

Morphological Diversity of “Tuni” and “Afo” Cloves, Endemic to the Maluku Islands, Indonesia

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Abstract

“Tuni” and “Afo” cloves are endemic clove varieties from the Maluku islands. Until now, there is still little information on morphological diversity in plant populations and information on the characteristics between the two varieties. The research aims to provide information on the morphological diversity and characteristics of “Tuni” and “Afo” cloves from the Maluku Islands. Morphological characterization of the “Tuni” variety of cloves was carried out at its distribution location on Ambon Island, Maluku Province. In contrast, “Afo” cloves were characterized at their distribution location on Ternate Island, North Maluku Province. The research was carried out in July 2023-May 2024. The descriptor used for morphological identification was the modified Tropical Fruit Descriptors. The characterized clove plants consisted of 30 “Tuni” clove plants and 30 “Afo” clove plants, so a total of 60 plants were characterized. The results of the Hierarchical Cluster Analysis (HCA) based on 54 morphological characters that were carried out showed two groups with a dissimilarity coefficient of 44%. The first group is a group of “Tuni” clove accessions, which are clustered with a similarity of 91%, and the second group is a group of “Afo” clove accessions, which are clustered with a similarity of 90%. The results of Principle Component Analysis (PCA) obtained a total diversity of 75.4%, where the specific characteristics of “Tuni” cloves obtained were stem bark color, crown shape, branching angle, leaf thickness, old leaf color, shoot color, leaf petiole tip color, flower stalk weight, flower length, flower tube diameter. The specific characteristics of “Afo” cloves obtained from PCA are plant height, stem circumference, North-South canopy width, East-West canopy width, leaf length, leaf texture, leaf spiciness, ripe picked flower color, picked ripe flower crown color, ripe fruit color, and color seed.

Keywords: Ambon, biplot, cluster analysis, dendrogram, Ternate

Introduction

The Maluku Islands, including Maluku Province and North Maluku Province, are known as “The Center of Origin” for the distribution of cloves in the world (Mahulette et al., 2022; Tamnge and Yusnaini, 2021; Wattimena et al., 2023). Cloves in the Maluku Islands region are one of the leading plantation commodities that are a source of income for farmers who live in the plantation sector (Alfian et al., 2019; Mahulette et al., 2019b). Cloves are a historical commodity that holds historical value in the arrival of Europeans to the Maluku Islands (Suparman et al., 2018, 2017a; Tamnge and Yusnaini, 2021). Cloves are widely used as raw materials in the Kretek cigarette manufacturing industry and as a spice (Mahulette et al., 2022; Wattimena et al., 2023). Other uses, especially in the biopharmaceutical sector, are due to the active compounds containing medicinal properties (Hariyadi et al., 2020b; Mahulette et al., 2019a). Cloves are also widely used as food preservatives in the food and beverage industry, vegetable pesticides, aromatherapy, and various other agro-industrial products (Elbestawy et al., 2023; Nurjannah et al., 2013; Srivastava and Singh, 2023).

The Maluku Islands have a high genetic diversity of cloves because they are the original distribution area for cloves (Mahulette et al., 2022, 2019). According to Mahulette et al. (2022), the genetic diversity of cloves in Maluku Province that has been identified consists of several varieties, including “Tuni” cloves, “Red Zanzibar”, “White Zanzibar”, “Forest” cloves, “Raja” cloves, “Bogor” cloves, “Tae”, “Boiselang”, “Jinten” cloves, and “Damar” cloves. Of all the cloves that have been identified, it is reported that only the “Tuni” variety has been released as a superior clove variety from

Maluku Province. "Tuni" cloves in Maluku Province can be found in almost all regions because it is the dominant variety cultivated by farmers (Namakule et al., 2024; Solissa et al., 2023). The "Tuni" variety of cloves has been released as a superior clove variety from Maluku Province since 2013 based on Ministry of Agriculture Decree No. 4964/Kpts/SR.120/12/2013 (Kementan, 2013).

