name Central Java madu pineapple, while of the 12 accessions in Riau Province, nine accessions belonged to 'Queen' with the local names kualu pineapple and moris pineapple and three accessions of 'Spanish' with the local name Riau madu pineapple.

Based on the characterization results of the three pineapple cultivars, there were some variations in character between cultivars. The color of middle leaves in the three cultivars was green, dark green, dark green with red

**Table 2:** Qualitative and quantitative characteristics in pineapple accessions

| Character number | Parameter |
|---|---|
| **Qualitative Characters** | |
| 1 | Growth habit (upright, semi upright, spreading) |
| 2 | Color of middle leaves (green, dark green, dark green with red mottling, dark green with dark red mottling) |
| 3 | Color of margin leaves (green, dark green) |
| 4 | Spine direction at the leaf base (antrose, retrose, both) |
| 5 | Direction of spines (only ascendant, only descendent, both) |
| 6 | Coloration of leaf spines (greenish, yellowish-green, reddish) |
| 7 | Distribution of spines (behind tip or near base only, behind tip and near base, along all margins, occur irregularly along both margins) |
| 8 | Presence of aerial sucker (absent, present) |
| 9 | Bractea color (dark reddish-orange with white mottling, reddish-orange with white mottling) |
| 10 | Sepal color (greenish, dark red with white mottling) |
| 11 | Peduncle color (green, dark green, yellowish-green) |
| 12 | Fruit shape (square-like, oval, round, conical, long-conical, pyramidal, cylindrical-slight taper, cylindrical-sharp taper, pyriform, reniform) |
| 13 | Fruit color when unripe (brownish-green with white mottling, dark purple-black color with white mottling) |
| 14 | Fruit color when ripe (yellow with green mottling, golden yellow, dark yellow to orange, dark yellow to orange with green mottling) |
| 15 | Eye profil (flat, normal, prominent) |
| 16 | Eye surface (small, medium, large) |
| 17 | Fruit flesh color (yellow, golden yellow, pale yellow) |
| 18 | Fruit base leaf color (yellowish-green, brownish-green, pink) |
| 19 | Color of crown basal leaves (pink, green, dark green) |
| 20 | Crown characters (single, multiple, single with crownlet) |
| 21 | Crown shape (cone, oblong blocky, acron, long-conical, lengthenend cylindrical, lengthenend cylindrical with bunchy top) |
| 22 | Color of crown leaves (dark green, dark green with red mottling) |
| 23 | Presence of spines on crown leaves (smooth, spine at the tip, spine at the middle and tip, spine along all margins, piping) |
| 24 | Color of crown leaf spines (reddish-orange, reddish, greenish, yellowish-green) |
| **Quantitative Characters** | |
| 25 | Plant height without fruit (cm) |
| 26 | Plant height with the fruit (cm) |
| 27 | Stem diameter (cm) |
| 28 | Length of longest leaf (cm) |
| 29 | Width of the widest part of the longest leaf (cm) |
| 30 | Peduncle diameter (cm) |
| 31 | Number of peduncle |
| 32 | Number of aerial suckers |
| 33 | Number of underground suckers |
| 34 | Fruit weight with the crown (g) |
| 35 | Fruit weight without crown (g) |
| 36 | Fruit diameter (cm) |
| 37 | Fruit core diameter (cm) |
| 38 | Fruit length (cm) |
| 39 | Number of fruitlets |
| 40 | Eye depth (cm) |
| 41 | Number of crown |
| 42 | Crown length (cm) |
| 43 | Crown weight (g) |
| 44 | Number of crown leaves |

mottling, and dark green with dark red mottling. 'Cayenne' cultivar had two variations in the color of middle leaves that were green, dark green with red mottling (Fig. 2a–b). 'Queen' cultivar had two color variations of the middle leaves, namely dark green and dark green with red mottling (Fig. 2c–e), while 'Spanish' had a dark green color with red mottling (Fig. 2f). The colors of leaves margin were found to be different in each cultivar. 'Queen' and 'Cayenne' had green to dark green leaves margin color (Fig. 2a–e), while 'Spanish' had dark green leave margin color (Fig. 2f).

