

# Minimal number of morphoagronomic characters required for the identification of pineapple (*Ananas comosus*) cultivars in peatlands of Riau, Indonesia

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Manuscript received: 24 July 2021. Revision accepted: 24 August 2021.

**Abstract.** Rosmaina, Elfianis R, Almaksur A, Zulfahmi. 2021. Minimal number of morphoagronomic characters required for the identification of pineapple (*Ananas comosus*) cultivars in peatlands of Riau, Indonesia. *Biodiversitas* 22: 3854-3862. Pineapple (*Ananas comosus* L Merr) is a tropical fruit that has high economic value. In Riau Province, Indonesia, pineapples grow and produce well on various types of land, including the highly acidic peatland. There are many types of pineapples grown by from generation to generation, but so far, there have been no reports regarding the diversity of pineapples in peatlands. This study aimed to determine the minimal number of characters distinguishing pineapple morphological and agronomic characters in peatlands. The observations were done on 24 local genotypes of pineapple in peatlands. Characterization was carried out on 49 morphological and agronomic characters according to the Pineapple descriptor from the International Board for Plant Genetic Resources (IBPGR). The data were analyzed by Multivariate Analysis, in which the principal components analysis was used for qualitative and quantitative traits. Based on the results of this study, there were at least 12 characters proposed to describe pineapple in peatlands, viz. seven qualitative characters (fruit base leaf color (collar), fruit shape, bractea color, fruit eye profile, fruit eye surface, flesh color, crown attachment to fruit) and five quantitative characters (fruit weight, fruit flesh weight, plant height, number of leaves and leaf length). Out of the 49 traits observed, 12 selected characters can be used as a minimal number of characters that can be used to identify pineapple cultivars on peatland. The findings of this research are rewarding for the conservation and management of genetic resources, selection, and breeding activities of pineapple plants.

**Keywords:** Multivariate analysis, peatland, pineapple descriptor, qualitative and quantitative traits

## INTRODUCTION

Pineapple (*Ananas comosus* [L.] Merr.) is a tropical fruit from the Bromeliaceae family with high economic value after banana. Indonesia is one of the largest pineapple-producing countries globally, after Costa Rica, the Philippines, and Brazil. Indonesia pineapple production has increased from 1.8 million tons in 2018 to 2.19 million tons in 2019, or an increase of 22% (FAO 2020). One of the pineapple-producing areas in Indonesia is Riau Province. Riau has several local pineapple cultivars that have been cultivated for generations. Generally, Pineapple in Riau province is cultivated on peatland with a high acidity level with a pH ranging from 2.5 to 4.5. Riau Province has the most extensive peatland in Indonesia of about 4 million hectares, and pineapple cultivation is carried out in that area. There are various types of pineapples that farmers have planted from generation to generation, but so far, there have been no reports regarding the diversity of pineapples in peatlands. Farmers often planted several pineapple cultivars simultaneously on the same land so that natural crossing can occur between cultivars, which increases the pineapple diversity in the field.

Genetic diversity can be determined through morphological, molecular, and chemical characterization. Morphological characterization is the primary identification used for plant identification because it is a tangible manifestation of phenotypic diversity. Although this technique has several weaknesses, such as it depends on the season and growth phase of the plant, the morphological identification provides an overview that can directly be distinguished from differences in characters and advantages of a genotype. The use of morphological characters in pineapple identification has been reported by Hadiati et al. (2003), Machado et al. (2011), Burhooa & Ranghoo-sanmukhiya (2012), Hernita et al. (2019), and Rodriguez-alfonso et al. (2020) using some of the available characters. The use of many characters in identification often results in excessive information (Daher et al. 1997) because of the many correlated characters or low genetic diversity. In addition, many of the characters measured are often considered less effective in distinguishing cultivars, for example in chili. Silva et al. (2013) reported 30 characters from 56 characters that are considered effective in distinguishing chilli accession, for casava, there were 13 characters out of 22 characters for cultivar identification

(Silva et al. 2017), in pineapples, it was reported that there were 14 characters out of 115 characters which were considered effective in distinguishing genotypes (Rodriguez-alfonso et al. 2020), and in *wild Rosa* of 56 characters only ten characters were effective in distinguishing genotypes (Singh et al. 2020). Therefore, the determination of the minimal number of characters for cultivar identification is essential. Besides reducing costs and time, it also speeds up the selection process in plant breeding.