As part of the Maluku Islands, North Maluku Province also has a high genetic diversity of cloves (Suparman et al., 2018, 2017b). The results of a preliminary survey in 2023 it has been identified that there are several superior varieties of cloves in North Maluku Province, namely "Afo", "Sikotok", "Siputih", "Red Zanzibar" cloves, "White Zanzibar" cloves, "Rica" cloves, "Sibela", "Ordinary" cloves, "Maluku" cloves, "Bogor" cloves, "Long Flower Stalk" cloves, and "Forest" cloves. Farmers widely cultivate this clove variety because it has superior agronomic characteristics and exceptionally high production. "Afo" are the oldest cloves in the clove history in North Maluku Province and have been released as superior clove varieties since 2010 based on Minister of Agriculture Decree No. 3680/Kpts/SR.120/11/2010 (Lumbessy, 2023).

Like cloves in general, "Tuni" and "Afo" clove varieties have cross-pollination characteristics (Hariyadi et al., 2020b; Suparman et al., 2018). Cross-pollination over a long period allows diversity to be found in the population. Until now, there is little information regarding the morphological differences between the two superior clove varieties from the Maluku Islands. Therefore, morphological characterization activities of "Tuni" and "Afo" cloves should be carried out to obtain information on morphological diversity between the two varieties. Characterization is also essential to see the extent of morphological differences in the population of each variety. Information on the results of this characterization is useful in plant breeding programs to obtain high-yielding clove plant genotypes (Mahulette et al., 2022).

Material and Methods

Place and Time

Morphological characterization was performed on two superior local clove varieties from the Maluku Islands: "Tuni" cloves from Maluku Province and "Afo" cloves from North Maluku Province. Morphological characterization of "Tuni" cloves was carried out in the distribution area of "Tuni" cloves in Maluku Province, namely on Ambon Island (Wakasihu Village, S: 0346'14.4", E: 12757'06.2", altitude 68.0

mdpl; Assilulu Village, S: 0341'38.1", E: 12755'22.2", altitude 54.4 mdpl; and Mamala Village, S: 0333'31.2", E: 12811'39.8", altitude 41.1 mdpl). In contrast, morphological characterization of "Afo" cloves was carried out in the distribution area of "Afo" cloves in North Maluku Province, namely on Ternate Island (Tongole Village, N: 0047'27.5", E: 12721'26.8", altitude 400.0 mdpl; and Marikrubu Village, N: 0047'10.9", E: 12721'31.5", altitude 390.0 mdpl). The research was carried out in July 2023-May 2024.

Materials and Tools

The plant material used in morphological observations consists of two superior local clove varieties from the Maluku Islands: "Tuni" cloves from Maluku Province and "Afo" cloves from North Maluku Province. Clove trees are characterized as >20 years old with the same crown shape as the criteria and are free from pests and diseases. Equipment for observing the morphology of the two clove varieties consists of a meter for measuring tree height; a meter for measuring length, width, and trunk circumference; measuring ruler for measuring leaf length, flower length, fruit, and seed length; calipers to measure the diameter of flowers, fruit and seeds; digital scales for weighing flowers, fruit and seeds; easy leaf area software for measuring leaf area; RHS color chart 2015 for determining the color scale of leaves, fruit, seeds; GPS to retrieve the coordinates of the research location. The plant material used in morphological observations consists of two superior local clove varieties from the Maluku Islands: "Tuni" cloves from Maluku Province and "Afo" cloves from North Maluku Province. Clove plants are characterized as >20 years old with the same crown shape as the criteria and are free from pests and diseases. Equipment for observing the morphology of the two clove varieties consists of a meter for measuring tree height; a meter for measuring length, width, and trunk circumference; measuring ruler for measuring leaf length, flower length, fruit, and seed length; calipers to measure the diameter of flowers, fruit and seeds; digital scales for weighing flowers, fruit and seeds; easy leaf area software for measuring leaf area; RHS color chart 2015 for determining the color scale of leaves, fruit, seeds; GPS to retrieve the coordinates of the research location.

Research Methods

Morphological characterization of "Tuni" and "Afo" cloves using survey methods and random sampling. The observation of morphological characters refers to the modified Tropical Fruit Descriptors (IPGRI, 1980) and Mahulette et al. (2022). Morphological characterization was carried out on 60 clove plants, 30 of which were "Tuni" clove plants characterized in

Maluku Province and 30 of which were “Afo” clove plants characterized in North Maluku Province. The criteria for selected plants are >20 years old, have the same branches, and are free from pests and diseases.

