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Research Article

Type and Morphological Character of Local Cloves (*Syzygium aromaticum* (L.) Merr. & L. M. Perry) from North Maluku Province, Indonesia

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ABSTRACT

The North Maluku Province is renowned for being the original region where clove distribution started. This region comprises several island groups with high clove diversity. The research aimed to investigate and to recognise the morphological diversity of local cloves in North Maluku Province. The study employed a survey method, which included exploring six islands, namely Ternate, Tidore, Halmahera, Moti, Bacan, and Kasiruta, and led to the discovery of 13 local clove accessions. These accessions are Afo, Zanzibar Merah, Sikotok, Siputih, Rica, Maluku, "Gagang Panjang" clove, Sibela I, Sibela II, Forest Clove, White Zanzibar, Bogor clove, and "Biasa" clove. Based on Hierarchical Cluster Analysis (HCA), all clove accessions were morphologically characterised and classified into two groups with a dissimilarity coefficient of 49 %. The first group is the cultivated type of cloves that consists of local Afo cloves, Sibela I, Sibela II, Siputih, Sikotok, Rica, Red Zanzibar, "Gagang Panjang" clove, White Zanzibar, Bogor cloves, "Biasa" cloves, and Maluku cloves. On the other hand, the second group is the wild-type clove group, namely Forest Cloves . The characteristics of local clove accessions based on Principle Component Analysis (PCA) showed a total diversity of 52.5 %.

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INTRODUCTION

The Maluku Islands, consisting of Maluku Province and North Maluku Province in Indonesia, are considered the centre of origin of cloves in the world (Sundari et al. 2019; Tamnge & Yusnaini 2021; Mahulette et al. 2022; Naziella et al. 2022). The Maluku Archipelago region is believed to contain significant clove diversity due to its origin as a clove distribution centre (Alfian et al. 2019; Hariyadi et al. 2020; Kembauw et al. 2021a, 2021b; Wattimena et al. 2023). Previous explorations into clove diversity have been conducted in Maluku Province, leading to the identification of several local clove varieties, including Tuni, Boiselang, Red Zanzibar, White Zanzibar, Bogor, Jinten, Tae, Damar, Forest Clove, and Raja (Mahulette et al. 2022). This information supports the claim that North Maluku Province possesses a high clove diversity, as it was also part of the original clove distribution centre (Sundari et al. 2019; Tamnge & Yusnaini 2021). The existence of Afo cloves on Ternate Island in North Maluku Province, which are over 350 years old, serves as historical evidence that this area is indeed part of the centre of origin for global clove distribution (Sundari et al. 2019; Tamnge & Yusnaini 2021; Aboe 2022).

North Maluku Province is among the top 10 provinces in Indonesia in terms of clove production (Ditjenbun 2020). The province produced an average of 4,260 tons of clove, contributing to about 3.21 % of the national production. The clove area in North Maluku Province is expected to reach 26,502 hectares (BPS Maluku Utara 2022). Although the clove commodity area in this province is less vast than that in other central provinces of Indonesia, the region has high clove productivity due to many superior local clove varieties and agro-climatic suitability. To discover more about the diversity of local clove varieties in North Maluku Province, it is essential to carry out exploration activities on each island group to identify the existence of local clove accessions. This exploration should be followed by identifying and characterising local clove accessions based on their morphological features.

According to Anisa et al. (2022) and Hartati et al. (2022), carrying out morphological characterisation in plant breeding programs is crucial as it is the initial stage in identifying high-yielding genotypes. This type of characterisation helps gather information about identity, diversity, and relationships between plant species (Hernosa et al. 2022; Ustari et al. 2023). The diversity obtained at the morphological level is significant in selecting plant genotypes with high yield potential and creating a database of plant species diversity to develop varieties (Diaguna et al. 2022; Dini et al. 2023; Wattimena et al. 2023).

The North Maluku Province comprises multiple clusters of islands with distinct agro-climatic features. These islands are believed to hold a rich diversity of cloves as they were the first areas of clove distribution. However, more information is needed on the diversity of clove in each island group within the province. It is crucial to conduct an exploration and morphological characterisation of local cloves on each island group in North Maluku to gather comprehensive information about the diversity of clove in the entire Maluku Islands region.

MATERIALS AND METHODS

In this study, 13 different clove accession groups clove types were analysed for their characteristics. These accessions were collected from 6 islands in North Maluku Province, Indonesia, where clove plants are commonly found. The islands include Ternate, Tidore, Halmahera, Moti, Bacan, and Kasiruta. The plants were sampled and measured between July and September 2023, and only those that were over 15 years old, had a uniform crown shape, and were free from pests and diseases were selected for characterisation . From the 13 types of cloves characterised five sample plants were selected from each type of clove, so 65 plants were measured. Each plant sample was then

taken, with 10 samples of leaves, flowers, fruits, and seeds for measurement. The measured morphological characteristics included crown morphology, branching, leaves, and flower buds. To measure these characteristics, equipment such as a Haga meter for tree height, measuring tape for crown width and stem circumference, ruler for leaf length and width and flower length, ImageJ software for leaf area, digital caliper for flower diameter, RHS 2015 colour chart for color scale of stems, leaves, and flowers, and GPS for plant sample coordinates were used.

A survey method was utilised in this study, with purposive sampling for measurement. A total of 54 morphological characters were measured based on the Tropical Fruit Descriptors (IPGRI) (1980) and modified by Mahulette et al. (2022). The resulting measurements were then used to create a dendogram for grouping and determining each clove accession's distinguishing characteristics. Hierarchical Cluster Analysis (HCA) was used for dendogram creation, while Principle Component Analysis (PCA) was used to determine character traits. Differences in morphology between different clove types were analysed using the LSD test. R Stat 3.1.0 software was used for HCA and PCA, and STAR 2.0.1 software was used for the LSD test.

RESULTS AND DISCUSSION

Exploration of local cloves in North Maluku

Local clove exploration was conducted on six islands in North Maluku Province, Indonesia, resulting in the discovery of several unique groups of local clove accessions. Figure 1 displays the distinct accession groups found on each island. Ternate Island had five local clove accessions: Afo, Red Zanzibar, Sikotok, Siputih, and Rica. Tidore Island also had five accession: Maluku Cloves, Gagang Panjang Cloves, Red Zanzibar, Afo, and Sikotok. Bacan Island identified five local clove accessions: Sibela I, Sibela II, Forest clove, White Zanzibar, and Red Zanzibar. Kasiruta Island had three local clove accessions: Red Zanzibar, Bogor, and Biasa. Halmahera Island had four local clove accessions: Afo, Red Zanzibar, Sikotok, and Maluku cloves. Moti Island had three local clove accessions: Maluku, Zanzibar Merah, and Sikotok. Overall, the exploration discovered 13 local clove accessions across the six islands, as outlined in Table 1.

Upon research, it was discovered that Afo cloves are primarily distributed in the Mount Gamalama area of Ternate Island, their original distribution location. Ternate Island also boasts a significant distribution of Red Zanzibar, Sikotok, Siputih, and Rica cloves. Red Zanzibar cloves can also be found on other explored islands, such as Tidore Island, Bacan Island, Kasiruta Island, Halmahera Island, and Moti Island. Sibela I and Sibela II cloves are mainly distributed in the Sibela Mountain area on Bacan Island, their original distribution area. Biasa cloves are primarily distributed on Kasiruta Island, while Maluku cloves are mainly distributed on Halmahera Island. Moreover, other cloves are present, such as Gagang Panjang cloves on Tidore Island, Forest and White Zanzibar cloves on Bacan Island, and Bogor cloves on Kasiruta Island. However, their distribution is less significant.

