

Type and morphological character of local clove (*Syzygium aromaticum*) from Maluku, Indonesia

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Manuscript received: 28 November 2021. Revision accepted: 18 February 2022

Abstract. Mahulette AS, Alfian A, Suyadi, Supriyanto, Situmorang J, Matatula AJ, Kilkoda AK, Nendissa JI, Wattimena AY. 2022. Type and morphological character of local clove (*Syzygium aromaticum*) from Maluku, Indonesia. *Biodiversitas* 23: 1301-1309. Maluku Islands are known as the origin for the distribution of cloves (*Syzygium aromaticum* L.) in the world, where the diversity of clove germplasm is high. So far, information on the diversity of local clove morphology in Maluku is still very limited. The study was aimed to characterize the morphological diversity of local clove accessions in Maluku. The study was conducted in three distribution areas in Maluku, namely Ambon Island, Seram Island, and Haruku Island. Characterization was carried out on 130 local clove accessions of Maluku based on 32 morphological characters. The exploration identified nine types of cloves, namely Tuni, Forest Clove, Raja, Boiselang, Zanzibar, Bogor, Jinten, Tae, Damar, and three variants of Forest Clove, two variants of Raja, and two variants Zanzibar. Forest cloves, Raja, Boiselang Jinten, Tae, Damar are classified as wild-type cloves, while Tuni, Zanzibar and Bogor cloves are classified as cultivated cloves. The Hierarchical Cluster Analysis (HCA) obtained 2 large groups of local cloves with 57% agro-morphological differences. The first group is Forest Clove and Boiselang, while the second group is other local clove accessions (Tuni, Jinten, Red Zanzibar, White Zanzibar, Bogor, Damar, Tae, and Raja). The Principle Component Analysis (PCA) shows a total diversity of 66.7% with 4 characters based on grouping. These cloves are also categorized into wild type, cultivated, aromatic, and non-aromatic types.

Keywords: Ambon, cluster analysis, diversity, PCA

INTRODUCTION

The Maluku Islands are known as “the center of origin” of clove distribution in the world (Alfian et al. 2019; Hariyadi et al. 2020; Mahulette et al. 2019a, 2021; Sundari et al. 2019). As the origin, Maluku has a high diversity of clove germplasm. According to Ditjenbun (2020), Maluku has been the largest clove producer in Indonesia since 2015, with an average contribution of 15.37%. The area of clove plantations in 2018 was recorded at 569.052 ha, then increased to 570.353 ha in 2020 with a recorded production of 131.014 tons in 2018 and increased to 137.758 tons in 2020 (Ditjenbun 2020)

The clove diversity in Maluku has not been widely reported until now. Maluku has the potency to find a variety of local cloves with high diversity. Information on clove diversity can be done through plant characterization at the morphological level. (Yulianah et al. 2020) explained that plant morphological characteristics are essential in developing plant breeding programs, especially in selecting superior genotypes. The diversity of clove can be obtained by identifying plant morphological diversity in the field. The morphological diversity of various cloves can provide

important information like agronomic character and variety development (Alfian et al. 2019; Mahulette et al. 2019b; Yulianah et al. 2020).

The morphological variations of plants can be shown by making a dendrogram of the percent similarity followed by Principal Component Analysis (PCA) to determine each clove type (Mahulette et al. 2019b). According to Lawati et al. (2021), Mahulette et al. (2019b, 2019a), and Palizdar et al. (2021), character traits can provide specific plant character information to be used as a reference in making plant descriptors for plant identification. Therefore, it is important to carry out this research to identify the morphological characters of local Maluku clove germplasm. The information is important for the development of Maluku’s local clove in the future.