Research Implementation

The research implementation began with labeling the selected sample plants. Each selected plant is then characterized by morphology, including habitus, stem, branches, leaves, flowers, fruit, and seeds. Measurements of leaves, flowers, fruit, and seeds from each plant were carried out on ten samples from each plant. Leaf measurements were carried out on the 4th leaf from the tip, while flower measurements were carried out on flower buds that had entered the ripening-picking phase marked by a change in color from dark green to greenish-yellow. Fruit and seed measurements were carried out on fruit that had entered the physiological ripening phase, which was marked by a change in fruit color to blackish purple.

The measurement results’ morphological characters are qualitative and quantitative. The qualitative characters were given a measurement value score, and together with the quantitative characters, a grouping dendrogram was made using Hierarchical Cluster Analysis (HCA). The characterizing characteristics of each clove variety used Principal Component Analysis (PCA).

Data Analysis

The data resulting from morphological characterization were analyzed using Hierarchical Cluster Analysis (HCA) to obtain a grouping dendrogram between

all “Tuni” and “Afo” clove plant samples. The characterization data was followed by Principal Component Analysis (PCA) to get the specific characteristics of “Tuni” and “Afo” cloves (plant descriptors). Hierarchical Cluster Analysis (HCA) and Principal Component Analysis (PCA) were performed using R Stat 3.1.0 software (Mahulette et al., 2019, 2022).

Result and Discussion

Morphological Characters of “Tuni” and “Afo” Cloves From the Maluku Islands Based on Hierarchical Cluster Analysis (HCA)

Morphological characterization of “Tuni” and “Afo” cloves from the Maluku Islands was carried out on 30 “Tuni” clove plants from Maluku Province and 30 “Afo” clove plants from North Maluku Province based on 54 morphological characters. The analysis uses Hierarchical Cluster Analysis (HCA) to obtain a grouping dendrogram based on character similarities between the characterized plant genotypes. The overall grouping results of “Tuni” and “Afo” clove accessions based on HCA are presented in Figure 1. According to Hartati et al. (2022) and Mahulette et al. (2022), HCA is a cluster analysis widely used to group groups of plants based on similar characteristics. This grouping is essential for plant breeding studies to select plant genotypes with high-yield potential (Mahulette et al., 2019c and Wang et al., 2014).

Based on the Hierarchical Cluster Analysis (HCA) results, “Tuni” and “Afo” cloves from the Maluku Islands can be divided into two large groups with a dissimilarity coefficient of 44% or only 56%

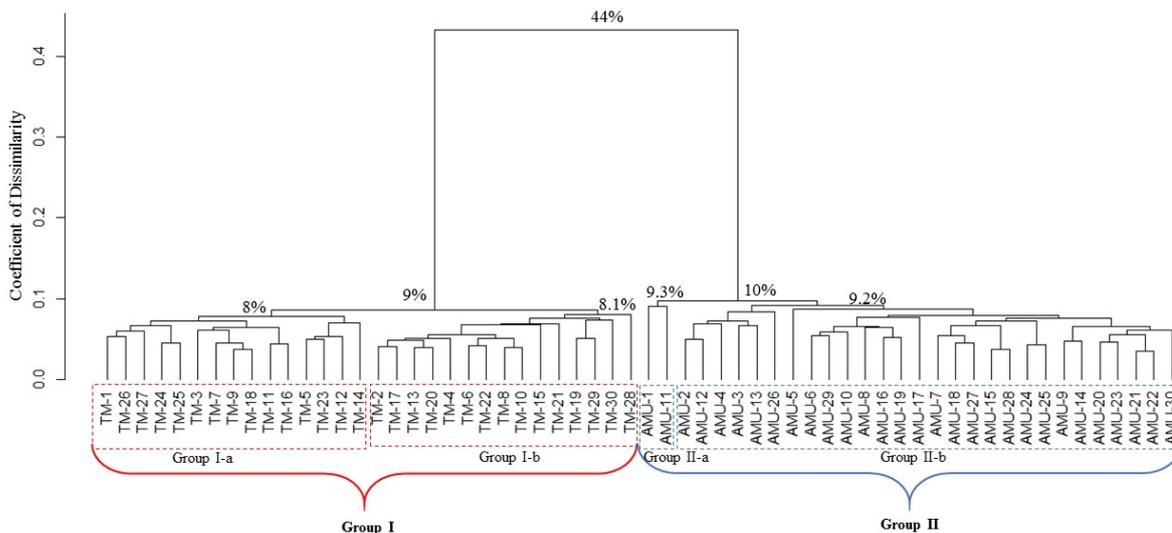


Figure 1. Dendrogram of grouping 60 clove samples from the Maluku Islands based on 54 morphological characters. “Tuni” cloves (Code: TM-1 – TM-30), “Afo” cloves (Code: AMU-1 – AMU-30).