It has been observed that most local clove accessions are of the cultivated type and possess an aromatic profile. However, the non-aromatic forest cloves found on Bacan Island are an exception to this trend. Among the aromatic group of cloves are Afo cloves, Red Zanzibar, Sikotok, Siputih, Rica, Maluku cloves, Gagang Panjang, Sibela I, Sibela II, White Zanzibar, Bogor cloves, and Biasa cloves. According to Biernasiuk et al. (2023), Gengatharan et al. (2023), and Salsabila et al. (2023), cultivated cloves are known for their strong aroma, which is attributed to high levels of eugenol. Conversely, non-aromatic cloves, like Forest cloves, have a milder aroma due to low levels of eugenol, as reported by Mahulette et al. (2020, 2021) and Aziz et al. (2023).

Recent research has discovered a variety of local cloves that stand out

Table 1. Accession of local cloves on six islands in North Maluku Province, Indonesia.

Accession	Distribution	Type
Afo*)	Ternate, Tidore, Halmahera Island	Cultivated type)/aromatic
Red Zanzibar *)	Ternate, Tidore, Bacan, Kasiruta, Halmahera and Moti Island	Cultivated type)/aromatic
Sikotok*)	Ternate, Tidore, Halmahera, and Moti Island	Cultivated type)/aromatic
Siputih*)	Ternate Island	Cultivated type)/aromatic
Rica	Ternate Island	Cultivated type)/aromatic
Maluku	Tidore, Halmahera, and Moti Island	Cultivated type)/aromatic
Gagang Panjang	Tidore Island	Cultivated type)/aromatic
Sibela I	Bacan Island	Cultivated type)/aromatic
Sibela II	Bacan Island	Cultivated type)/aromatic
Forest Clove	Bacan Island	Wild type)/non-aromatic
White Zanzibar	Bacan Island	Cultivated type)/aromatic
Bogor	Kasiruta Island	Cultivated type)/aromatic
Biasa	Kasiruta Island	Cultivated type)/aromatic

Note:*) indications have been released as superior varieties.

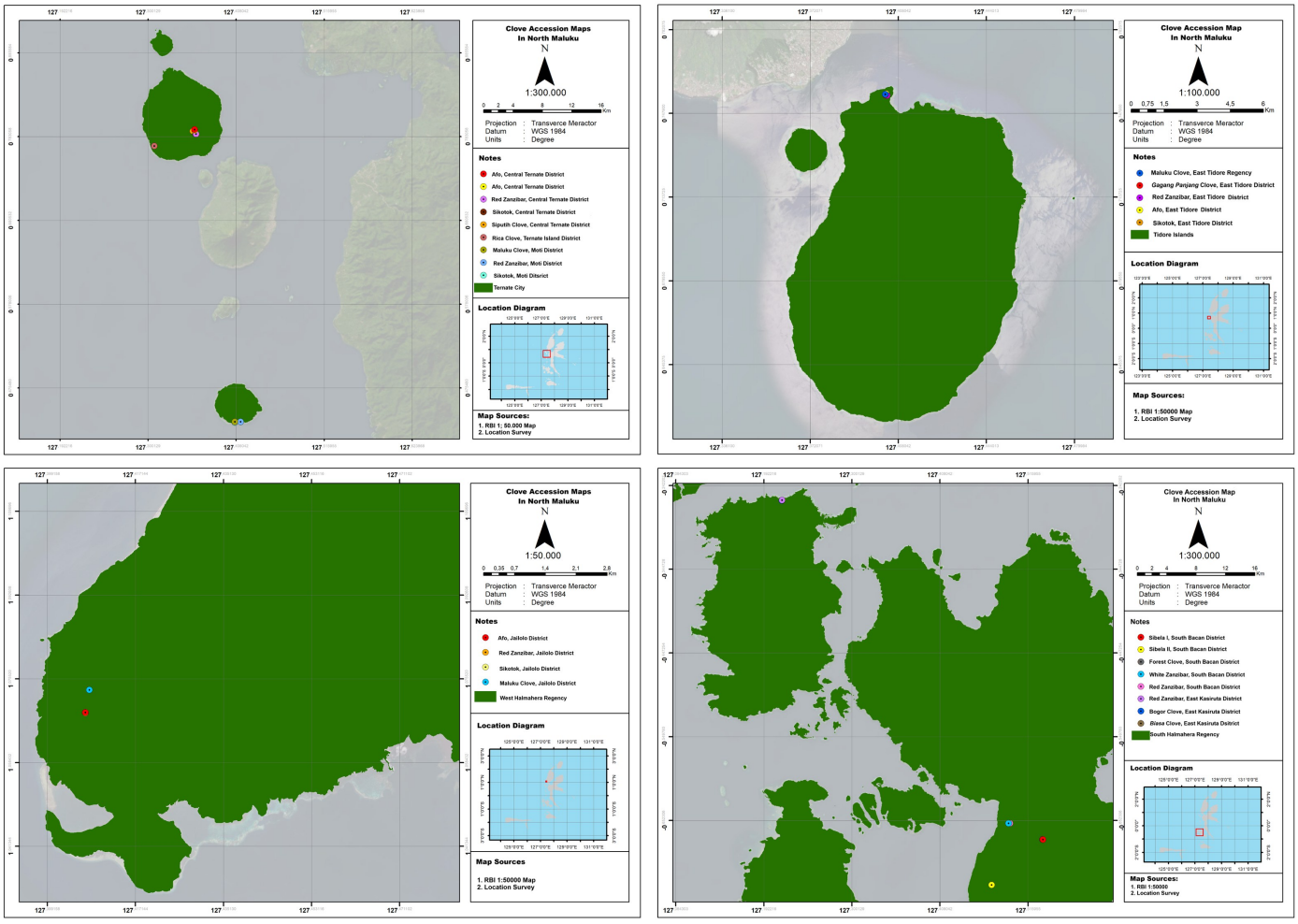

Figure 1. Research location at the six island in North Maluku.

as superior, including Afo, Red Zanzibar, Sikotok, and Siputih. Furthermore, studies have revealed clove variants, such as Red Zanzibar and White Zanzibar, which differed only in the colour of their shoots. Moreover, Sibela I, and Sibela II cloves have unique variants that vary in flower size, leaf size, and crown shape. According to Mahulette et al. (2022) and Wattimena et al. (2023), cloves can exhibit variations in their populations despite belonging to the same species. It is due to cross-pollination over time, which can lead to the emergence of new variants within the population (Mahulette et al. 2019a, 2019b, 2020; Hariyadi et al. 2019).

The study showed that the morphological diversity of cloves discovered in North Maluku Province differed gnificantly from previous explorations conducted in Maluku Province (Sundari et al. 2019; Mahulette et al. 2022). This exploration shows that only Red Zanzibar, White Zanzibar, Bogor, and Forest cloves share similar genotypes in Maluku Province. However, Afo Clove, Sikotok, Siputih, Rica, Maluku Clove, Gagang Panjang Clove, Sibela I, Sibela II, and Biasa Clove were exclusively identified in North Maluku Province. These findings confirmed that Maluku and North Maluku Province (Maluku Archipelago) possess remarkable morphological diversity in clove distribution. The high morphological diversity in these two provinces further supports the thought that they are the centre f origin cloves worldwide.