The multivariate analysis technique effectively differentiates characters that play an essential role and removes characters considered less relevant. This technique has been widely used, such as in tomatoes (Goncalver et al. 2009), chili (Ortiz et al. 2010; Sudre et al. 2010; Silva et al. 2017), in wild Rosa (Singh et al. 2020), and Pineapple (Rodriguez-alfonso et al. 2020). This study aimed to identify the minimal number of qualitative and quantitative characters contributing to the diversity of pineapple cultivars on peatlands.

## MATERIALS AND METHODS

### Study area

This research was conducted in six districts in Riau Province, including Kampar, Dumai, Rokan Hilir, Indragiri Hilir, Siak, and Bengkalis districts (Figure 1). This research was conducted in 2019-2020. The samples used in this

study were pineapples cultivated for generations by farmers in 24 gardens spread over six districts of pineapple production centers in Riau Province.

### Procedures

Observations were made on 46 traits (20 qualitative and 26 quantitative characters) following the Pineapple Descriptor standard published by the International Board for Plant Genetic Resources (IBPGR 1991) on pineapple plants that entered the flowering phase until harvest. Each genotype was observed as many as 30 plants so that there were 720 samples plants. The qualitative characters followed included growth type, plant height, stem diameter, stem color, leaf shape, leaf color, leaf length, leaf width, number of leaves, distribution of spine, presence of bractea, bractea color, petal color, sepal color, leaf base of fruit color (collar), fruit shape, fruit color when unripe, fruit color when ripe, fruit eye profile, fruit eye surface, flesh color, fruit peduncle color and, crown leaf color and crown attachment to fruits. The measurement of quantitative characters included plant height, leaf length, leaf width, number of suckers, number of shoots, number of slip, stem diameter, fruit weight with crown, fruit weight without crown, flesh weight, fruit length, fruit diameter, peduncle diameter, eye depth, core diameter, crown height, crown weight, number of crown leaf, fruit weight/crown weight ratio, total soluble solids (TSS), titratable acidity (TA), vitamin C content, TSS/TA ratio, water content, and edible part.



**Figure 1** Sampling location of 24 genotypes of Pineapple in Riau province. KPR = Kampar District (101° 15'58"E, 0° 25'44"N), RHR= Rokan Hilir District (101°3'7.1"E, 1° 37'1.2"N), DM = Dumai City (101°30'27,8"E, 1°37'47"N), BKL= Bengkalis District (102° 03' 34.2"W, 01° 36' 12.1"N), SK = Siak District (102°11'10"W, 1°4'54"N), IDH = Indragiri Hilir District (102°50'56.47"E, 0°33'16.49"S)

### Data analysis

The selection of minimal number of characters that contribute to diversity was carried out using the principal component analysis (PCA) employing the Pearson correlation matrix. The character that has the most considerable vector value is the character that contributes to diversity. Data processing and scatter plot creation was carried out using statistical software SAS (Statistics Analysis System) ver.9.0. The UPGMA dendrogram was constructed using MPSV software.

## RESULTS AND DISCUSSION

### Accessions Identification

Plant identification was carried out in the farmer's farm at the physiological maturity stage. Based on the identification carried out, the 24 pineapple accessions were classified into two cultivars, i.e., *Queen* pineapple and *Smooth cayenne* pineapple. The *Queen* pineapple consists of two types with the local name "Kualu pineapple" (Figure 2.D, H, L, P, T) and "Bubur pineapple" (Figure 2.B, F, J, N, R), whereas *Smooth cayenne* pineapple has two local names, i.e., Madu pineapple (Figure 2.C, G, K, O, S) and Bangka pineapple (Figure 2.A, E, I, M, Q). Based on visual observation, pineapple cultivated in the peatland can be distinguished based on the presence of spines, fruit shape, collar color, bractea color, unripe fruit color, fruit color at ripening, and flesh color. The qualitative characters are generally controlled by major genes (1 or 2 genes), which expression are less influenced by environmental factors. These traits controlled by major genes include the distribution of spines and flower color. Both characters are controlled by 1-2 genes (Hu et al. 2021). Furthermore, Burhooa & Ranghoo-Sanmukhiya (2012) reported that leaf shape and fruit shape could clearly distinguish pineapples.