similarity. The first group consisted of 30 “Tuni” clove accessions, which clustered with a similarity of 91% (9% dissimilarity). In comparison, the second group consisted of 30 “Afo” clove accessions, which grouped with a similarity of 90% (10% dissimilarity). The first group in the dendrogram is divided into two groups of accessions, where the first group (group I-a) consists of 15 accessions with a similarity coefficient of 92% (dissimilarity 8%), and the second group (group I-b) consists of 15 accessions with a similarity coefficient of 91.9% (dissimilarity 8.1%). The second group in the dendrogram is also divided into two groups, where the first group (group II-a) consists of 2 accessions with a similarity coefficient of 90.7% (dissimilarity 9.3%), and the second group (group II-b) consists of 28 accessions with a similarity coefficient of 90.8 % (dissimilarity 9.2%).

According to Hariyadi et al. (2020a) and Rosmaina et al. (2021), similar characteristics in a plant population can cause a group of plants to separate from other groups. Furthermore, according to Jan et al. (2012) and Mahulette et al. (2022), more similarities in morphological characters in a plant group will show

closer relationships within the population. Groups of plants with distant relationships tend to show many differences in their characteristics.

The morphological diversity found in the study's “Tuni” and “Afo” clove populations was caused by many factors, including plant genetics, the environment, and their interactions. Cloves are cross-pollination, so natural pollination over a long period can cause character variations in the plant population. According to Karuwal et al. (2021) and Singh et al. (2013) High diversity in a plant population is essential in the breeding field because it can provide information on the diversity of genetic traits and the level of plant variability for selecting superior genotypes. Growing environmental factors such as climate and soil can also influence differences in morphological characteristics in a plant population.

The morphology of the “Tuni” and “Afo” clove accession groups as a result of grouping is shown in Figures 2-5. In contrast, the results of measuring the morphological characters of the accession groups of the two varieties are presented in Table 1.

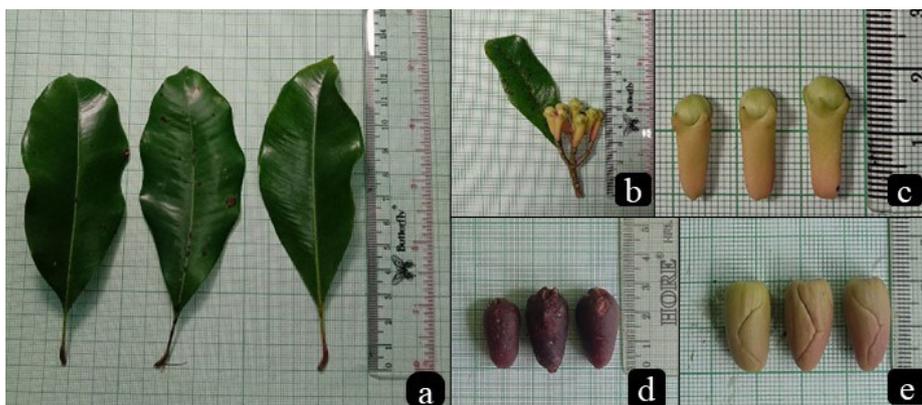


Figure 2. Morphology of “Tuni” cloves group I-a: leaves (a), floral arrangement (b), flower buds (c), fruits (d), and seeds (e)

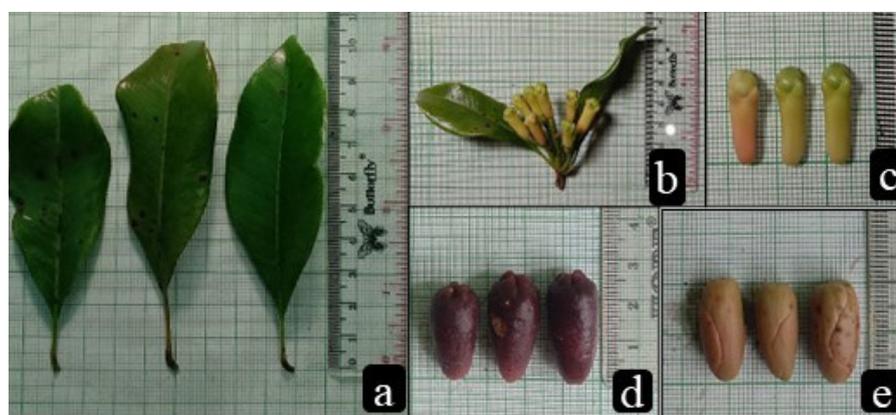


Figure 3. Morphology of “Tuni” cloves group I-b: leaves (a), floral arrangement (b), flower buds (c), fruits (d), and seeds (e)