The presence of spine in leaves was one of the characters that can clearly distinguish between pineapple cultivars. In addition, the distribution of spines and direction of leaf spines between cultivars were also varies. The direction of leaf spines of 'Cayenne' was ascendant and descendent, while 'Queen' and 'Spanish' cultivars were only ascendant. The color variations of leaf spines in the three pineapple cultivars were greenish (‘Cayenne’), yellowish-green (‘Cayenne and ‘Queen’) and reddish (‘Queen’ and ‘Spanish’). The accessions of ‘Cayenne’ had distribution of spines at the tips and bases of leaves (Fig. 2a–b), which was different from ‘Queen’ and ‘Spanish’ where the spines were distributed along all margins of leaves (Fig. 2c–f).

The bracts color showed variations, that were dark reddish-orange with white mottling on 'Cayenne' (Fig. 2g–h), and reddish-orange with white mottling on 'Queen' and 'Spanish' (Fig. 2i–l). The sepal color showed that there were

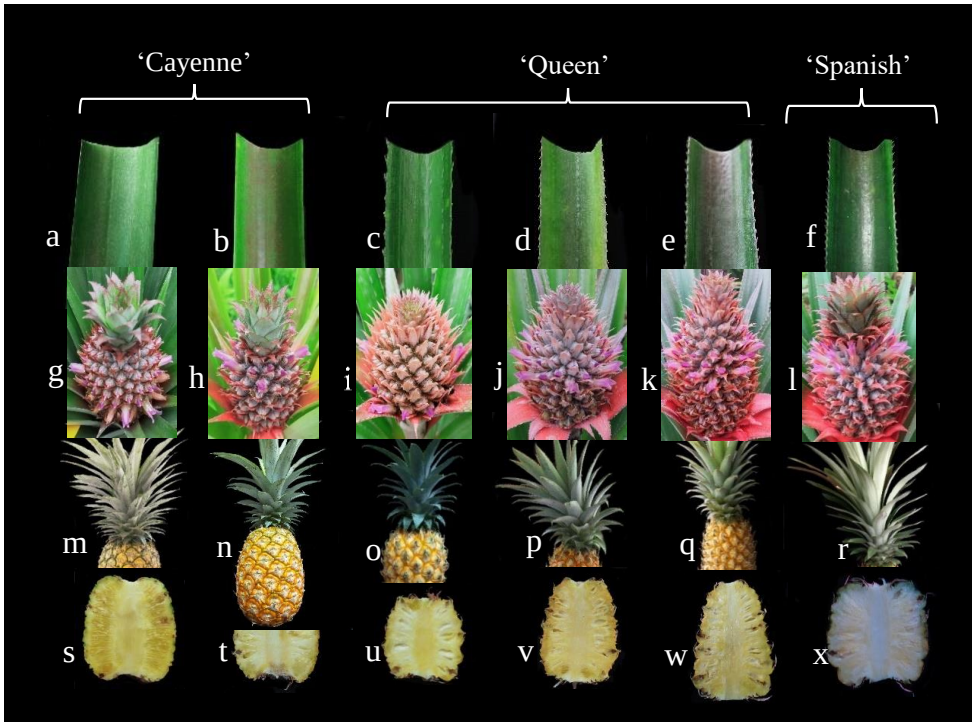


**Fig. 2:** Morphological variations of leaves (a-f), flowers (g-l), fruits (m-r), and flesh fruits (s-x) in three pineapple cultivars in Central Java and Riau Provinces: (a,g,m,s) kopyor pineapple, (b,h,n,t) benggolo pineapple, (c,i,o,u) Central Java madu pineapple, (d,j,pv) kualu pineapple, (e,k,q,w) moris pineapple, (f,l,r,x) Riau madu pineapple