MATERIALS AND METHODS

Morphological characterization of Maluku, Indonesia local cloves was carried out in 3 local clove distribution areas, namely Ambon Island, Seram Island, and Haruku Island, in March-June 2021 (Figure 1). The plant materials

were selected from productive local cloves that were >20 years old. Characterization was carried out on 13 groups of clove accessions and their variants, where each accession was represented by ten plants so that there were 130 plants in total. The morphological characteristics measured included trees (height, growth direction, crown shape), stems (the size of the stem circumference, the character of the bark, the color of the bark, the direction of growth of the main stem), branches (north-south canopy width, east-west canopy width, branch direction, branch angle, lower branch height), leaves (leaf index, length, width, and leaf area, petiole length, leaf position, leaf shape, leaf tip shape, leaf base shape, upper and lower leaf surface, leaf edge, leaf venation shape, leaf thickness, leaf texture, leaf color age, shoot color, petiole tip color, leaf aroma, leaf spiciness), flowers bud (flower stalk length, flower stalk weight, number of flower arrangements, flower shape, flower crown shape, flower length, flower tube diameter, flower weight, young flower color, ripe flower color), fruits (shape, length, width, weight, color), seeds (shape, length, width, weight, color). Measurement of tree height using a tree height measuring instrument, namely the Haga meter (metallwarenfabrik/Jerman); length, width canopy, and circumference of the tree trunk measurement using a meter; leaf length using a ruler; leaf area using free Image J software; length of fruit and seeds using a ruler; fruit and seed weight using digital scale; determination of color characters using the 2015 RHS color chart.

The research has used a survey method, and the determination of the selected sample was carried out randomly. Observations were made on 32 morphological characters (trees, stems, branches, leaves, color, size, wide, length of flowers bud, fruits, seeds) referring to Mahulette et al. (2019a) modified. The observed morphological characters were used as nominal or measurement variables. The nominal variable is then given a value score to be confirmed. The morphological characterization of local Maluku clove accessions was analyzed by Hierarchical Cluster Analysis (HCA) and Principle Component Analysis (PCA) using R Stat 3.1.0 software (Mahulette et al. 2019a). The LSD test (Least Significance Different) was used to see differences in morphological characters among accessions of local cloves.

RESULTS AND DISCUSSION

The character of Maluku local clove

The characterization results found nine varieties, namely Tuni, Forest Clove, Raja, Boiselang, Zanzibar, Bogor, Jinten, Tae, and Damar, with several variants (Table 1). Tuni is dominantly distributed throughout the Maluku region. At the same time, other local clove accessions are concentrated in Central Maluku Regency, especially on Ambon Island and Haruku Island, such as Tae cloves on Haruku Island and Damar on Seram Island, West Seram Regency.