*Queen* cultivar is the most widely cultivated pineapple species in Riau Province; of the 24 locations observed, only two sites have *Smooth cayenne* cultivars, namely Kempas Jaya and Pedekik, while 22 other sites cultivated the *Queen* cultivar. *Queen* cultivars have spines throughout the leaves, with 64-101 cm in leaf length, small and prominent fruit eyes, 0.6-1.7 kg fruit size varies, Total soluble solid ranged of 11-17°Brix. Generally, *Queen* has a cylindrical slight taper shape and a sharp cylindrical taper. This study found two types of *Queen* cultivars (Bubur and Kualu) with contrasting qualitative and quantitative characters. Differences in qualitative characters of Bubur with the others *Queen* can be seen from the attachment of the crown to the fruit (without a neck or short neck). Bubur genotype has a short neck (Figure 2.N), while the other genotypes are without neck, the color of the fruit is bright green (Figure 2.N), greenish-yellow of the collar (Figure 2.J) and white flesh (Figure 2.R).

This study found three genotypes of *Smooth Cayenne*, namely G10, G11, and G20. *Smooth cayenne* pineapples generally have piping/spineless leaves. The genotypes G10 and G20, which belong to the *Smooth cayenne* group, have spines between their leaves, with relatively wide leaf sizes (4-8 cm), have cylindrical fruit, fruit size ranges from 1.3-2.2 kg, eyes wide and flat, TSS range of 13-19 °Brix) Bangka genotype (G11) is *Smooth cayenne* cultivars without spines in leaves, dark red-purple bractea and collar, it has strong purple gradation, and its fruit size (around 0.9-1.7 kg) is smaller than that of G10 and G20, TSS. 9-15 °Brix. *Smooth cayenne* pineapple is suitable for processed products or canned pineapple. Generally, the color of the collar on *Smooth cayenne* in peat areas is intense red to dark red-purple, fruit weight can reach 4 kg/fruit (Adje et al. 2019). Furthermore, Chan et al. (2003) reported *Smooth cayenne's* average fruit weight of 1.88 kg. Pineapple have been domesticated for a long time through vegetative propagation. The results of several studies indicate that sexual recombination (both naturally and through artificial hybridization) and somatic mutations play an important role in phenotypic diversity in pineapple plants (Sripaoraya 2009; Souza et al. 2011; Chen et al. 2019).

### Qualitative character

Out of the eighteen qualitative characters observed, only 12 were different among the genotypes, while the rest six characters were the same between the 24 genotypes observed. The contrasting differences among genotypes can be seen in the distribution of spines, leaf color, stem color, bractea color, petal color, leaf color on basal fruit (collar), fruit shape, fruit color when unripe, eye profile, eye surface, flesh color, peduncle color, fruit color when ripe and crown shape. Qualitative characters are generally less influenced by the environment. Still, they are controlled by the major genes of one or several genes. The inheritance of qualitative traits is generally also straight forward, which can be studied through the genetic segregation of the offspring.

A pair of alleles control the of spines on pineapple leaves, namely *s* allele (recessive) and *S* allele (dominant). The spines along the leaves have a homozygous recessive allele (*ss*), while non-spine leaves have a heterozygous allele (*Ss*), the homozygous dominant allele (*SS*) has spine leaf tips (Collins 1968; Sripaoraya 2009). The results of a recent study by Junior et al. (2021) reported that the spine character on the leaves are controlled by two loci, each of which had a pair of alleles, where the spineless leaf had the genotype "*Ppss*" heterozygous P locus and homozygous recessive *s* locus. Spiny leaf has three phenotypes of spiny along with the leaf (*ppss*), Spiny-tip (*ppSS*), piping/spineless (*PpSS*; *PpSs*; *Ppss*) Urasaki et al. 2015). The shape of the spines on the leaves are divided into spiny-tip, spiny, piping, smooth, and sandpaper (Coppens d'Eeckenbrugge and Sanewski 2011). However, the pineapple cultivated by farmers in Riau peatlands only has two leaves type, namely piping, and spiny leaf.