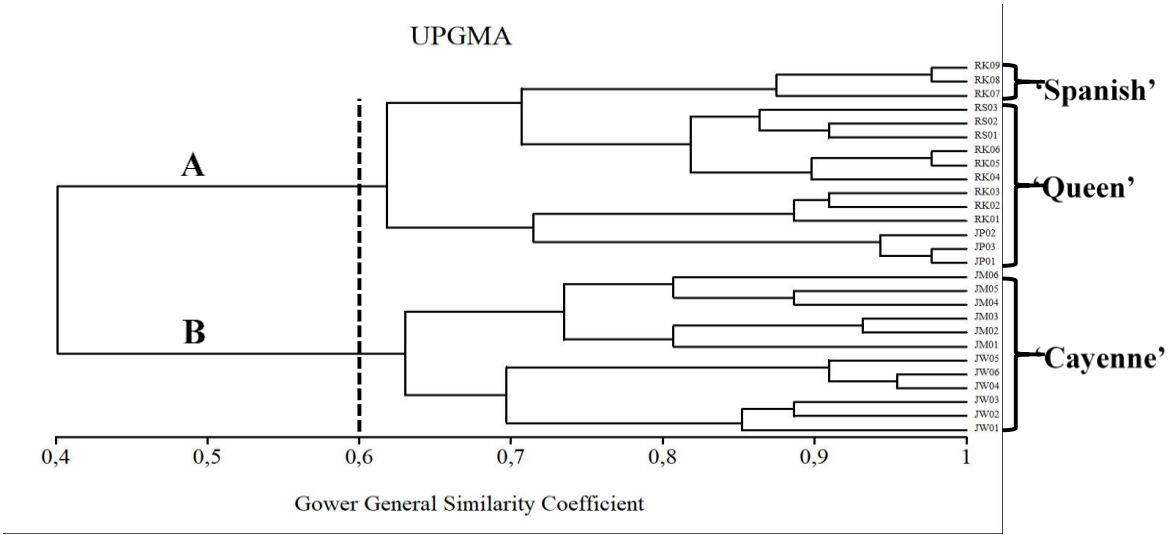


**Fig. 3:** Dendrogram of *Ananas comosus* accession from Central Java and Riau Provinces based on morphological characters

two color variations that distinguish between 'Cayenne', 'Queen' and 'Spanish'. 'Cayenne' had greenish and dark red sepals with white mottling, while 'Queen' and 'Spanish' had the same sepals color of greenish and reddish-orange with white mottling.

The fruit colors when ripe in the three cultivars had four variations (Fig. 2m–r), namely yellow with green mottling ('Cayenne'), golden yellow ('Cayenne' and 'Queen'), dark yellow to orange ('Queen') and dark yellow to orange with green mottling ('Spanish'). The color character of the fruit flesh varied between cultivar, namely yellow to golden yellow in 'Cayenne' (Fig. 2s and t), yellow in 'Queen' (Fig. 2u–w) and pale yellow in 'Spanish' (Fig. 2x). The crown shape of the three cultivars observed

includes lengthened cylindrical (‘Queen’), lengthened cylindrical with bunchy top (‘Cayenne’), long conical (‘Queen’ and ‘Spanish’) (Fig. 2m–r).

Based on the morphological characters, it showed that there were seven different characters that significantly distinguish between cultivars, which were the character of the length of longest leaf, the number of peduncle slips, fruit weight with the crown, fruit weight without the crown, fruit diameter, fruit core diameter, and eye depth that differentiate between ‘Queen’, ‘Cayenne’ and ‘Spanish’ (Table 3). ‘Spanish’ had the highest average leaf length of 93.00 ± 6.00 cm. ‘Queen’ had most, peduncle slips, while ‘Cayenne’ had the highest fruit weight with the crown, fruit weight without the crown, fruit diameter, fruit core diameter and eye depth characters compared to other two cultivars.

**Phenetic relationship of pineapple accession in Central Java and Riau Provinces**

Cluster analysis based on 44 morphological characters of 27 pineapple accessions from Central Java and Riau provinces grouped into two main clusters, clusters A and B at the phenon line of 60% similarity index (Fig. 3). Cluster A consisted of 15 accessions, which were 12 accessions of ‘Queen’ (JP01-JP03, RK01-RK06, RS01-RS03) originating from Central Java (Pemalang) and Riau (Kampar and Siak) Provinces and three accessions of ‘Spanish’ (RK07-RK09) originating from Riau Province (Kampar), while cluster B consisted of 12 accessions of ‘Cayenne’ (JW01-JW06, JM01-JM06) originating from Central Java Province (Wonosobo and Magelang) (Fig. 3).

The scatter biplot graph of the PCA results based on qualitative and quantitative morphological characters were grouped into two main clusters (Fig. 4). The results of this grouping were also similar to the results of the dendrogram showing two main clusters (Fig. 3). Cluster A consisted of 15 accessions of ‘Queen’ dan ‘Spanish’ (JP01-JP03, RK01-RK09, RS01-RS03) grouped based on the four main contributing characters, which were reddish orange to reddish color of crown leaf spines, the spines on crown leaves along all margins, distribution of spines along all margins, and sepal color was greenish and reddish-orange with white mottling. In cluster B consisted of 12 accessions of ‘Cayenne’ (JW01-JW06, JM01-JM06) grouped based on the four main contributing characters, which were bracts color was dark reddish-orange with white mottling, ascendant and descendent leaf spine direction, yellowish-green fruit base leaf color and crown shape was lengthened cylindrical with bunchy top (Table 4).