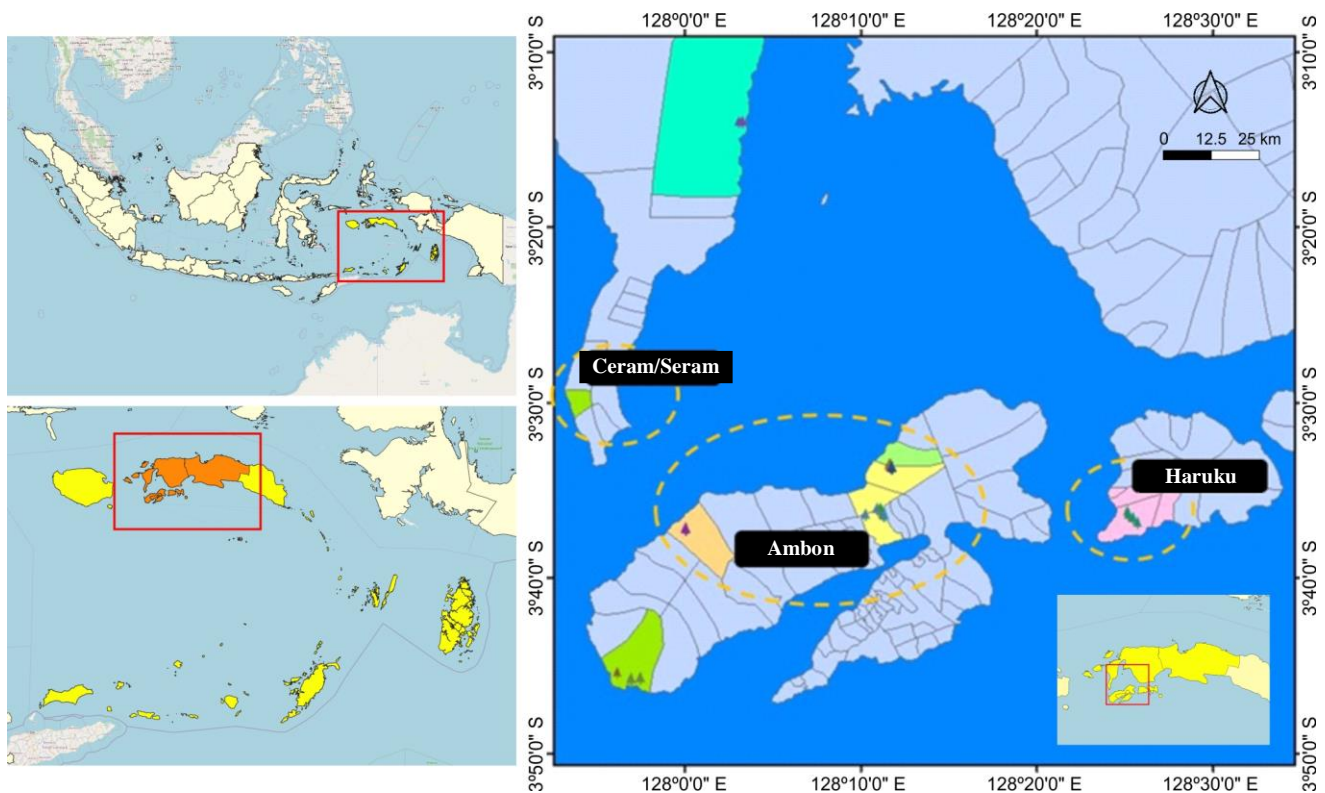


Figure 1. Maps of clove distribution in Maluku, Indonesia

Table 1. Maluku local clove variety, Indonesia

Clove variety	Variant	Distribution area	Type
Tuni	*	All Maluku area	Cultivated/aromatic
Forest clove	Group I	Ambon and Seram Island	Wild type/non-aromatic
	Group II	Ambon and Seram Island	Wild type/non-aromatic
	Group III	Ambon and Seram Island	Wild type/non-aromatic
Raja	Group I	Ambon Island	Wild type/non-aromatic
	Group II	Ambon Island	Wild type/non-aromatic
Zanzibar	Red shoots	Ambon and Seram Island	Cultivated/aromatic
	White shoots	Ambon and Seram Island	Cultivated/aromatic
Bogor clove	*	Ambon and Seram Island	Cultivated/aromatic
Boiselang	*	Ambon Island	Wild type/non-aromatic
Jinten	*	Ambon and Seram Island	Wild type/aromatic
Tae	*	Haruku Island	Wild type/non-aromatic
Damar	*	Seram Island	Wild type/non-aromatic

Note: * No variant

The clove accessions have seven variants: the Forest clove with three variants, the Raja clove with two variants, and the Zanzibar clove with two variants. According to Alfian et al. (2019) and Badou et al. (2020), cloves are cross-pollinated plants, so natural pollination in the long term can produce new variants in the population. In the study, the local cloves of Tuni, Zanzibar, Bogor, and Tae were identified as cultivated cloves from the aromatic group, while Forest clove and Raja as wild-type cloves from the non-aromatic group. The Boiselang, Jinten, and Damar were identified as wild-type cloves but had a strong aroma similar to cultivated cloves, so they were classified as aromatic wild-type cloves (Alfian et al. 2019; Hariyadi et al. 2020, 2019; Mahulette et al. 2020a, 2020b, 2019b, 2021). Tuni have been released as superior varieties based on Decree No. 4964/Kpts/SR.120/12/2013, while other local clove accessions are still in the limited assessment stage (Hariyadi et al. 2020; Mahulette et al. 2019b).

Differences in the morphology of Maluku local clove

The Maluku clove accessions had specific characters that differentiated them from other clove accession groups. The measurement of the morphological characters showed significant differences in morphological characters, especially the lower branch height and leaf characters (Table 2).