**Figure 2.** Diversity of the qualitative and morphological characters of Pineapple in Riau peatlands. Diversity of color and leaf shape [A] leaf shape and color of Bangka [B] leaf shape and color of Bubur [C] leaf shape and color of Gemilang [D] leaf shape and color of Kualu, [E] flower of Bangka, [F] Flower of Bubur, [G] flower of Gemilang, [H] flower of Kualu, [I] young fruits and color of collar Bangka genotype [J] young fruits and color of collar Bubur genotype, [K] young fruits and color of collar Gemilang genotype, [L] young fruits and color of collar Kualu genotype, [M] mature fruit and fruit shape of Bangka, [N] mature fruit and fruit shape of Bubur, [O] mature fruit and fruit shape of Gemilang, [P] mature fruit and fruit shape of Kualu, [Q] flesh color Bangka, [R] flesh color of Bubur, [S] flesh color of Gemilang, and [T] flesh color of Kualu.

The Bangka (G11) and Madu (G10) genotypes are *Smooth cayenne* cultivar with green leaf color of green and dark green to reddish-green. The difference between these two genotypes lays in the leaf line. Bangka genotype has a darker outer line, while Madu pineapple has a dark outer and light outline in the middle of the leaf (Figures 2.B). Bubur genotype has a light green or bright green leaf color

compared to other genotypes. Other characters that look contrast are the color of the sepals, the color of the bracts, and the color of the collar (leaf base on fruit). In general, the sepal color has a purple gradation. It's just that the level of color density was different, *Smooth cayenne* cultivar has a solid purple color and Queen cultivar has a pale purple color. The bractea color looks very contrasting in the

observed genotypes. Bangka and Madu (*Smooth cayenne* cultivar) have a solid red bractea color, while the queen cultivar has a yellowish-orange bractea color. The collar color of *Smooth cayenne* cultivar is dark red (Figure 2.I, K), while that of the queen cultivar is pinkish to orange (Figure 2.L).

The fruit shape was apparently varied and easy to distinguish. Generally, the Smooth cayenne cultivar has a conical shape, while the Queen cultivar has a cylindrical fruit shape with a slightly tapered tip to a sharp point. The conical shape is the most preferred in the market (Junior et al. 2021). Bubur genotype is the only type that has a short neck. The flesh color also varied between the tested genotypes which the Bangka genotype has a golden yellow flesh color (Figure 2.Q), Madu genotype has a deep golden yellow flesh color (Figure 2.S), Kualu genotype has pale yellow color (Figure 2.T). A contrasting difference is found in Bubur genotype that has white flesh color (Figure 2.R).

### Principal Component Analysis (PCA) of Qualitative Characters

Principle component analysis (PCA) is used to investigate how much the influence each character has on diversity in the population. The main component (PC) considered is the PC having an eigenvalue larger than one. Of the 18 characters observed, 12 characters differed among populations. PCA results of qualitative characters showed three main components (PC1-PC3) with a total variability of 91.66%. The first principal component (PC1) contributed 56.04% variation, which the characters that contributed to the variation were the color of the collar and fruit shape. The second principal component (PC2) contributed to the total variation of 29.47%, which the contributed main characters were bractea color, collar color, eye profile, and eye surface. The third principal component (PC3) contributed to the total variation of 6.14%, with the main characters playing a role were flesh color, the eye surface, and the presence or absence of a neck on the fruit. Out of the 12 qualitative characters, the collar color, fruit shape, bracts color, eye profile, eye surface, and flesh color provided a significant contribution to the diversity of Pineapple in Peatland (Table 1), so that these characters are critical to be considered in pineapple cultivar identification. Rodríguez-Alfonso et al. (2020) reported qualitative characters that contributed to pineapple diversity in Cuban, namely the eye profile, fruit shape, fruit color when ripe, and flesh color with PC1 and PC2 contribution of 61.06% and 21.68%, respectively. In addition, Adje et al. (2019) reported that the bractea color and fruit shape contributed to the diversity and could distinguish pineapple cultivars. Characters that contributed to diversity should be a concern in the identification of Pineapple (Bartholomew et al. 2003; Bartholomew et al. 2010).