Principal Component Analysis (PCA) based on the 44 morphological characters showed two principal components (PC1, PC2) with 24 characters that contributed to form the clusters, which a total value of the cumulative variation of 55.14%. The first principal component (PC1) accounted for variation of 37.55%, which the characters that contributed to the variation were spine direction at the leaf base, direction of spines, coloration of leaf spines, distribution of spines, bracts color, sepal color, fruit color when ripe, eye profile, fruit base leaf color, color of crown basal leaves, crown shape, color of crown leaves, presence of spines on crown leaves and color of crown leaf spines. The second principal component (PC2) accounted for variation of 17.58%, which the characters that contributed to the variation were color of margin leaves, presence of aerial sucker, fruit shape, plant height with the fruit, stem diameter, width of the widest part of the longest leaf, peduncle diameter, fruit length, number of fruitlets and number of crown leaves (Table 4).

Based on the PCA results, an identification key was made to differentiate between Cayenne’, ‘Queen’ and ‘Spanish’ using qualitative morphological characters that contribute to grouping accessions into three cultivars The following was key identification for pineapple cultivars from Central Java and Riau Provinces:

| | | |
|---|---|---|
| 1a. | Distribution of spines along all margins of the leaves, the sepal color is greenish and reddish-orange with white mottling, reddish orange to reddish color of crown leaf spines, spines on the crown leaves along all margins. | Go to 2 |
| 1b. | Distribution of spines only at the tip and base of the leaves, the sepal color is greenish and dark red with white mottling, green and yellowish-green color of crown leaf spines, spines on the crown leaves at the middle and tip. | ‘Cayenne’ |
| 2a. | Conical and long conical fruit shape, fruit flesh color is yellow, fruit color when ripe is golden yellow and dark yellow to orange. | ‘Queen’ |
| 2b. | Rounded fruit shape, fruit flesh color is pale yellow, fruit color when ripe is dark yellow to orange with green mottling. | ‘Spanish’ |

## Discussion

The 27 pineapple accessions from Central Java and Riau Provinces based on morphological characters grouped into three cultivars, namely ‘Cayenne’, ‘Queen’ and ‘Spanish’. The identification of pineapple cultivars from Central Java Province has never been carried out, while the identification of pineapple cultivars in Riau has been reported previously by Amda *et al.* (2020) and Rosmaina *et al.* (2021), that there were three cultivars, namely 'Cayenne', 'Queen' and 'Abacaxi'. The results of this study provide additional information that 'Spanish' as one type of pineapple cultivar is also found in Riau Province. 'Spanish' has previously been reported in North Sumatra and West Sumatra (Hadiati *et al.* 2003). In addition, 'Spanish' was also found in other countries such as Cuba (Rodríguez-Alfonso *et al.* 2020) and Thailand (Vanijajiva 2012).

Based on the quantitative morphological characters identified, there were seven characters that could significantly distinguish between ‘Cayenne’, ‘Queen’ and ‘Spanish’. In previous studies, these seven characters were shown to significantly differentiate between pineapple cultivars (Hadiati *et al.* 2003; Rodríguez-Alfonso *et al.* 2020; Rosmaina *et al.* 2021). Both qualitative and