Morphological diversity of North Maluku local clove accessions

North Maluku clove accessions from exploration were differentiated by measuring several morphological characters. The results of the different tests showed significant differences in several morphological characteristics such as leaf length, leaf width, flower length, flower diameter, flower weight, and number of flowers per set (Table 2).

Through morphological character measurements, it is evident that the Forest Clove accessions boast the largest leaf and flower sizes among all local North Maluku clove accessions. However, despite its larger size, the number of flowers per set of the Forest clove accession is relatively less than the Biasa and Gagang Panjang clove accessions. The shortest leaf length was observed in the Bogor clove and was not significantly different from the leaf length of the Sikotok and Rica accessions. Similarly, the Rica clove exhibited the shortest leaf width and was not significantly different from the leaf width of the Sikotok. The Sibela I and Sibela II had the shortest flower bud length. However, it was similar to the flower length of the Gagang Panjang clove, Bogor cloves, and Biasa cloves. The Biasa and Gagang Panjang cloves had the highest number of flowers per arrangement. Despite having more flowers per set, the Gagang Panjang clove had the lowest flower diameter and weight. These morphological variations among the different accession groups could be attributed to genetic differences. North Maluku Province is a part of the original distribution area of cloves, and various accessions of cloves with varying morphological characters can be found there. According to Kayoumu et al. (2022) and Qiao et al. (2022), genetic differences in a plant population cause numerous morphological differences. Environmental factors and cultivation techniques also contribute to the diversity of a plant population (Ezin et al. 2022; Qiao et al. 2022).

Grouping of North Maluku local clove accessions based on Hierarchical Cluster Analysis (HCA)

A Hierarchical Cluster Analysis (HCA) was conducted on 13 different clove types in North Maluku to categorise them based on 44 morphological traits. Each type was represented by five plants, resulting in 65 plants analysed (Figure 2). HCA is commonly used to group plants with similar traits (Hartati et al. 2022; Mahulette et al. 2022). This grouping can assist in identifying plant groups with high agronomic potential, particularly in terms of production characteristics. The widespread use of HCA in plant breeding to gain insights into plant diversity (Ezin et al. 2022; Ustari et al. 2023). This information is valuable in plant breeding, particularly when selecting parents for crossbreeding.

Hierarchical Cluster Analysis (HCA) revealed that all the local clove accessions can be divided into two large groups with a dissimilarity coefficient of 49 %. The first group includes almost all local clove accessions, such as Afo cloves, Sibela I, Sibela II, Siputih, Sikotok, Rica, Red Zanzibar, Gagang Panjang, White Zanzibar, Bogor cloves, Biasa cloves, and Maluku cloves. On

Table 2. Differences in the morphological characters of North Maluku local cloves

Accessions	Leaf length (cm)	Leaf Width (cm)	Flower length (cm)	Flower diameter (mm)	Flower weight (g)	Number of flowers per arrangement
Afo	12.75 ± 0.74^{b}	4.61 ± 0.53^{ef}	1.84 ± 0.11^{c}	3.99 ± 0.36^{e}	0.302 ± 0.04^{bcd}	19.04 ± 1.23^{d}
Red Zanzibar	12.73 ± 0.72^{b}	5.27 ± 0.32^{bc}	2.07 ± 0.08^{b}	4.23 ± 0.08^{de}	0.304 ± 0.02^{bc}	23.80 ± 1.30^{b}
Siputih	9.78 ± 0.30^{cd}	3.86 ± 0.17^{g}	1.79 ± 0.12^{cd}	4.44 ± 0.20^{d}	0.324 ± 0.04^{b}	16.20 ± 1.64^{e}
Sikotok	9.11 ± 0.47^{de}	3.54 ± 0.13^{gh}	1.77 ± 0.10^{cd}	3.95 ± 0.18^{e}	0.264 ± 0.03^{cde}	7.20 ± 1.48^{h}
Rica	9.40 ± 0.65^{de}	3.24 ± 0.18^{h}	1.81 ± 0.12^{cd}	4.11 ± 017^{e}	0.340 ± 0.05^{b}	17.00 ± 2.35^{de}
Gagang Panjang	12.17 ± 0.58^{b}	4.91 ± 0.10^{cde}	1.75 ± 0.03^{cde}	3.28 ± 0.33^{f}	0.206 ± 0.02^{f}	26.00 ± 1.58^{ab}
Sibela-I	12.84 ± 0.81^{b}	5.07 ± 0.56^{bcd}	1.65 ± 0.02^{e}	4.23 ± 0.02^{de}	0.240 ± 0.01^{ef}	9.40 ± 0.55^{gh}
Sibela-II	9.52 ± 0.58^{cd}	3.75 ± 0.25^{g}	1.65 ± 0.02^{e}	4.24 ± 0.01^{de}	0.248 ± 0.01^{def}	9.60 ± 0.55^{g}
White Zanzibar	12.62 ± 0.77^{b}	4.84 ± 0.31^{de}	2.03 ± 0.05^{b}	4.08 ± 0.11^{e}	0.300 ± 0.02^{bcd}	21.40 ± 3.71^{c}
Forest Clove	18.45 ± 0.49^{a}	8.89 ± 0.57^{a}	2.36 ± 0.23^{a}	6.66 ± 0.35^{a}	0.796 ± 0.12^{a}	13.58 ± 1.89^{f}
Bogor	8.70 ± 0.30^{e}	4.77 ± 0.16^{de}	1.69 ± 0.05^{de}	5.25 ± 0.27^{b}	0.336 ± 0.04^{b}	12.80 ± 1.30^{f}
Biasa	9.76 ± 0.28^{cd}	4.29 ± 0.07^{f}	1.76 ± 0.06^{cde}	4.83 ± 0.36^{c}	0.336 ± 0.01^{b}	26.40 ± 2.07^{a}
Maluku	10.23 ± 0.69^{c}	5.32 ± 0.23^{b}	1.85 ± 0.06^{c}	4.92 ± 0.35^{c}	0.318 ± 0.02^{bc}	13.20±1.30^{f}

Note: Numbers followed by the same letter in the same column are not significantly different in the 5 % α LSD test.