PCA scatter plots were used to classify each genotype based on the 12 qualitative characters observed. The results of the PCA scatter plot separated the 24 tested genotypes into three groups (Figure 2). The first group consisted of three genotypes of *Smooth cayenne* cultivars, namely G20, G10, and G11. The genotypes in the first group have a conical fruit shape, red bractea, and red to dark red color of collar, golden yellow to deep golden yellow of the flesh,

large and flat of eyes. The second group consisted of eight genotypes, of which five accessions G12, G13, G14, G15, and G16 were *Queen* cultivars originating from Siak Regency, while three accessions (G17, G18, and G19) were included in *Queen* cultivars originating from Bengkalis Regency. The genotypes in the second group have a reddish orange bractea color, cylindrical slightly tapered ends fruit shape, yellowish green-collar color, small and prominent fruit eyes, and yellow, pale flesh color. These data indicated that the *Queen* cultivar originating from Siak and Bengkalis has similar morphologically, predominantly qualitative characters.

Based on this study's results, qualitative characters can clearly distinguish among cultivars, which the Queen cultivar is separated far apart from the Smooth Cayenne cultivar. This confirms that the qualitative characters are highly effective in determining plant cultivars.

Qualitative characters are relatively stable and dominantly influenced by genetic factor and less influenced by the environment factor. Another factor affecting the stability of qualitative characters in pineapples is high self-incompatibility, so *selfing* rarely occurs. *Selfing* on pineapples was reported to fail in forming seeds but crosses different cultivars succeeded in seeds formation (Chan 1993; Sripaoraya 2009), and vegetative propagation of pineapple will result in the character of the clone being the same as the parent. *Ananas comosus* has *self-incompatible* properties that have been cultivated for a long time through vegetative propagation. It is suspected that this is a domestication strategy for edible pineapple (Coppens d'Eeckenbrugge et al. 1993). *Self-incompatible* pineapples are gametophytic, interfering with pollen tube growth (Brewbaker and Gorrez 1967). Qualitative characters are generally less influenced by the environment. Still, they are more influenced by the simple genetics of one or several genes. Some simple qualitative characters reported include the color of papaya leaves (Nascimento et al. 2019), flower color and seed growing habits (Yadav et al. 2007), the presence or absence of spines on pineapple leaves (Collins and Kerns 1946; Souza et al. 2011; Urasaki et al. 2015), and fusarium resistance in peanuts (Batista et al. 2007).

**Table 1.** Eigenvalue, the percentage of total variation and correlation between qualitative characters and the three main components (PC1-PC3) of Pineapple in Peatlands at Riau, Indonesia

Qualitative character	PC1	PC2	PC3
Distribution of spines	-0.03	-0.06	-0.03
Bractea color	<b>0.22</b>	<b>0.73</b>	0.33
Sepal color	0.05	0.12	-0.12
Fruit base leaf color (collar)	<b>0.90</b>	<b>-0.32</b>	-0.14
Fruit shape	<b>-0.27</b>	-0.10	-0.15
Fruit eye profile	0.15	<b>0.35</b>	<b>-0.29</b>
Fruit eye surface	-0.15	<b>-0.35</b>	<b>0.29</b>
Flesh color	0.13	-0.15	<b>0.52</b>
Peduncle color	0.02	-0.05	0.35
Crown shape	-0.06	-0.09	-0.12
Fruit color when unripe	-0.01	0.23	0.12
Crown attachment to fruit	-0.06	0.05	<b>-0.49</b>
Eigen value	18.55	9.76	2.03
% Variation	56.04	29.47	6.14
% Cumulative	56.04	85.52	91.66

**Principal Component Analysis (PCA) of quantitative character**

Quantitative characters are measurable characteristics, usually influenced by the environment. The 24 qualitative characters observed were significant different among genotype, thus, it is difficult to make decisions on which characters contributed the most to variation. Therefore, multivariate analysis through principal component analysis (PCA) is needed. PCA analysis was carried out using the original variable. The derived variable was not used because it has a very high correlation to the original variable (Brush et al. 2011; Poljak et al. 2015). Based on the PCA of 22 qualitative characters, it can be seen that the three main components (PC1-PC3) can distinguish variations in pineapples in Riau peatlands of up to 96.46%, which PC1, PC2, PC3 accounts variation for 81.87%, 7.99%, 4.595%, respectively (Table 2). A PCA with the total value of the cumulative variation of 75% is considered sufficient to differentiate diversity (Marison 1978). Characters that contribute to genetic diversity are characters that have immense vector value. Quantitative characters are strongly influenced by the environment, genotype, and the interaction between the environment and genotype. The inheritance of quantitative characters is complex, and many genes has a minor contribution to the phenotype. Inheritance of quantitative characters is generally studied by estimating population parameters (Rosmaina et al. 2016; Candido et al. 2017; Rohaeni and Yunani 2017; Coelho et al. 2019).