**Table 3:** Twenty character variations of quantitative pineapple from Central Java and Riau Provinces

| No. | Characters | Cayenne | Queen | Spanish |
|---|---|---|---|---|
| 1 | Plant height without fruit | 88.25 ± 15.48a | 79.00 ± 7.65a | 78.67 ± 0.57a |
| 2 | Plant height with the fruit | 71.92 ± 10.36a | 68.08 ± 10.74a | 69.00 ± 2.00a |
| 3 | Stem diameter | 6.28 ± 0.44a | 5.42 ± 0.99a | 6.03 ± 0.23a |
| **4** | **Length of longest leaf** | **85.38 ± 13.00 ab** | **79.25 ± 6.02a** | **93.00 ± 6.00b** |
| 5 | Width of the widest part of the longest leaf | 5.33 ± 0.77a | 4.29 ± 1.26a | 5.00 ± 0.00a |
| 6 | Peduncle diameter | 2.53 ± 0.41a | 2.20 ± 0.63a | 2.63 ± 0.11a |
| **7** | **Number of peduncle slip** | **0.17 ± 0.57a** | **2.08 ± 2.19b** | **0.00 ± 0.00a** |
| 8 | Number of aerial suckers | 1.67 ± 2.34a | 3.25 ± 3.27a | 0.67 ± 0.57a |
| 9 | Number of underground suckers | 0.33 ± 0.49a | 1.00 ± 1.12a | 0.00 ± 0.00a |
| **10** | **Fruit weight with the crown** | **1934.08 ± 912.27b** | **970.08 ± 443.12a** | **1573.33 ± 75.43ab** |
| **11** | **Fruit weight without crown** | **1653.25 ± 775.24b** | **819.17 ± 394.78a** | **1339.33 ± 155.28ab** |
| **12** | **Fruit diameter** | **12.79 ± 2.03b** | **9.77 ± 1.33a** | **12.06 ± 0.11b** |
| **13** | **Fruit core diameter** | **3.08 ± 1.04b** | **2.04 ± 0.49a** | **2.63 ± 0.11ab** |
| 14 | Fruit length | 15.45 ± 2.58a | 14.15 ± 4.22a | 12.33 ± 0.57a |
| 15 | Number of fruitlets | 136 ± 24,81a | 127.50 ± 31.13a | 121.33 ± 5.13a |
| **16** | **Eye depth** | **3.04 ± 0.72b** | **1.83 ± 0.24a** | **2.06 ± 0.11a** |
| 17 | Number of crowns | 1.08 ± 0.28a | 1.00 ± 0.00a | 1.00 ± 0.00a |
| 18 | Crown length | 22.83 ± 3.81a | 17.50 ± 5.79a | 22.33 ± 13.57a |
| 19 | Crown weight | 276.00 ± 156.90a | 149.25 ± 75.15a | 231.33 ± 198.89a |
| 20 | Number of crown leaves | 111.42 ± 17.34a | 109.92 ± 35.23a | 105.67 ± 15.04a |

Numbers followed by the same letter in a row indicate no significant difference in Duncan test at a significant level of 0.05%; Bold character indicates the significant difference in each cultivar