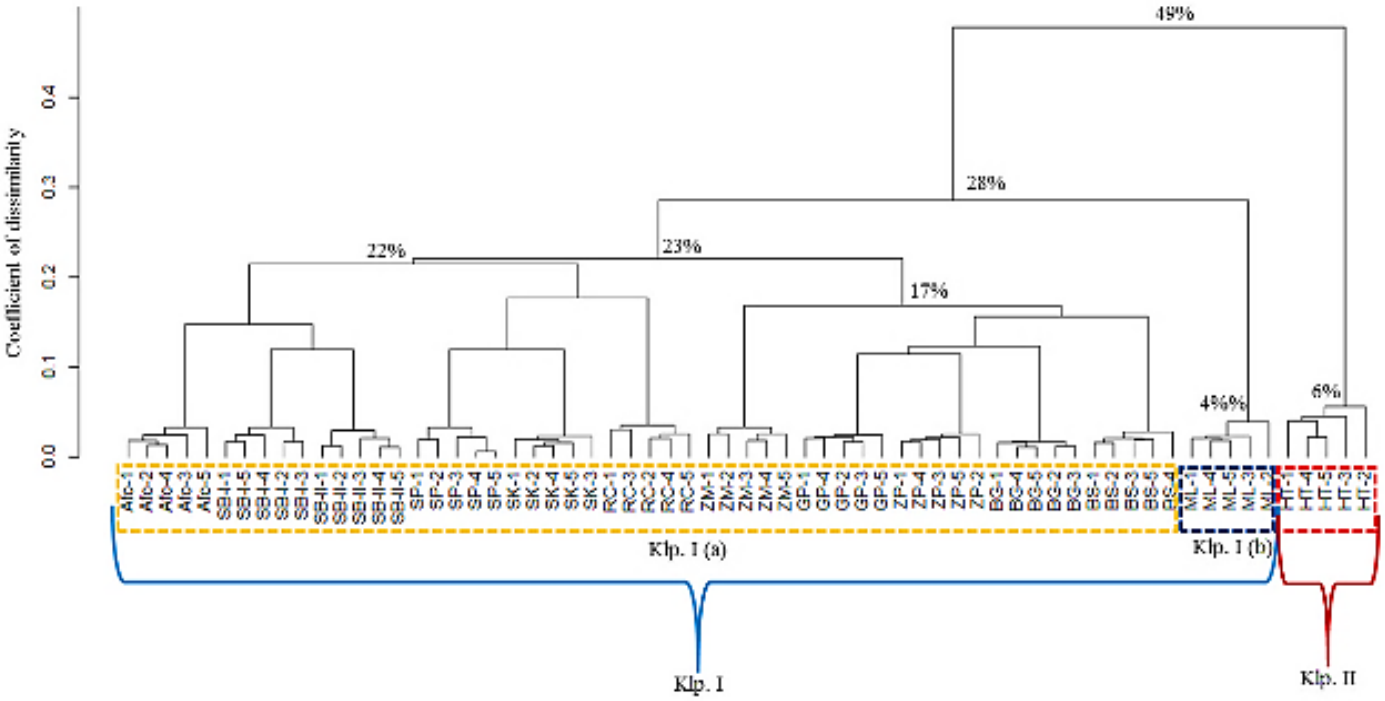

Figure 2. Dendogram of North Maluku local cloves grouping based on morphological characters. Clove accessions: Afo (Afo), Sibela I (SB), Sibela II (SB II), Siputih (SP), Sikotok (SK), Rica (RC), Red Zanzibar (ZM), Gagang Panjang (GP), White Zanzibar (ZP), Bogor (BG), Biasa (BS), Maluku (ML), Forest Clove (HT).

the other hand, the second group consists only of the Forest clove. The first group was divided into two subgroups with a dissimilarity coefficient of 28 %. The first subgroup, group I-a, includes Afo cloves, Sibela I, Sibela II, Siputih, Sikotok, Rica, Red Zanzibar, Gagang Panjang, White Zanzibar, Bogor cloves, and Biasa cloves. Meanwhile, the second subgroup, group I-b, includes Maluku cloves. Group I-a was then further divided into two subgroups with a dissimilarity of 23 %. The first subgroup includes Afo, Sibela I, Sibela II, Siputih, and Sikotok, while the second subgroup includes Red Zanzibar, Gagang Panjang, White Zanzibar, Bogor cloves, and Biasa cloves. According to previous studies by Mahulette et al. (2022) and Dini et al. (2023), plants are grouped if they share similar characteristics. Additionally, studies by Jan et al. (2012), Mahulette et al. (2022), and Suliansyah et al. (2023) suggested that plants with close kinship tend to have more shared characteristics compared to

plants with distant kinship, which exhibit more diverse characteristics.

Group I

Group I based on Hierarchical Cluster Analysis (HCA), consisted of 12 local clove accession groups with 72 % similarity (28 % dissimilarity). All local clove accession group members are cultivated type cloves from the aromatic group. This group consists of Afo cloves, Sibela I, Sibela II, Siputih, Sikotok, Rica, Red Zanzibar, Gagang Panjang, White Zanzibar, Bogor cloves, Biasa Cloves, and Maluku cloves (Figure 3-9).

The Afo clove (Figure 3A) is a highly similar group within the population, with a 98 % clustering rate. Distinguished by its unique stem that divides at the base, the Afo clove boasts an average height of 35.04 m, a conical crown shape, and a 45° branching angle. The lowest branch height of this group is 1.34 m, and its leaves are elliptical, with a length of 12.75 cm, a width of 4.61 cm, and an index of 2.79, resulting in a leaf area of 35.32 cm^2. The old leaves of the Afo clove exhibit a deep yellowish green/green group/ N134B colour, while the shoots have a moderate yellowish pink/greyed-orange group/N170D colour. The flower buds of this group are flat funnels, with an average of 19.04 flowers per series, a length of 1.84 cm, and a diameter of 3.99 mm. The buds weigh 0.30 g and have a light greenish-yellow/ yellow group/4C color.

The Sibela I clove (Figure 3B) accession group shares a 96 % similarity level. The most notable feature of this group is the smaller size of their flower buds compared to other clove accessions, though they are slightly larger than those of the Sibela II group. Additionally, like the Afo clove, the main stem of this group divides at the base. These accessions have an average tree height of 30.20 m with a slightly rounded crown shape, a divided main stem, a lower branch height of 1.58 m, and a branching angle of 45°. Compared to the Sibela II group, this group's leaves and flower buds are slightly larger. The elliptical leaves measure 12.84 cm in length and 5.07 cm in width, with a leaf size index of 2.54 and a leaf area of 66.95 cm^2. The leaf colour is deep yellowish green/green group/N134B, while the shoot color is brilliant yellow-green/ yellow-green group/ 149A. The flat funnel-shaped flowers have 9.40 per series, and the ripe flower buds are 1.65 cm long, 4.24 mm in diameter, and weigh 0.24 g. They are a brilliant yellow-green/yellow-green group/150C in color.

The Sibela II clove (Figure 4C) accession groups are clustered with a 95 % similarity rate. This group has a few notable characteristics, such as a conical crown, slightly smaller leaves, and flower buds, compared to the Sibela I clove accession group. On average, the trees in this group have a height of 34.23 m, with a dividing main stem, conical crown, lowest branch height of 1.34 m, and a branching angle of 45°. The leaves are elliptical, with a length of 9.52 cm, a width of 3.75 cm, and an index of 2.55. They have a leaf area of 34.08 cm^2 and a dark leaf color of deep yellowish green/green group/N134A. The shoot colour is moderate yellowish pink/greyed-orange group/N173D. The flower buds of this group are flat funnel-shaped, with a flower length of 1.60 cm, a diameter of 4.24 mm, and a weight of 0.25 g. Members of this group tend to have 9.40 flowers per series and have a brilliant yellow-green/ yellow-green group/150C flower color.