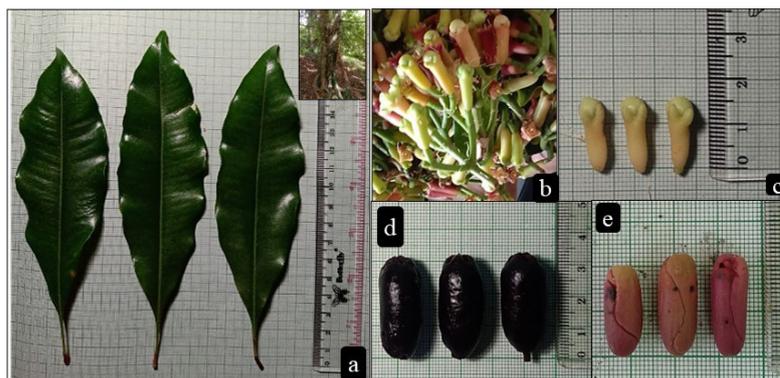


Figure 4. "Afo" cloves group II-a: leaves (a), flower arrangement (b), flower buds (c), fruits (d), and seeds (e)



Figure 5. "Afo" cloves group II-b: leaves (a), floral arrangement (b), flower buds (c), fruit (d), and seeds (e)

Group I. The first group in the grouping consists of 30 accessions that cluster with a dissimilarity coefficient of 9% (91% similarity). This group is further divided into two groups, namely "Tuni" group I-a and "Tuni" group I-b:

"Tuni" group I-a. This group comprises 15 accessions that cluster with 92% similarity (dissimilarity coefficient 8%). Members of this group have a leaf length of 9.83 cm, a leaf width of 3.99 cm, and a leaf area of 46.59 cm², and the color of the old leaves is intense yellow green (yellow-green group/N144C). The length of the flower stalk is 3.91 cm, the weight of the flower stalk is 1.03 g, the picked ripe flowers (flower buds) of the group members have a flower length of 1.95 cm, a diameter of 5.14 mm, a weight of 0.37 g, and the number of flowers per set is 14.87 flowers. The color of picked ripe flowers (flower buds) is light greenish yellow (yellow group/4B). This group has fruit with a length of 2.85 cm, diameter of 12.10 mm, weight of 2.47 g, and fruit color is dark purple (purple group/79A). The seeds of members of this group are 2.09 cm long, 9.31 mm in diameter, weigh 1.36 g, and the seed color is light purple (purple group/ 75B).

"Tuni" group I-b. This group comprises 15 accessions that cluster with a similarity of 91.9% (dissimilarity coefficient 8.1%). Members of this group have a leaf

length of 8.88 cm, a leaf width of 3.69 cm, and a leaf area of 40.42 cm², and the color of the old leaves is intense yellow green (yellow-green group/N144C). The length of the flower stalk is 3.57 cm, the weight of the flower stalk is 1.22 g, the picked ripe flowers (flower buds) of the group members have a flower length of 1.67 cm, a diameter of 4.84 mm, a weight of 0.28 g, and the number of flowers per set is 18.73 flowers. The color of picked ripe flowers (flower buds) is light greenish yellow (yellow group/4B). This group has fruit with a length of 2.66 cm, diameter of 12.58 mm, weight of 2.58 g, and fruit color is dark purple (purple group/79A). The seeds of members of this group are 2.03 cm long, 9.22 mm in diameter, weigh 1.19 g, and the seed color is light purple (purple group/75B).