The characters that play a role in distinguishing the genotypes in PC1 with a total contribution of variation of 81.87% included fruit weight, flesh weight, plant height, and the number of leaves. In PC2, leaf length, plant height, number of leaves, and flesh weight contributed 7.99% to the total variation. PC3 only contributed 4.59% to the variation with the contributing characters including plant height, number of leaves, flesh weight, and fruit weight (Table 2). Based on PCA analysis, five quantitative characters contributed the most to variations in pineapple plants on peatland, namely fruit weight, fruit flesh weight, plant height, number of leaves, and leaf length. These characters were also reported to have high variation in pineapple diversity in Cuba (Rodríguez-Alfonso et al. 2020).

PCA scatter plots based on the quantitative characters of 24 genotypes were grouped into two main groups. The first group was the *Smooth cayenne* group, which consisted of three genotypes, namely G10, G12, and G20. Based on five quantitative characters that contribute to variation, three genotypes have 1.6-1.7 kg of fruit weight, 1.2-1.4 kg of fruit flesh weight, 100-128 cm of plant height, 85-95 cm of leaves length, and 41-50 number leaves/plant. The genotypes in this first group have relatively large fruit and plant sizes.

All *Queen* cultivars were grouped into the second group. The second group was divided into two subgroups, the first subgroup consisted of six genotypes (G01, G02,

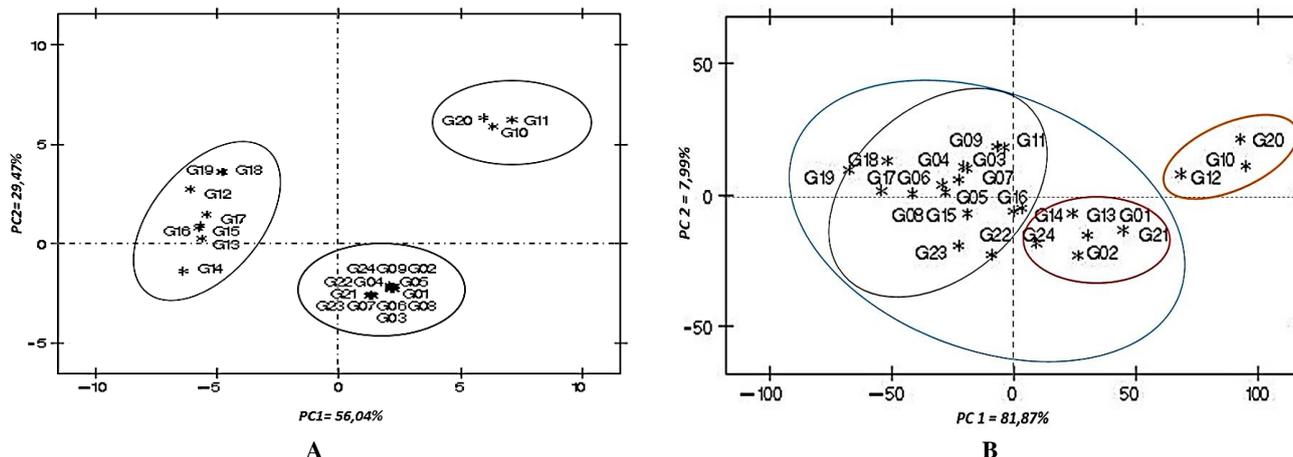
G13, G14, G21, and G24), and the second subgroup consisted of 15 genotypes (Figure 3). The genotypes belonging to the second subgroup had an average fruit weight of 1.27 kg, a flesh weight of 850 g, a plant height of 90 cm, an average length of 68 cm, an average leaf number of 47 leaves/plant. This subgroup is a *Queen* cultivar with relatively large fruit size. The second sub-group was the *Queen* cultivar with relatively small fruit size, i.e. an average fruit weight of 860 g, a flesh weight of 680 g, a plant height of 98 cm, an average leaf length of 80 cm, and a leaf number of 38-43 leaves/plant.

**Table 2.** Eigenvalue, the percentage of total variation and correlation between qualitative characters and the three main components (PC1-PC3) in Pineapple in Riau Peatlands.