Tuni, Raja group II, and Boiselang have the highest branch height (>4.0 m). The shortest lower branch height is red Zanzibar, white Zanzibar, Bogor, Tae, and Jinten cloves (<1.5 m). Raja group II had the highest leaf index (2.89) and lowest on Boiselang clove (1.77). The longest petiole length was shown in Bogor cloves and the shortest in Tuni local cloves, Raja group II, and Boiselang. Differences in genetics cause morphological differences among local clove accessions. In addition, other factors such as the growing environment of cloves also influence. Phenotypic differences among plant accessions are influenced by genetic factors and strongly influenced by environmental conditions where they grow (Adu et al. 2021; Ji et al. 2021; Luong et al. 2021; Tesfaye 2021).

Hierarchical Cluster Analysis (HCA) of Maluku local clove

Hierarchical Cluster Analysis (HCA) was conducted on 130 local clove accessions based on 32 morphological characters (Figure 2). Local cloves in Maluku are divided into two major groups with 57% agro-morphological differences. Group I is Forest Clove and Boiselang. Group II is Tuni, Jinten, Red Zanzibar, White Zanzibar, Bogor, Damar, Tae, and Raja. Forest Clove and Boiselang have a similarity based on morphological characters of 73%. The analysis divided the Raja cloves with other local clove groups (Tuni, Jinten, Red Zanzibar, White Zanzibar, Bogor, Damar, and Tae) into two large groups with an agro-morphological difference of 27%. Grouping in cluster analysis is more determined by the number of similar characters (Alam et al. 2021; Jin et al. 2021; Kang et al. 2021; Liantoni et al. 2021; Loukili et al. 2021; Rathinavel 2018; Zhang 2021).

Group I

The first group consisted of Forest cloves and Boiselang (Figures 3-4). Forest cloves have three variants: large (group I), medium (group II), and small (group III) morphology. Forest Clove group I has a similarity rate of 88%. This group was characterized by large leaf and flowers bud but slightly smaller fruit and seeds than group II. Forest Cloves group I had the longest leaves (20.67 cm), the widest (9.85 cm), and the largest leaf area (180.93 cm²). The leaf color is deep yellowish-green. Forest Clove group II has a 90% similarity level. This group has medium leaf size but has the largest fruits and seeds of the other accession groups. The forest clove group II had leaves with a leaf length of 17.89 cm, a width of 8.61 cm, a leaf area of 130.28 cm². Forest Clove group III has a similarity level of 92%. The most prominent character of the population was the smallest leaf, flower, fruit, and seed size of the all forest clove group. Forest Clove group III had the shortest leaves (15.13 cm), the narrowest leaf width (6.99 cm), the smallest leaf area (97.56 cm²), and the yellow-green leaf color.

Boiselang group consisted of 10 accessions with 99% similarity. The most prominent character of the population members of this group is the shape and thickness of the

leaves, which are similar to forest cloves but have a spicy aroma similar to cultivated cloves. Boiselang has very thick leaves, obovate leaf shape, blunt leaf tips, rounded leaf bases, flat-leaf edges with extended leaf veins. Boiselang had a leaf size (index) of 1.77, leaf length of 10.14 cm, a leaf width of 5.73 cm, a leaf area of 37.28 cm², a fragrant and spicy leaf aroma.

Group II

The second group consisted of Tuni, Jinten, Red Zanzibar, White Zanzibar, Bogor, Damar, Tae, and Raja (Figures 5-11). The second group has the most prominent differences from the first group in leaf shape and aroma. This group has an elliptical leaf, is relatively thin, and has a spicy aroma compared to the first group. However, each of

these accession groups has a distinguishing morphological character among the others.

Tuni belongs to the aromatic group of cloves and has been released as a superior variety based on the Decree of the Minister of Agriculture No. 4964/Kpts/SR.120/12/2013. The most prominent character is the elliptical leaf shape, dark yellow-green leaf color (141B/Deep yellowish green/green group), and has a distinctive aroma of fragrant leaves and spicy flowers. Tuni had a leaf size (index) of 2.67, an average leaf length of 9.46 cm, a leaf width of 3.55 cm, a leaf area of 21.26 cm², a petiole length of 1.50 cm, the color of the tip of the petiole yellowish pink, dark yellow-green leaf color, yellowish-green shoot color and fragrant and spicy leaf aroma.