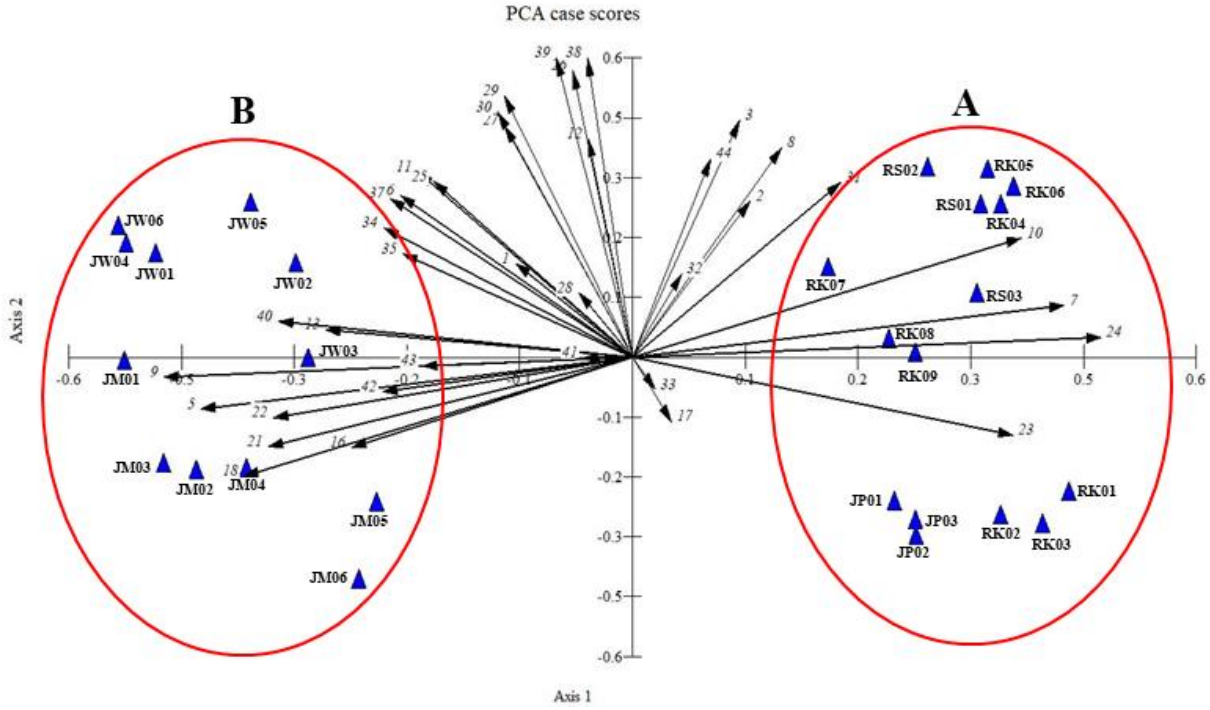


**Fig. 4:** Scatter biplot PCA 27 accessions of pineapple from Central Java and Riau Provinces based on morphological characters

quantitative characters can be important characters to distinguish pineapple cultivars. However, quantitative characters have the disadvantage of being more easily influenced by environmental factors, the genotype, their interactions or both. The qualitative characters were controlled by simple genes while the quantitative characters were controlled by many genes (Rosmaina *et al.* 2019).

Pineapple cultivars from Central Java and Riau Provinces showed the highest variation in morphological characters on leaves and fruits. These characters on leaves and fruits can distinguish between 'Queen', 'Spanish and 'Cayenne'. This was supported by Burhooa and Ranghoo-Sanmukhiya (2012), who stated that pineapple leaves and fruits can be the main distinguishing morphological character between cultivars. The description of differences of cultivar can be useful for the purpose of breeding and

**Table 4:** Eigenvalue, percentage of variance, cumulative percentage and character loading on the first three principal components

| Character Number | Morphological Characters | Principal Component (PC) | |
|---|---|---|---|
| | | PC 1 | PC 2 |
| 1. | Growth habit | -0,06 | 0,10 |
| 2. | Color of middle leaves | 0,06 | 0,16 |
| 3. | Color of margin leaves | 0,06 | **0,24** |
| 4. | Spine direction at the leaf base | **-0,24** | -0,05 |
| **5.** | **Direction of spines** | **-0,24** | -0,05 |
| 6. | Coloration of leaf spines | **0,21** | 0,12 |
| **7.** | **Distribution of spines** | **0,24** | 0,05 |
| 8. | Presence of aerial sucker | 0,08 | **0,22** |
| **9.** | **Bracts color** | **-0,26** | -0,02 |
| **10.** | **Sepal color** | **0,21** | 0,12 |
| 11. | Peduncle color | -0,12 | 0,19 |
| 12. | Fruit shape | -0,02 | **0,23** |
| 13. | Fruit color when unripe | -0,17 | 0,03 |
| 14. | Fruit color when ripe | **0,21** | -0,08 |
| 15. | Eye profil | **0,26** | 0,02 |
| 16. | Eye surface | -0,15 | -0,09 |
| 17. | Fruit flesh color | 0,02 | -0,07 |
| **18.** | **Fruit base leaf color** | **-0,21** | -0,12 |
| 19. | Color of crown basal leaves | **0,26** | 0,02 |
| 20. | Crown characters | -0,03 | 0,00 |
| **21.** | **Crown shape** | **-0,20** | -0,09 |
| **22.** | **Color of crown leaves** | **-0,20** | -0,06 |
| **23.** | **Presence of spines on crown leaves** | **0,21** | -0,08 |
| 24. | Color of crown leaf spines | **0,26** | 0,02 |
| 25. | Plant height without fruit (cm) | -0,11 | 0,18 |
| 26. | Plant height with the fruit (cm) | -0,03 | **0,30** |
| 27. | Stem diameter (cm) | -0,07 | **0,24** |
| 28. | Length of longest leaf (cm) | -0,03 | 0,07 |
| 29. | Width of the widest part of the longest leaf (cm) | -0,07 | **0,27** |
| 30. | Peduncle diameter (cm) | -0,07 | **0,25** |
| 31. | Number of peduncle | 0,11 | 0,18 |
| 32. | Number of aerial suckers | 0,03 | 0,09 |
| 33. | Number of underground suckers | 0,01 | -0,03 |
| 34. | Fruit weight with the crown (g) | -0,14 | 0,13 |
| 35. | Fruit weight without crown (g) | -0,13 | 0,11 |
| 36. | Fruit diameter (cm) | -0,13 | 0,17 |
| 37. | Fruit core diameter (cm) | -0,13 | 0,16 |
| 38. | Fruit length (cm) | -0,03 | **0,31** |
| 39. | Number of fruitlets | -0,04 | **0,31** |
| 40. | Eye depth | -0,19 | 0,04 |
| 41. | Number of crown | -0,03 | 0,00 |
| 42. | Crown length (cm) | -0,14 | -0,04 |
| 43. | Crown weight (g) | -0,12 | -0,01 |
| 44. | Number of crown leaves | 0,04 | **0,21** |
| Eigen value | | 3,75 | 1,75 |
| Variance (%) | | 37,55 | 17,58 |
| Cumulative variance (%) | | 37,55 | 55,14 |