Quantitative character	PC1	PC2	PC3
Plant height (cm)	<b>0.074</b>	<b>0.334</b>	<b>0.430</b>
Leaf length(cm)	0.050	<b>0.689</b>	0.055
Leaf width (cm)	0.010	0.008	0.010
Number of leaves	<b>0.060</b>	<b>-0.432</b>	<b>0.767</b>
Number of sucket	0.004	-0.026	-0.079
Number of shoot	0.001	0.014	-0.010
Number of slip	0.002	-0.060	0.013
Stem diameter(cm)	0.008	0.053	0.055
Fruit weight (g)	<b>0.777</b>	-0.251	<b>-0.326</b>
Flesh weight (g)	<b>0.613</b>	<b>0.287</b>	<b>0.269</b>
Fruit length (cm)	0.039	-0.037	-0.027
Crown height (cm)	-0.057	0.088	-0.028
Fruit diameter (cm)	0.020	0.013	-0.004
Peduncle diameter (cm)	0.008	0.001	0.003
Eye depth	0.004	0.002	0.003
Core diameter	0.011	-0.014	-0.012
Number of crown leaves	0.029	-0.008	0.090
Crown weight	-0.025	0.098	0.058
Total soluble solid (TSS)	0.020	-0.041	-0.025
Total titrase acid (TTA)	-0.007	0.011	-0.023
Vitamine C	-0.021	-0.132	-0.056
Water content	0.040	-0.188	0.135
Eigenvalue	1850.292	180.6697	103.7225
% Variation	81.87	7.99	4.59
% Cumulative	81.87	89.87	94.46

**Table 3.** Eleven minimal number of characters (qualitative and quantitative) that contribute to pineapple variation in peatlands of Riau Province

Qualitative characters	Quantitative characters
Fruit base leaf color (collar)	Fruit weight
Fruit shape	Flesh weight
Bractea color	Plant height
Fruit eye profile	Leaf length
Fruit eye surface	Number of leaves
Flesh color	
Crown attachment to the fruit	



**Figure 3.** Scatter Plot PCA 24 genotype of pineapple cultivated in peatland Riau, Indonesia based on: A. qualitative characters, B. quantitative characters

Based on PCA on qualitative and quantitative characters, 12 main characters were selected. These includes seven qualitative characters (collar color, fruit shape, bractea color, fruit eye profile, fruit eye surface, fruit flesh color, and the presence or absence of a neck on the fruit) and five quantitative characters (fruit weight, flesh weight, plant height, leaf length, and the number of leaves) (Table 3). These twelve selected characters can be used as a minimal number of characters to identify pineapple cultivars in peatland. Pineapple breeding is directed to the ideal type, i.e. without spines leaves, resistant to fusarium, high fruit quality, and high and stable yield (Cabral et al. 2009; Reinhardt et al. 2012; Ventura et al. 2009) so that selection should be done on the characters that support these breeding goals.

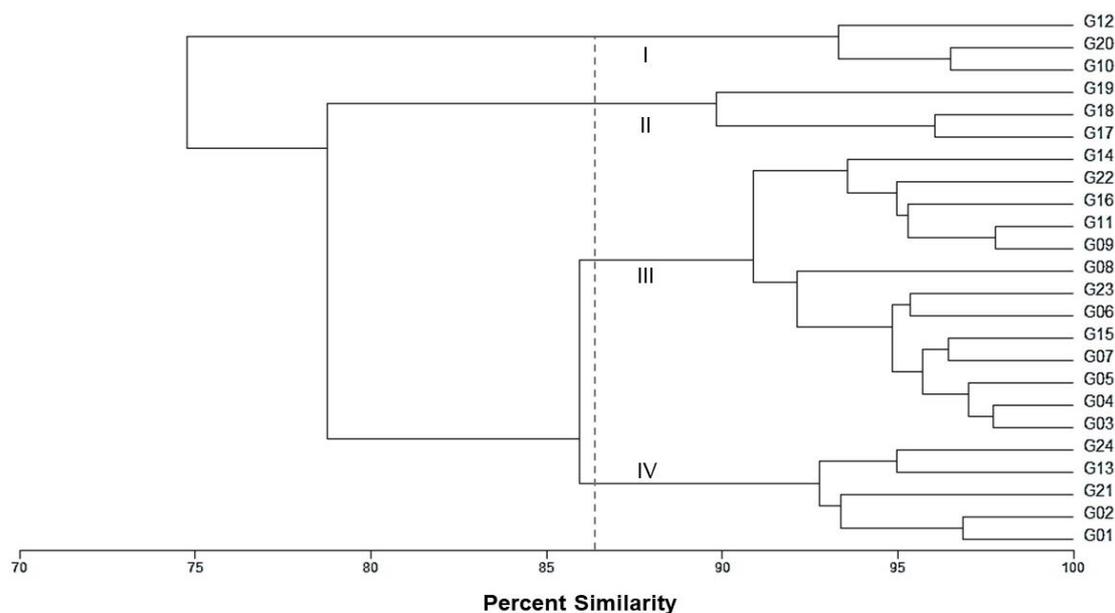
Out of 49 characters observed, there was 12 selected character that contributed significantly to the variation in pineapple plants on peatland. The number of characters found in this study was less than that reported by Rodriguez-Alfonso et al. (2020), with 14 characters were distinguishing pineapple plants in Cuba. Fruit shape, eye profile, eye surface, flesh color, fruit diameter, crown weight are characters that have a significant contribution to diversity (Rodriguez-Alfonso et al. 2020). The cumulative PCA percentage values for pineapple's qualitative and quantitative characters on peatlands were 91.66% and 94.46%, respectively. According to Banda and Kumarasamy (2020), the minimum threshold for the cumulative percentage value is 60%. That means that eleven characters are considered adequate for distinguishing pineapple cultivars in Riau Peatlands.