The Siputih clove (Figure 4D) accession groups clustered with a similarity level of 94 %. One identifying feature of this group is the bright yellow hue of its leaves and flower buds, which set it apart from other groups in the population. The trees in this accession group have an average height of 29.84 m and a cone-shaped crown with a main stem that does not divide. The lowest branch height is 1.32 m, and the branching angle is 45°. The leaves are elliptical, measuring 9.78 cm in length and 3.86 cm in width. The leaf size index is 2.52, with a leaf area of 26.70 cm^2. The older leaves are more vibrant

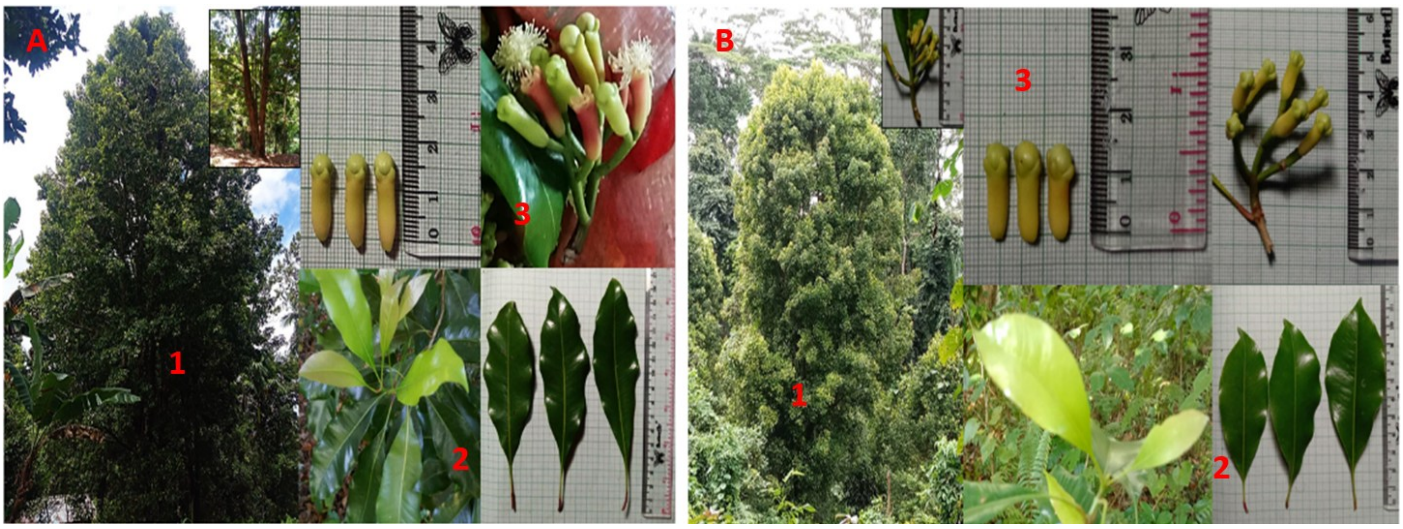

Figure 3. Afo clove (A), Sibela-I clove (B). Tree (1), Leaves (2), Flower Bud (3).

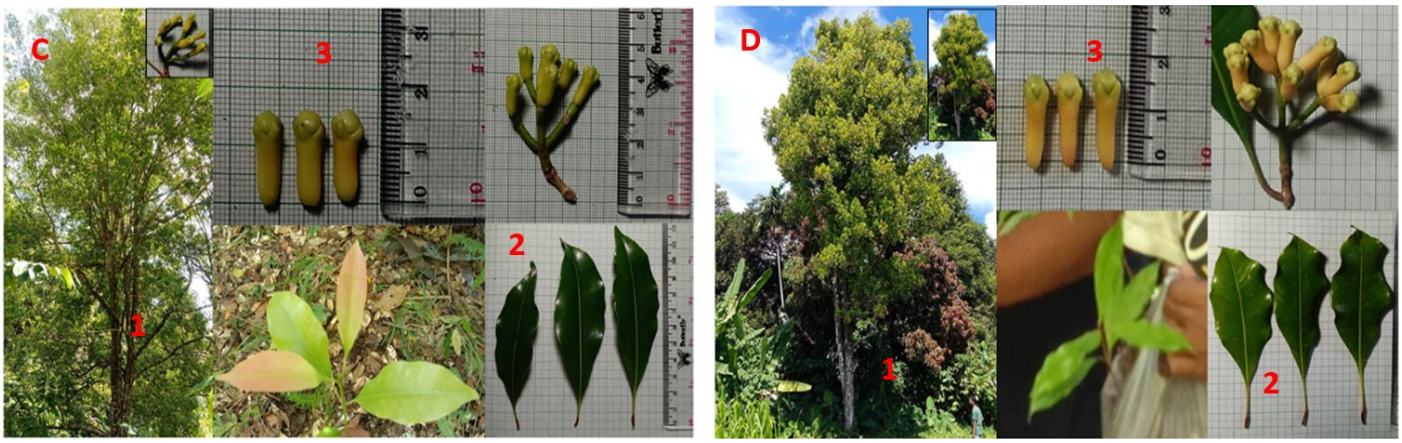

Figure 4. Sibela II Clove (C), Siputih clove (D). Tree (1), Leaves (2), Flower Bud (3).

than other clove accessions, such as the strong yellow-green/yellow-green group/N144C, while the shoots have a grayish reddish orange/greyed-orange group/174D. The mature flower buds of this group are flat and funnel -shaped, with a length of 1.79 cm, a diameter of 4.44 mm, and a weight of 0.32 g. Each set contains an average of 16.20 flowers, and the color of the ripe flower buds is light yellow/yellow group/12C.

The Sikotok clove (Figure 5E) accession group shares a 98 % similarity in clustering. This group is characterized by its small leaves, short handle, and easily falling flower buds. On average, members of this group have a tree height of 20.14 m, with a conical crown and an undivided main stem. The lower branch is typically at a height of 1.10 m, with a branching angle of 45°. The elliptical-shaped leaves have a length of 9.11 cm, a width of 3.54 cm, a leaf size index of 2.58, and a leaf area of 25.29 cm^2. The old leaves are a strong yellow-green/green group/143C, while the shoots are a brilliant yellow-green/yellow-green group/154C. When picked ripe, the flower buds of this group are flat funnel-shaped, with an average of 7.20 flowers per arrangement. The flower bud is 1.77 cm long and 3.95 mm in diameter, weighing 0.26 g, and appears in a brilliant yellow-green/yellow-green group/154C color.

The Rica clove (Figure 5F) accession group is clustered with 95 % similarity. These cloves display a morphology similar to Sikotok cloves, though they differ in their branching direction, which curves downwards. The mature plucked flowers of this group are known for their reddish color and do not fall off easily. Trees belonging to this group have an average height of 20.80 m with a slightly rounded crown shape and a main trunk that does not divide.

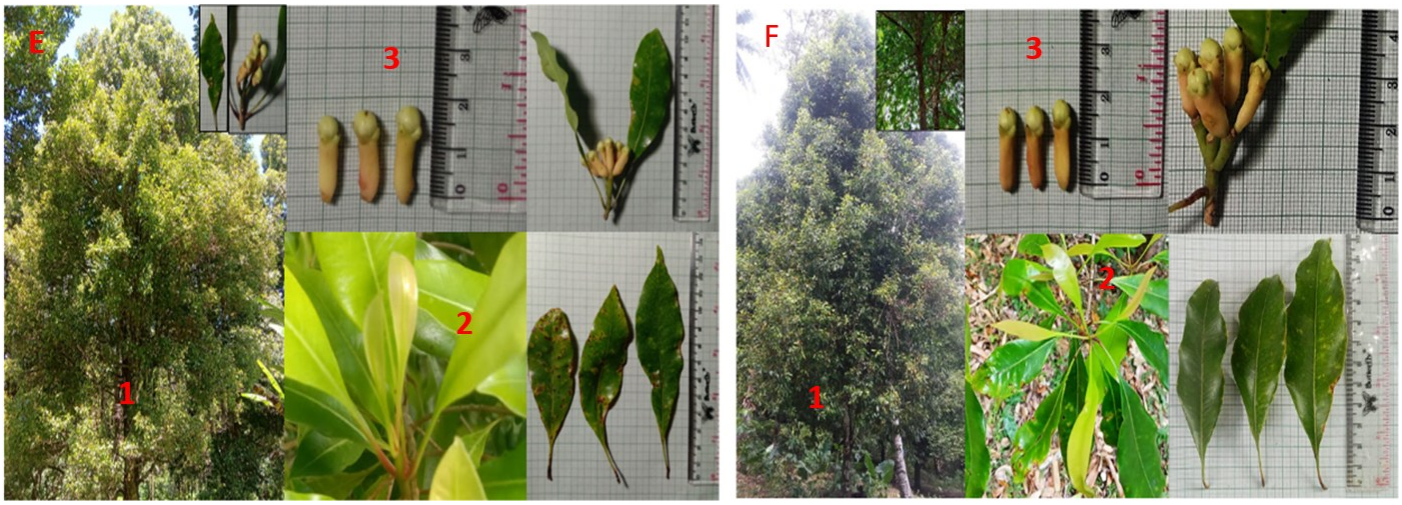

Figure 5. Sikotok Clove (E), Rica Clove (F). Tree (1), Leaves (2), Flower Bud (3).