**Note:** Bold character indicates main contributing character that distinguish between ‘Queen’, ‘Spanish’ and ‘Cayenne’

managing germplasm in the future (Nisha and Radhamany 2016; Rosmaina *et al.* 2021). According to Adje *et al.* (2019), the morphological variation among pineapple cultivars is important for clonal selection, which could be used for fruit quality and uniformity.

This study found that the 'Queen' and 'Spanish' were grouped into one cluster and separated them from 'Cayenne' based on the dendrogram and scatter biplot graph PCA. Rodríguez-Alfonso *et al*. (2020) also reported that 'Cayenne' pineapple cultivar from Cuba separated from 'Spanish' and Rosmaina *et al*. (2021) reported that pineapple cultivar ‘Queen’ from Riau, Indonesia separated from “Cayenne”. This study showed that 'Queen' and 'Spanish' had a higher similarity value than 'Cayenne'.

The characters that played an important role in grouping based on the PCA scatter biplot graph was shown with a long arrow line and each accession was marked with a triangle. The arrow line showed the strength of the character's influence, so the longer the arrow line, the higher the character's contribution to the cluster (Huqe *et al.* 2021). Based on PCA scatter biplot, this study found eight new characters that can distinguish ‘Queen’, ‘Spanish’ and ‘Cayenne’. In 'Queen' and 'Spanish' clusters, the four main contributing characters were color of crown leaf spines, the spines on crown leaves, distribution of spines and sepal color. These four main characters has never been reported

before in clustering 'Queen' and 'Spanish', so they can be used to recognize 'Queen' and 'Spanish'. 'Cayenne' cluster from this study had four diagnostic characters, which were bracts color, leaf spine directions, fruit base leaf color and crown shape. From previous studies, Rodríguez-Alfonso *et al.* 2020 reported that the diagnostic character of 'Cayenne' were fruit shape and eye form. In addition, Burhooa and Ranghoo-Sanmukhiya (2012) stated that the absent of spines that were only found at the base and tips of leaves were the most obvious distinguishing characters to distinguish 'Cayenne' them from other cultivars. The distribution of spines along all margins or only at the tips and bases of leaves in pineapple was one of the main distinguishing characters between two clusters A and B which were controlled by a pair of alleles, namely dominant and recessive alleles. Pineapple with spines along all margins of the leaves have a recessive homozygous allele, while spines only at the tip and base of the leaf have a dominant homozygous or heterozygous allele (Hadiati *et al.* 2003; Sripaoraya 2009). The findings of this study add characters that are useful for distinguishing 'Queen'. 'Spanish' and 'Cayenne'.

## Conclusion

Pineapple accessions in Central Java and Riau Provinces belonged to three cultivars, which were 'Queen', 'Spanish', and 'Cayenne', with the highest variation and distinguishing characteristics indicated by the leaves and fruits. Phenetic relationship produced two main clusters that separated 'Queen' and 'Spanish' from 'Cayenne'. Based on Principal Component Analysis result, there were eight main contributing characters that grouped three cultivars from Central Java and Riau Provinces into two main clusters.

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## Author Contributions

All authors participated in the discussion of the research results, and writing of this paper.

## Conflict of Interest

The authors declared no conflict of interest in this research.

## Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

## Ethics Approval

Not applicable to this paper.

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