#### Dendrogram of UPGMA

The UPGMA dendrogram based on 46 qualitative and quantitative characters showed that the 24 genotypes tested

were grouped into four groups at the level of morphological similarity of 86%. The first group was smooth cayenne cultivar, consisting of three genotypes (G12, G10, and G20). The second group consisted of three genotypes of *Queen* cultivar (G17, G18, and G19), which had a relatively small fruit and plant sizes. This group has an average plant height of 88.46 cm with 33 leaves/plant, an average fruit weight of 600 grams, an average flesh weight of 400 grams. This group has a pink collar, yellowish-green bract, and yellow flesh with cylindrical slight-taper fruit shape. The third group consisted of 13 *Queen* genotypes with plant and fruit sizes larger than the second group, the average of plant height of 94 cm, number of leaves of 47 sheet/plant, fruit weight of 880 grams, flesh weight of 640 grams, bract color yellow-orange, dark red collar color, and yellow to golden yellow of flesh. This third group has long conical and cylindrical sharp-taper fruit shapes. The fourth group consisted of 5 genotypes of the *Queen* cultivar. This group had the largest fruit size of the *Queen* cultivar with an average fruit weight of 1350 grams, 860 grams of flesh weight, yellowish-green bract color, dark red collar color, and golden yellow flesh with cylindrical fruit shapes.

The grouping of the 24 tested genotypes based on 46 characters (Figure 4) was the same as the grouping based on the 12 selected quantitative characters (Figure 3). The genotype grouping on the dendrogram (Figure 4) was carried out based on quantitative and qualitative characters such as fruit weight, plant height, number of leaves, fruit shape, bract color, collar color, and flesh color. These characters contributed significantly to the diversity of pineapples in peatlands, as described in PCA (Figures 2 and 3). This dendrogram confirms that 12 selected characters can be used as a minimal number of characters required to identifying pineapple on peatlands.



**Figure 4.** Dendrogram of unweighted pair group method with arithmetic mean (UPGMA) of 24 genotypes of pineapple cultivated in Riau peatlands based on quantitative characters.

In conclusion, this study shows that qualitative characters that can clearly distinguish cultivars. In contrast, quantitative characters separate genotypes based on size so that different cultivars can be grouped together if they have the same size. Based on the principal component analysis, both qualitative and quantitative characters, and the UPGMA dendrogram, there a minimum of 12 characters, out of 46 characters, that are proposed to be used for the identification of pineapple on peatlands, namely fruit weight, flesh weight, plant height, leaf length, number of leaves, collar color, fruit shape, bract color, fruit eye profile, fruit eye surface, flesh color, and crown attachment to the fruit.

#### ACKNOWLEDGEMENTS

This research is funded by Institute for Research and Community Service of the Universitas Islam Negeri Sultan Syarif Kasim, Pekanbaru, Riau, Indonesia.

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