The lower branches have a height of 1.63 m, and their branching angle is 90°. The leaves of this group are elliptical, with a length of 9.40 cm, a width of 3.24 cm, a leaf size (index) of 2.90, and a leaf area of 25.28 cm². The color of the old leaves is a strong yellow-green/green group/143C, and the shoot color is a moderate reddish orange/grey-red group/179C. This group's picked ripe flowers (flower buds) are flat funnel-shaped with a length of 1.81 cm, a diameter of 4.11 mm, and a weight of 0.34 g. The number of flowers per series is 17.00, and the color is light yellow-green/yellow-green group/154D.

The Red Zanzibar clove (Figure 6G) accession group has a 94 % similarity cluster. This group's most distinctive feature is the reddish hue of its shoots and flower buds and the higher number of flowers per series. On average, this accession has a tree height of 35.84 m, a conical crown, a lower branch height of 1.26 m, an undivided main stem, and an angle of branching of 45°. The leaves are elliptical, with a length of 12.73 cm, a width of 5.27 cm, a leaf size (index) of 2.42, a leaf area of 51.01 cm², and a deep yellowish green/green group/N134B leaf colour, with a strong red/red group/53B shoot colour. Members of this group have an average of 23.80 flowers per arrangement, shaped like a flat funnel. The flower buds have a length of 2.07 cm, a diameter of 4.24 mm, a flower weight of 0.30 g, and a moderate reddish orange/greyed-red group/178C colour.

The Gagang Panjang clove (Figure 6H) accession group is characterised by a 93 % similarity in clustering. This group is easily distinguished by its longer flower stalks and buds that appear greener than other accession groups. Trees in this group have an average height of 20.60 m, with a cone-shaped crown and a non-dividing main trunk. The lower branches are at a height of 1.34 m, and the branching angle is 45°. Leaves in this group are elliptical, 12.17 cm in length and 4.91 cm in width. The leaves have a leaf size (index) of 2.48, with a leaf area of 41.65 cm². The dark leaf colour is a deep yellowish green/green group/N134B, while the shoot colour is a moderate yellowish pink/greyed-red group /179D. Picked ripe flowers (flower buds) are flat funnel-shaped, with approximately 26.00 flowers per set. The flowers are 1.75 cm long, 3.28 mm in diameter, weigh 0.21 g, and are a brilliant yellow-green/yellow-green group/149B.

The White Zanzibar clove (Figure 7I) accession group is similar, at 96 %. These accessions have a similar morphology to the Red Zanzibar clove but with fewer red shoots and flowers. On average, this accession has a tree height of 27.80 m with a cone-shaped crown. The main trunk does not divide; the lowest branch height is 1.16 m, and the branching angle is 45°. The leaves are elliptical, measuring 12.62 cm in length and 4.84 cm in width. Their leaf size (index) is 2.61, with a leaf area of 46.78 cm². The dark leaf colour is a viv-

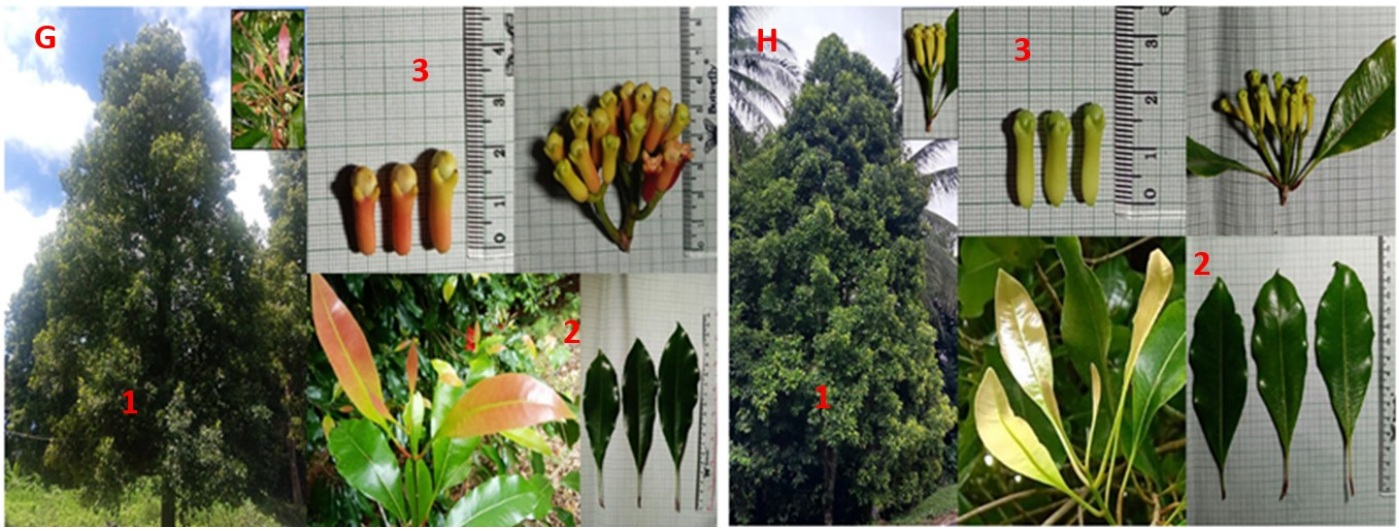

Figure 6. Red Zanzibar clove (G), Gagang Panjang clove (H). Tree (1), Leaves (2), Flower Bud (3).

id yellowish-green/green group/140A, and the shoot colour is a moderate yellowish pink/greyed-orange group /N170D. The ripe flower buds are flat funnel-shaped, with a length of 2.03 cm, a diameter of 4.08 mm, and a weight of 0.30 g. Each arrangement contains an average of 21.40 flowers, coloured brilliant yellow-green/yellow-green group/154C.

The Bogor clove (Figure 7J) accession group shares a 94 % similarity in clustering. These clove plants have a similar morphology to Red Zanzibar cloves but with slightly smaller leaves and flowers. Their trees average 18.00 m in height, with a conical crown and a main stem that does not divide. The lower branches start at 1.60 m in height, with a branching angle 45°. The leaves in this group are elliptical, measuring 8.70 cm in length, 4.77 cm in width, and with an index size of 1.83. The leaf area is 42.19 cm^2, with a deep yellowish green/green group/141B color. The shoot color is moderate reddish orange/greyed-red group/179C. The flower buds are flat funnel-shaped, 1.69 cm in length, and 5.25 mm in diameter. Each series has an average of 12.80 flowers, with a brilliant greenish yellow/yellow-green group/151D color.