Group II. The second group in the grouping consisted of 30 accessions with a dissimilarity coefficient of 10% (90% similarity). This group is further divided into two groups, namely "Afo" group II-a and "Afo" group II-b:

"Afo" group II-a. The first group of the "Afo" clove population consists of two accessions with a similarity level of 90.7% (dissimilarity coefficient 9.3%). Members of this group have a leaf length of 13.42 cm, a leaf width of 6.36 cm, and a leaf area of 50.21 cm², and the color of the old leaves is deep yellowish

Table 1. Morphological characteristics of "Tuni" and "Afo" cloves from the Maluku Islands, Indonesia

Genotype	Morphological characters	Parameters							Color*
		Height (m)	Shape	Length (cm)	Width (cm)	Area (cm ²)	Weight (g)	Total	
"Tuni" Group I-a	Habits	19.13±1.84	Cylindrical	-	-	-	-	-	-
	Lower branch	1.96±0.12	90° angle	-	-	-	-	-	-
	Leaf	-	<i>Elliptical</i>	9.83±0.66	3.99±0.32	46.59±7.97	-	-	Old leaves: intense yellow green (yellow-green group/N144C)
	Flower buds	-	Flat funnel	1.95±0.13	5.14±0.36	-	0.37±0.04	14.87±1.51	Flower buds: light greenish yellow (yellow group/4B)
	Flower stalk	-	Long	3.91±0.36	-	-	1.03±0.21	-	Physiologically ripe fruit: dark purple (purple group/79A)
	Fruit	-	Conical	2.85±0.20	12.10±0.94	-	2.47±0.30	-	Physiologically mature seeds: light purple (purple group/75B)
Seed	-	Conical	2.09±0.17	9.31±0.52	-	1.36±0.14	-	-	
"Tuni" Group I-b	Habits	18.80±1.01	Cylindrical	-	-	-	-	-	-
	Lower branch	1.83±0.16	90° angle	-	-	-	-	-	-
	Leaf	-	<i>Elliptical</i>	8.88±0.58	3.69±0.27	40.42±6.07	-	-	Old leaves: intense yellow green (yellow-green group/N144C)
	Flower buds	-	Flat funnel	1.67±0.14	4.84±0.32	-	0.28±0.03	18.73±2.81	Flower buds: light Greenish yellow (yellow group/4B)
	Flower stalk	-	Short	3.57±0.39	-	-	1.22±0.23	-	Physiologically ripe fruit: dark purple (purple group/79A)
	Fruit	-	Conical	2.66±0.15	12.58±0.58	-	2.58±0.34	-	Physiologically mature seeds: light purple (purple group/75B)
Seed	-	Conical	2.03±0.13	9.22±0.49	-	1.19±0.14	-	-	

"Afo" Group I-a	Habits	32.00±2.82	Cone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Lower branch	1.45±0.49	45° angle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Leaf	-	Elliptical	13.42±2.70	6.36±1.92	50.21±0.16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Flower buds	-	Flat funnel	1.68±0.04	3.62±0.24	-	0.26±0.02	19.00±1.41	-	-	-	-	-	-	-	-	-	-	-	-	
	Flower stalk	-	Long	2.60±0.00	-	-	0.38±0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Fruit	-	Conical	3.15±0.70	12.27±2.09	-	3.87±0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Seed	-	Conical	2.30±0.00	8.05±0.00	-	1.06±0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	
	"Afo" Group I-b	Habits	29.46±3.06	Cone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Lower branch	1.55±0.23	45° angle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Leaf	-	Elliptical	13.13±1.24	6.24±0.93	38.71±4.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flower buds		-	Flat funnel	1.73±0.06	3.96±0.30	-	0.28±0.02	18.00±1.39	-	-	-	-	-	-	-	-	-	-	-	-	
Flower stalk		-	Long	2.81±0.14	-	-	0.35±0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	
Fruit		-	Conical	3.06±0.31	12.14±1.06	-	3.13±0.34	-	-	-	-	-	-	-	-	-	-	-	-	-	
Seed		-	Conical	2.36±0.17	8.27±0.57	-	1.28±0.17	-	-	-	-	-	-	-	-	-	-	-	-	-	

Note: * Color standards are based on the 2015 RHS color chart criteria.

green (green group/N134B). The length of the flower stalk is 2.60 cm, the weight of the flower stalk is 0.38 g, the ripe flower buds of the group members have a flower length of 1.68 cm, a diameter of 3.62 mm, a weight of 0.26 g, and the number of flowers per set is 19.00 flowers. The color of picked ripe flowers (flower buds) is light greenish yellow (yellow group/4C). This group has fruit with a length of 3.15 cm, diameter of 12.27 mm, weight of 3.87 g, and fruit color is dark red (red-purple group/59A). The seeds of members of this group are 2.30 cm long, 8.05 mm in diameter, weigh 1.06 g, and the seed color is moderate red (grayed red group/181B).