Table 2. Comparison of morphological characters of Maluku local cloves

Clove variety	Lowest branch height (m)	Leaf size (index)	Leaf length (cm)	Leaf width (cm)	Leaf area (cm ²)	Leaf petiole length (cm)
Tuni	4.00±0.22a	2.67±0.16ab	9.46±0.26h	3.55±0.16h	21.26±6.91e	1.50±0.07d
Forest clove group I	1.388±0.75cde	2.06±0.12f	20.67± 1.60a	9.85±0.80a	180.93±29.86a	2.09±0.39b
Forest clove group II	2.058±0.52bc	2.07±0.20f	17.89± 1.83b	8.61±0.75b	130.28±28.08b	1.88±0.30bc
Forest clove group III	0.968±0.40e	2.16±0.11ef	15.13± 1.10c	6.99±4.03c	97.56±22.57c	1.95±0.27bc
Raja group I	2.47±0.78b	2.51±0.06bc	13.39±0.17d	5.33±0.16d	56.74±7.13d	2.00±0.03b
Raja group II	4.10±1.29a	2.89±0.20a	11.15±0.47efg	3.87±0.25fgh	35.54±4.80e	1.50±0.07d
Boiselang	4.0±0.16a	1.77±0.08g	10.14± 0.26gh	5.73±0.15d	37.28±5.24de	1.50±0.05d
Red Zanzibar	1.0±0.20de	2.21±0.14def	10.14± 0.26e	5.31±0.31d	28.27±4.04e	2.00±0.07b
White Zanzibar	1.0±0.16de	2.33±0.11cde	12.20± 0.34de	5.24±0.20d	36.05±5.66de	2.00±0.11b
Bogor	1.0±0.12de	2.42±0.13cd	10.50±0.22fgh	4.35±0.15efg	36.05±5.66e	3.00±0.08a
Jinten	1.50±0.24cde	2.51±0.21bc	9.48± 0.62h	3.79±0.21gh	23.84±4.15e	2.15±0.21b
Tae	0.73±0.14e	2.52±0.22bc	11.38± 0.40ef	4.54±0.30e	32.93±5.95e	1.66±0.19cd
Damar	1.76±0.21bcd	2.54±0.10bc	11.15±0.44efg	4.39±0.11ef	19.30±1.53e	1.66±0.34cd

Note: The numbers followed by the same letters in the same column show no significant difference using the LSD test at α of 5%