The Biasa clove (Figure 8K) accession group shares a 95 % similarity in its characteristics. One of the most notable traits of this group is the similarity in size and color of their leaves to cloves. The Tuni variety is typically cultivated in the Maluku Province and has a cone-shaped crown with more flowers per set than other group members. On average, this clove grow to a height of 17.80 m, have a cone-shaped crown, a single trunk, the lowest branch height of 1.39 m, and a branching angle of 45°. The elliptical leaves of this group measure 9.76 cm in length and 4.83 cm in width, have a leaf size index of 2.27, a leaf area of 29.84 cm^2, and exhibit a strong yellow-green/yellow-green group/N144C colour. The shoots of these trees are light yellow-green/yellow-green group/154D. Each arrangement produces around 26.40 flowers, with ripe flowers harvested in a flat funnel and exhibiting a brilliant yellow-green/yellow-green group/154C colour. The flowers have a length of 1.76 cm, a diameter of 4.83 mm, and weigh 0.33 g.

The Maluku clove (Figure 8L) accession group is 96 % similar in the cluster. Its members share distinct characteristics such as a slightly rounded crown shape and thicker, rounded leaves resembling wild-type cloves, yet with a spicier aroma than cultivated cloves. The average height of these trees is 21.60 m, with a non-dividing main stem, a slightly rounded crown shape, and a 90° branching angle. The ovate-shaped leaves have a length of 10.23 cm, a width of 5.32 cm, and a leaf size (index) of 1.92. They boast a leaf area of 48.78 cm^2, a deep yellowish green/green group/141 leaf colour, and a moderate yellowish pink/greyed-shoot colour, orange-group/N173D. Ripe flowers

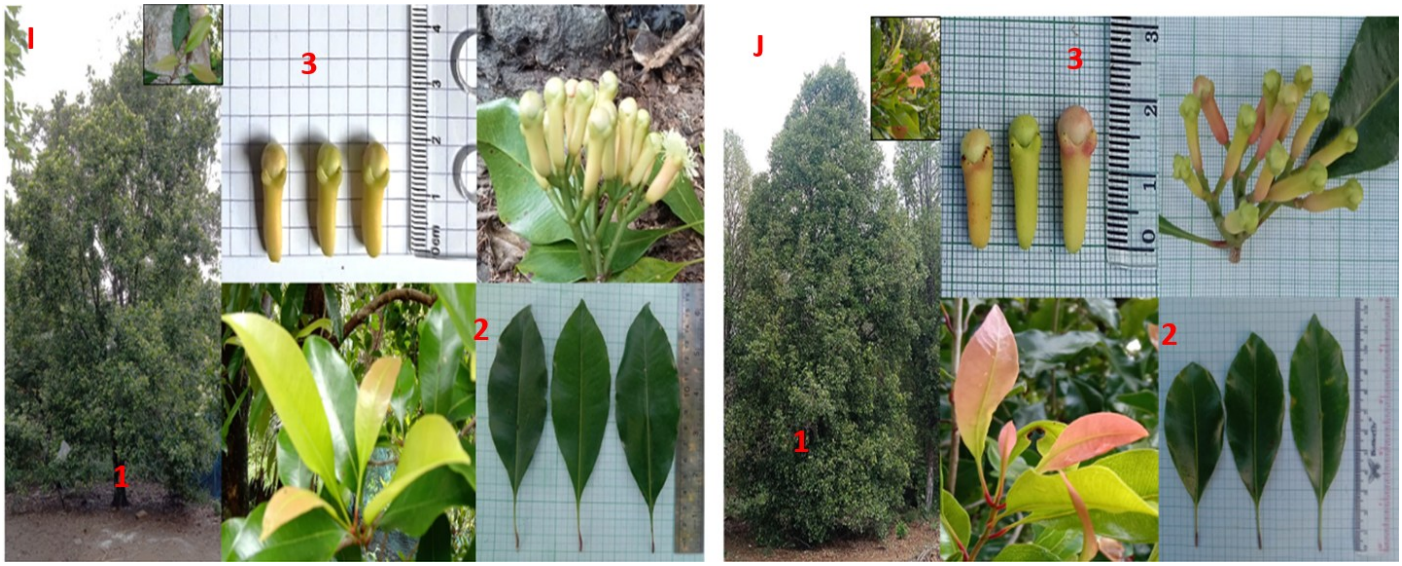

Figure 7. White Zanzibar clove (I), Bogor clove (J). Tree (1), Leaves (2), Flower Bud (3).

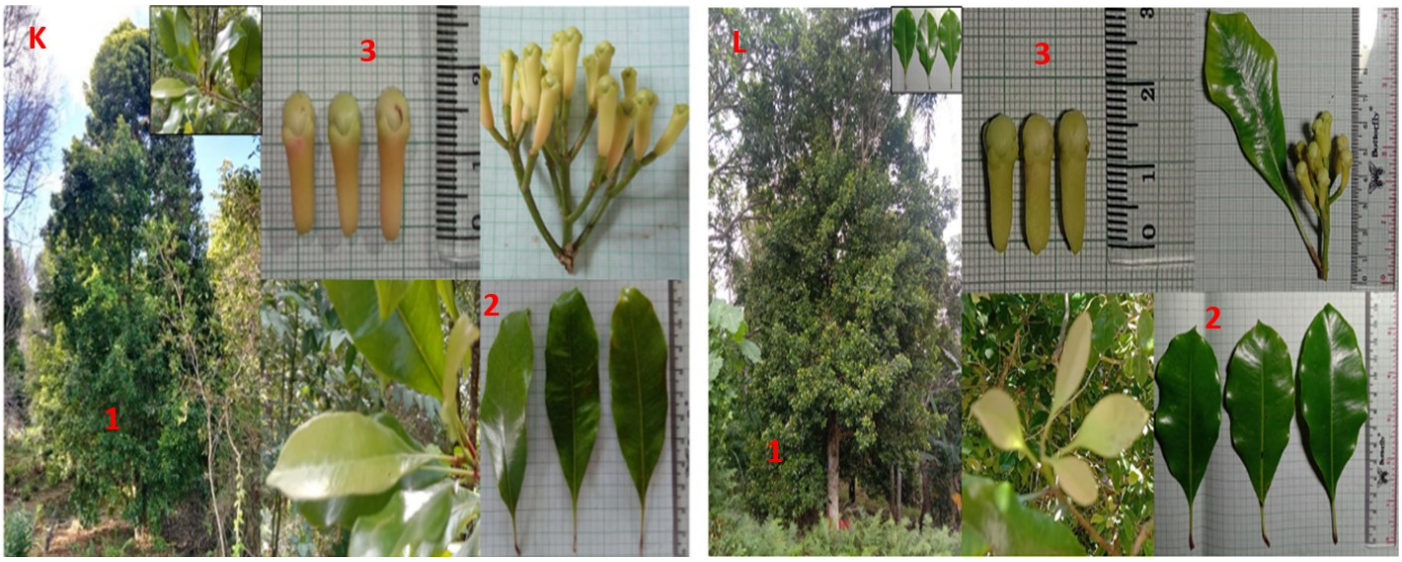

Figure 8. Biasa Clove (K), Maluku Clove (L). Tree (1), Leaves (2), Flower Bud (3).