“Afo” group II-b. The second group of the “Afo” clove population consists of 28 accessions with a similarity level of 90.8% (dissimilarity coefficient 9.2%). Members of this group have a leaf length of 13.13 cm, a leaf width of 6.24 cm, and a leaf area of 38.71 cm², and the color of the old leaves is deep yellowish green (green group/N134B). The length of the flower stalk is 2.81 cm, the weight of the flower stalk is 0.35 g, the ripe flower buds of the group members have a

flower length of 1.73 cm, a diameter of 3.96 mm, a weight of 0.28 g, and the number of flowers per set is 18.00 flowers. The color of picked ripe flowers (flower buds) is light greenish yellow (yellow group/4C). This group has fruit with a length of 3.06 cm, diameter of 12.14 mm, weight of 3.13 g, and fruit color is dark red (red-purple group/59A). The seeds of members of this group have a length of 0.17 cm, a diameter of 8.27 mm, and a weight of 1.28 g; the color of the seeds is moderate red (grayed red group/181B).

Characteristics of “Tuni” and “Afo” Cloves from the Maluku Islands Based on Principal Component Analysis (PCA)

Principal Component Analysis (PCA Variables and PCA-Biplot) was conducted on 60 clove accessions of 30 “Tuni” clove plants from Maluku Province and 30 “Afo” clove plants from North Maluku Province. PCA was carried out on 36 morphological characters that had data diversity. The analysis results showed that the total diversity of the data was 75.4%, where the characteristic character was shown by the most