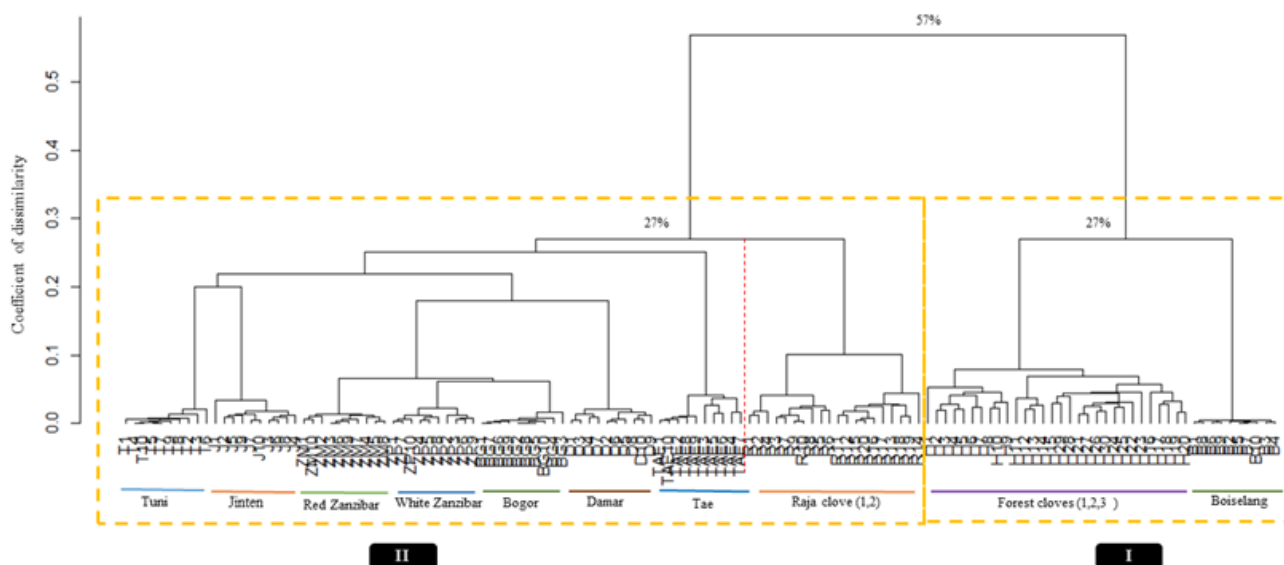


Figure 2. Dendrogram of 13 Maluku local cloves based on morphological characters. Tuni (T1-T10), Jinten (J1-J10), Red Zanzibar (ZM1-ZM10), White Zanzibar (ZP1-ZP10), Bogor (BGR1-BGR10), Damar (D1-D10), Tae (TAE1-TAE10), Raja (R1-R10), Forest Clove (H1-H30), Boiselang (B1-B10)



Figure 3. Forest clove group I (A-D), group II (E-H) and group III (I-L)



Figure 4. Boiselang clove



Figure 5. Tuni clove



Figure 6. Jinten clove



Figure 8. Bogor clove

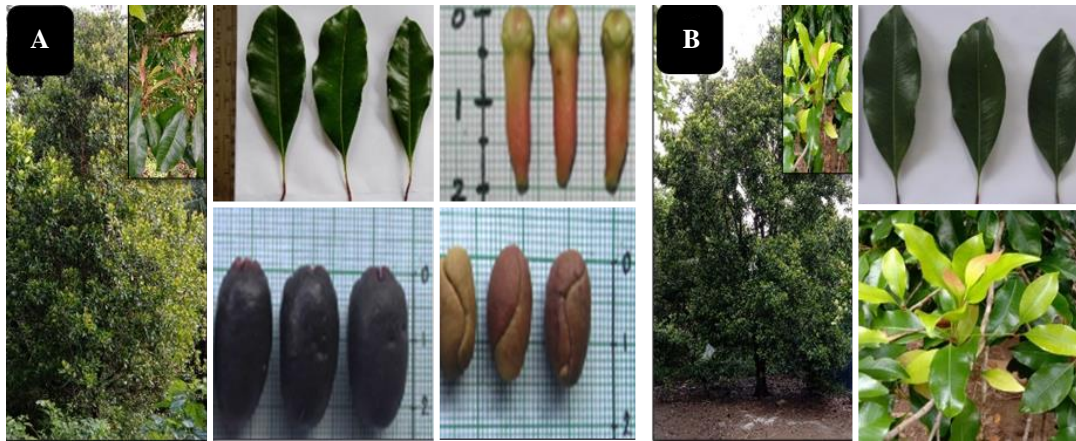


Figure 7. Red Zanzibar (A) and White Zanzibar (B)



Figure 9. Damar clove



Figure 10. Tae clove



Figure 11. Raja clove group I (left) and group II (right)

Jinten is an aromatic clove with the most prominent characteristics of this group is its narrow leaf size and the smallest flower bud of all Maluku local cloves and has a very fragrant leaf and flower aroma. Jinten had a leaf size (index) of 2.51, an average leaf length of 9.48 cm, a leaf width of 3.79 cm, a leaf area of 23.84 cm², a petiole length of 2.15 cm, the color of the petiole tip yellowish pink, leaf color is deep yellowish-green, yellowish-pink shoot color and the aroma of the leaves are very fragrant and spicy.

Zanzibar belongs to the cultivated cloves of the aromatic group. The Zanzibar is divided into two variants, namely red Zanzibar and white Zanzibar. The two variants have a similarity of 93%, with a difference of 7%. The primary difference between the two variants is only the color of the old leaves and the shoots. The red Zanzibar has leaf size (index) 2.21, average leaf length 11.70 cm, leaf width 5.31 cm, leaf area 28.27 cm², petiole length 2 cm, leaf tip color moderate red, leaf color dark green, shoot color moderate red. The white Zanzibar had leaf size (index) 2.33, average leaf length 12.20 cm, leaf width 5.24 cm, leaf area 36.05 cm², petiole length 2 cm, leaf tip color moderate red, leaf color dark green, shoot color moderate orange.