(flower buds) have a flat funnel shape, with 13.20 flowers per series. The flower buds measure 1.85 cm in length, 4.93 mm in diameter, weighing 0.32 g, and have a brilliant yellow-green/yellow-green group/154C colour.

Group II

Based on Hierarchical Cluster Analysis (HCA), Group II comprises Forest clove (Figure 9) accessions that cluster with 94 % similarity (Figure 15). These accessions are included in the wild-type cloves from the non-aromatic group. The distinguishing characteristics of this clove group are its rounded crown, large leaves and flowers, oval and thicker leaves, and a less spicy aroma in both flowers and leaves. The trees of this accession group have an average height of 35.14 m, a rounded crown shape with an undivided main stem, and a branching angle of 90°. The members of this group have the largest oval-shaped leaves with a leaf length of 18.45 cm, a width of 8.89 cm, a leaf size index of 2.08, a leaf area of 144.13 cm^2, and a dark yellow-green/yellow-green group/144A leaf colour. The shoot colour is a moderate yellowish pink/grayed-orange group/N173D. This group's picked ripe flowers (flower buds) are the largest, with a length of 2.36 cm, a diameter of 6.66 mm, a weight of 0.80 g, and a light yellow-green/yellow-green group/154D colour. The number of picked ripe flowers (flower buds) of members of this group is 13.58 flowers and is round and funnel-shaped.

Figure 9. Forest clove (M). Tree (1), Leaves (2), Flower Bud (3).

Characteristics of North Maluku local clove based on Principal Component Analysis (PCA)

The characteristics of local North Maluku cloves were examined through Principle Component Analysis (PCA) on 65 local clove accessions, using data from 39 diverse morphological characters. According to Greenacre et al. (2022) and Jolliffe (2022), PCA effectively identifies the most influential factors from many variables with high variability. According to Mahulette et al. (2022) and Wattimena et al. (2023), PCA is commonly used to identify key characteristics of a plant group. In this case, one character stood out as having the greatest impact among all those analysed Furthermore, as noted by Mahulette et al. (2022) and Ustari et al. (2023), defining characters are independent factors that can be distinguished from the larger set of variables analysed . The PCA results revealed a total diversity of 52.5 %. Vectors with a red scale indicated the identifying characters (Figure 10a). The vectors close to each accession represented its characteristic traits (Figure 10b).

Group I PCA results showed that Afo clove's distinguishing feature was the main stem division, while Sibela I and Sibela II cloves had spiciness and leaf aroma. Siputih had a ripe flower colour, Sikotok had larger leaves, and Rica cloves had a branching direction. Red Zanzibar cloves had the number of flowers per series, canopy width, and stem circumference. Long Handle cloves had longer flower stalks, White Zanzibar cloves had longer leaf stalks, Bogor cloves had shoot colour, Biasa cloves had bark color, and Maluku cloves had crown shape and branching angles. Group II / Forest Clove had characteristics such as lower branch height, leaf length, leaf width and area, leaf tip shape, leaf thickness, flower length, diameter, and weight.

CONCLUSIONS

North Maluku Province has identified 13 local clove accessions: Afo, Zanzibar Red, Sikotok, Siputih, Rica, Maluku, Gagang Panjang Clove, Sibela I, Sibela II, Forest cloves, White Zanzibar, Bogor cloves, and Biasa cloves. All clove accessions were categorised into two groups with a dissimilarity coefficient of 49 %. Based on Principle Component Analysis (PCA), each clove accession's characteristics were identified. The PCA results showed the characteristics that contribute the most to the grouping, where the characteristic attributed

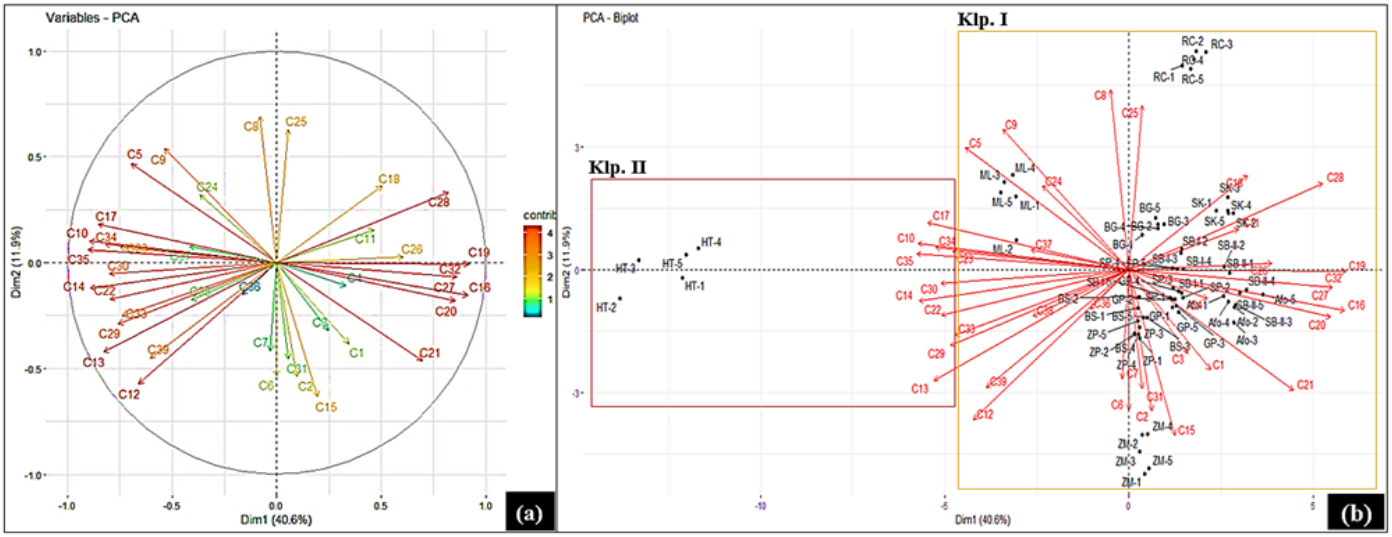

Figure 10. Characteristics of local clove accession groups in North Maluku based on Principle Component Analysis (PCA). Morphological characters, C1-C39; Clove accessions, Afo (Afo), Sibela I (SB), Sibela II (SB II), Siputih (SP), Sikotok (SK), Rica (RC), Red Zanzibar (ZM), Gagang Panjang (GP), White Zanzibar (ZP), Bogor (BG), Biasa (BS), Maluku (ML), Forest Clove (HT).

of Afo cloves obtained are the main stem that divides, Sibela I and Sibela II cloves are the spiciness and aroma of the leaves. Siputih cloves are the colour of ripe flowers, Sikotok is the size of the leaves, and Rica cloves are the branching direction. Red Zanzibar cloves are the number of flowers per arrangement, canopy width, and stem circumference; long-handled cloves are the length of the flower stalk; White Zanzibar cloves are the length of the leaf stalk; Bogor cloves are the colour of the shoots; Ordinary cloves are the colour of the bark, and Maluku cloves are the shape of the crown and the angle of the branching. Forest cloves, as wild-type cloves, are indicated to have characteristic characters in the height of the lowest branch, leaf length, leaf width, leaf area, leaf tip shape, leaf thickness, flower length, flower diameter, and flower weight. These 13 clove accessions prove North Maluku is the centre of origin and has high clove diversity. This accession can be used for future variety development.

AUTHOR CONTRIBUTION

All authors contributed to the published article's research, data collection, data analysis, and writing.

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CONFLICT OF INTEREST

There is no conflict of interest in this research.

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