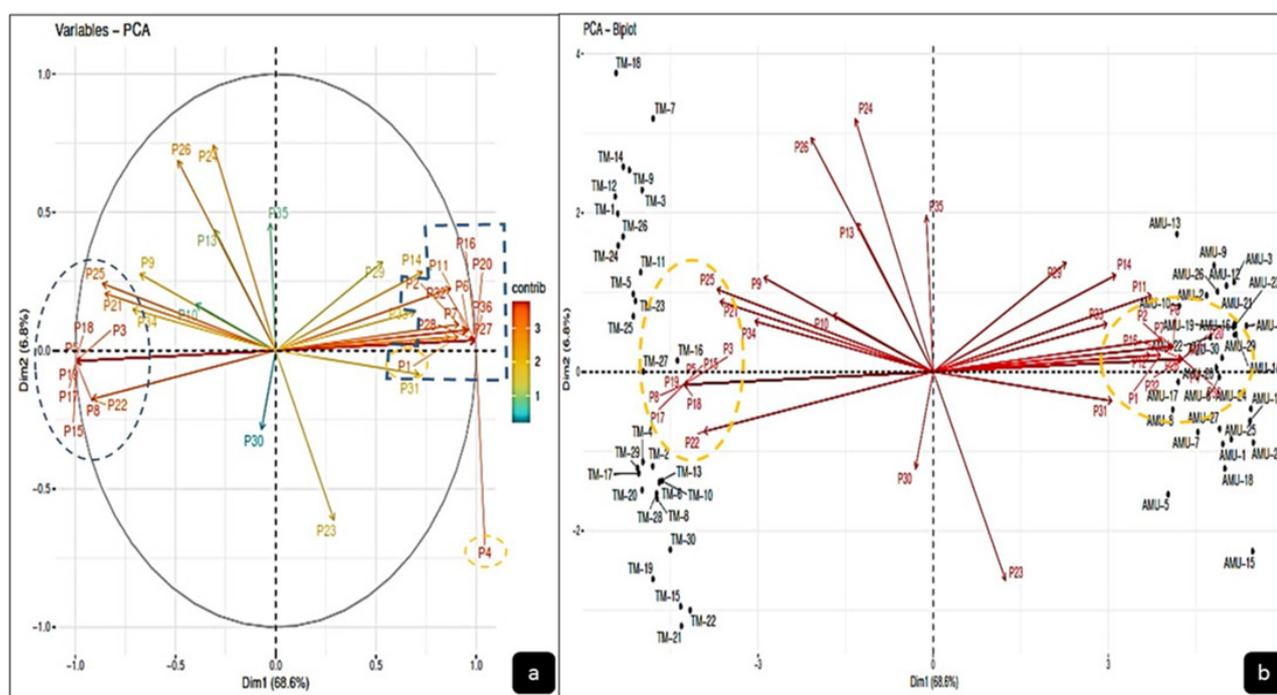


Figure 6. Principal Component Analysis: PCA variables (6a), PCA-Biplot (6b) 30 “Tuni” clove accessions from Maluku Province and 30 “Afo” clove accessions from North Maluku Province Based on 36 Morphological Characters. Accession of Clove Raja, R1-R30; Morphological characters, plant height (M1), stem circumference (M2), main stem (M3), crown shape (M4), canopy width U-S (M5), canopy width T-B (M6), lowest branch height (M7), leaf size (M8), leaf length (M9), leaf width (M10), leaf area (M11), petiole length (M12), leaf tip shape (M13), upper leaf surface (M14), lower leaf surface (M15), leaf thickness (M16), leaf texture (M17), dark leaf color (M18), shoot color (M19), petiole tip color (M20), leaf aroma (M21), leaf spiciness (M22), flower stalk length (M23), the weight of flower stalk (M24), number of flowers/series (M25), flower length (M26), flower tube diameter (M27), the weight of ripe flowers picked (M28), fruit length (M29), fruit width (M30), fruit weight (M31), mature fruit color (M32), seed length (M33), seed width (M34), seed weight (M35), seed color (M36).

extended vector with a red scale in the image (Figure 6a). The characteristics obtained in PCA can be used as a reference in describing the “Tuni” and “Afo” clove plant groups at the research location. According to Mahulette et al. (2022) and Rosmaina et al. (2021), PCA is widely used to determine the characteristics of a plant species. The characteristic characters obtained are the characters that contribute the most to the grouping. These characters have contributed more to the grouping than the total of the characters analyzed. According to Mahulette et al. (2022) and Sharma et al. (2018), the characteristic characters obtained by PCA can be used to identify a group of plants in a population. These characters are more independent and separate from the total of the characters analyzed.

The results of PCA-Biplot (Figure 6b) showed that the characteristics of “Tuni” cloves were stem bark color (P3), crown shape (P5), branching angle (P8), leaf thickness (P15), old leaf color (P17), shoot color (P18), leaf stalk tip color (P19), flower stalk weight (P22), flower length (P24), flower tube diameter (P25). Characteristics of “Afo” cloves obtained were plant height (P1), stem circumference (P2), North-South canopy width (P6), East-West canopy width (P7), leaf length (P11), leaf texture (P16), leaf pungency (P20), ripe flower color (P27), ripe flower corolla color (P28), ripe fruit color (P32), seed color (P36).

The specific characteristics found in both clove varieties are the most prominent characteristics of each clove variety. These characters can be used as a reference in describing the “Tuni” and “Afo” clove plant groups in a plant population and distinguishing the two varieties in a population. Morphological characteristics can be used as a reference when describing plants to be used as plant descriptors (Purnobasuki et al., 2014; Wattimena et al., 2023).

The use of PCA in describing cloves has been widely informed by Hariyadi et al. (2020a), Mahulette et al. (2019b), Namakule et al. (2024), and Wattimena et al. (2023). The results obtained in this study and those obtained in this study explain that differences in character traits can still be found even though they are within the same species. These differences in character are primarily influenced by genetic and environmental factors as well as their interactions. These characters can be used to inform specific plant characters, especially agronomic characters. Morphological information can also be used as a reference to identify other potentials, such as the content of essential compounds of each accession.

Conclusion

“Tuni” and “Afo” cloves from the Maluku Islands, based on Hierarchical Cluster Analysis, found two large groups with a dissimilarity coefficient of 44%. The first group consists of two groups of “Tuni” clove accessions, with a cluster with a similarity of 91%, and the second group consists of two groups of “Afo” clove accessions, with a cluster with a similarity of 90%. Principal Component Analysis (PCA) showed that the total morphological diversity in the “Tuni” and “Afo” clove populations was 75.4%. The PCA results showed that “Tuni” cloves can be identified by their stem bark color, crown shape, branching angle, leaf thickness, old leaf color, shoot color, leaf petiole tip color, flower stalk weight, flower length, and flower tube diameter. Characteristics to identify “Afo” cloves are plant height, stem circumference, North-South canopy width, East-West canopy width, leaf length, leaf texture, leaf pungency, ripe flower color, ripe flower corolla color, ripe fruit color, and seed color.

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