Bogor cloves are almost similar to red Zanzibar, but the most prominent differences are the shoots and petioles that look redder, and the leaf size is slightly smaller with slightly longer petioles than red Zanzibar. Bogor clove has a leaf size (index) of 2.42, an average leaf length of 10.50 cm, a leaf width of 4.35 cm, a leaf area of 27.56 cm², a petiole length of 3 cm, the color of the petiole tip is moderate red, dark green leaf color, moderate red shoot color, and fragrant and spicy leaf.

Damar is classified as an aromatic clove with the character of a tall tree with lush leaves and a dark color similar to a Damar tree. Damar has a leaf size (index) of 2.54, an average leaf length of 11.15 cm, a leaf width of 4.39 cm, a leaf area of 19.30 cm², a petiole length of 1.66 cm, the color of the petiole tip reddish-orange, dark green leaves, moderate orange shoot, fragrant and spicy leaf.

Tae is classified as an aromatic clove with a tall tree, thin leaves, and a prominent wavy leaf vein. Tae has a leaf size (index) of 2.52, an average leaf length of 11.38 cm, a leaf width of 4.54 cm, a leaf area of 32.93 cm², a petiole length of 1.66 cm, dark reddish-orange petiole tip, deep yellowish-green old leaf, dark reddish-orange leaf tip, moderate yellowish pink shoots.

Raja is classified as a non-aromatic clove with a morphological character similar to cultivated in the aromatic group, but the leaves and flowers do not have an aroma. The Raja accession group was divided into two variants with 90% similarity. The difference between the two variants is 10%. The primary difference between the two variants is only in the size of the leaves and the height

of the lowest branches. Raja group I had a slightly larger leaf length and width, but the first branch height was slightly lower than the second group. Raja group I has a leaf size (index) of 2.51, an average leaf length of 13.39 cm, a leaf width of 5.33 cm, a leaf area of 56.74 cm², a petiole length of 2 cm, moderate reddish-orange petiole tip, dark green leaf, strong yellow-green shoots, leaves, and flowers do not have a spicy aroma. Raja group II has a slightly smaller leaf size than the first group. This group has a leaf size (index) of 2.89, an average leaf length of 11.15 cm, a leaf width of 3.87 cm, a leaf area of 35.54 cm², a slightly shorter leaf stalk length of 2 cm, a moderate reddish orange leaf tip, and dark old leaf, strong yellow-green shoots, and the leaves and flowers are not spicy.

Principle Component Analysis (PCA) Maluku local clove

The Principle Component Analysis (PCA) results were based on 130 Maluku local clove accessions with 32 morphological characters. The analysis showed a total diversity of 66.7%, with four groups of characters (Figure 12). According to Aleem et al. (2021) and Seo et al. (2021), PCA can describe the most contributing characters from several highly variable characters. Based on PCA, the main character is the item with the longest vector character. The first group consisted of the characters of leaf length (PD), leaf width (LBD), leaf area (LSD), leaf thickness (KTBD), leaf texture (TKSD), leaf tip shape (BUD), leaf base shape (BPD), old leaf color (WDT), stem circumference (LB), crown shape (BT). This character was indicated to be the main character of Forest Cloves. The second group consisted of plant height (TT) and branching angle (SP), which were the characteristics of Boiselang. The third group was the character of leaf shape (BD), leaf aroma (AD), leaf spiciness (KPDS), leaf index (ID), upper and lower leaf surfaces (PAD, PBD). These characters are indicated to Tae, Jinten, Damar, Tuni, and Raja. The fourth group was shoot color (WP), petiole tip color (WUTD), leaf veins (UD), stem bark color (WKB), and leaf stalk length (PTD) indicated the main character of Red Zanzibar, White Zanzibar, and Bogor cloves.

In conclusion, the study identified 13 Maluku local cloves accessions, namely Tuni, Forest cloves (group I, II and III), Raja (group I and II), Boiselang, Red Zanzibar, White Zanzibar, Bogor, Jinten, Tae, and Damar. The results of HCA conducted on 130 accessions based on 32 morphological characters obtained two large groups with 57% agro-morphological differences. Group I is Forest Clove and Boiselang, group II is Tuni, Jinten, Red Zanzibar, White Zanzibar, Bogor, Damar, Tae, and Raja. Principle Component Analysis (PCA) resulted in a total diversity of 66.7% with four main character groups.

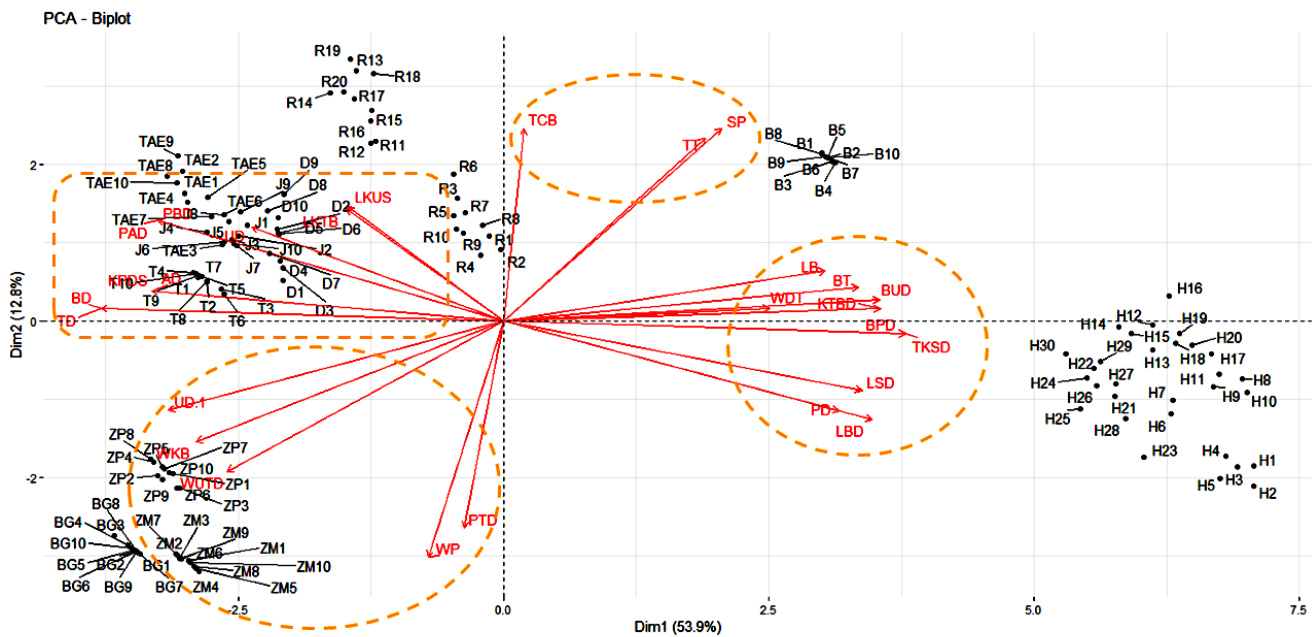


Figure 12. Principle Component Analysis (PCA) 13 Maluku local clove with 32 morphological characters. TT: plant height; LB: stem circumference; WKB: bark color; BT: canopy shape; LKUS: north-south canopy thickness; LKTB: east-west canopy width; SP: branching angle; TCB: lowest branch height; UD: leaf size; PD: leaf length; LBD: leaf width; LSD: leaf area; PTD: petiole length; BD: leaf shape; BUD: leaf tip shape; BPD: leaf base shape; PAD: leaf top surface; TD: edge leaf; UD: leaf veins; KTBD: leaf thickness; TKSD: leaf texture; WDT: dark leaf color; WP: shoot color; WUTD: leaf tip color; AD: leaf aroma; KPDS: leaf spiciness. Tuni (T1-T10), Jinten (J1-J10), Red Zanzibar (ZM1-ZM10), White Zanzibar (ZP1-ZP10), Bogor (BGR1-BGR10), Damar (D1-D10), Tae (T1-T10), Raja (R1-R10), Forest Cloves (H1-H30), Boiselang (B1-B10)

ACKNOWLEDGEMENTS

The authors acknowledge to Southeast Asian Regional Centre for Tropical Biology (SEAMEO BIOTROP) for supporting the fund of the research.

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