Selection of highly productive clove trees in the Anambas population

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Abstract. The productivity of cloves in Indonesia is low, probably due to the use of inferior seeds. The success of plant cultivation is determined by many factors, including the use of quality seeds. This study aims to select high-yielding clove trees, which can be recommended as a quality source of seeds. The research was conducted in Anambas Islands Regency, in a population of cloves belonging to a farmer. A highly productive population was selected as the genetic material following the guidelines for selecting the clove population. Furthermore, highly productive mother trees were selected from this population with the criteria of production average 80 kg tree⁻¹. In addition to their production potential, their morphological characters and chemical compound content were also observed. Twenty mother trees with a production potential of more than 100 kg of flowers tree⁻¹ were selected as high yielding trees. The morphological characters of the selected trees do not resemble any of the released varieties. The content of essential oils and main chemical components is following the Indonesian National Standard of clove quality. Twenty highly productive trees can be recommended for further research for use as sources of quality seeds.

1. Introduction

Clove (Syzygium aromaticum L. Merr and Perr.) is an evergreen tree belonging to Myrtaceae. This species is native to Indonesia, especially from the Moluccas Islands [1]. The majority of cloves (more than 90%) are processed along with tobacco to produce "kretek" cigarettes, mainly used in Indonesia. Clove is also used as a spice, pharmaceutical, flavoring, and perfumery [2].

Until now, clove is still one of the strategic commodities and indirectly contributes significantly to state revenue. In Indonesia, the clove plantation area in 2018 is estimated to be up to 596,052 ha, with production reaching 131,014 metric tons [3]. This production amount accounts for nearly 74% of global output, followed by Madagascar, Zanzibar, India, and Sri Lanka [4]. Therefore, Indonesia is known as the leading clove producer in the world.

Indonesia’s cloves’ productivity is 410 kg of dried flowers ha⁻¹, equivalent to 4.10 kg of dried flowers tree⁻¹ [3]. This productivity is very low compared to its genetic potential and productivity in other producing countries. Clove productivity in Kenya is 900 kg ha⁻¹ and in Tanzania is 1147 kg ha⁻¹ [5]. The low productivity of clove at the national level is likely caused by the low quality of seeds, damage and aging of plants, and low plant maintenance. These are probably related to the fact that most of the clove plantation (more than 98 %) is cultivated by small farmers (approximately 1,046,302 farmers),
who have less access to production inputs, and only less than 2% is cultivated by extensive state and private plantations [3].

Increasing national clove productivity is necessary by rehabilitating unproductive, old, and damage trees so that quality seed sources are needed. Unfortunately, the availability of quality seeds for cloves is limited because there are only four recommended seed sources: Zanzibar Karo, Zanzibar Gorontalo, AFO, and Tun Bursel. Another way to provide quality seed sources can be done by selecting high production mother trees from a highly productive population.

Although the national average productivity of cloves is low, there are several highly productive clove populations. Clove plantation in Anambas Regency is highly productive, among others is on the island of Siantan. The clove plantation in Siantan is 114.10 ha, with production reached 80.8 tons, equivalent to productivity 702.61 kg of dried flowers ha⁻¹, which is higher than national clove productivity. This area was then chosen for the selection program.

Clove cultivation in Anambas Regency began in the 1970s during the clove self-sufficiency program, in which seeds came from Bogor. Bogor became a source of seeds in the self-sufficiency program in the 1970-1980s. The clove plantation in Bogor was began by the Dutch in 1933 in the Cimanggu experimental garden, which consisted of various varieties. Clove is a cross-pollinating species [6,7] so that the clove progenies derived from Bogor distributed to other parts in Indonesia will be diverse.

The success of a selection program is determined by the genetic diversity of the original population. The wider the genetic diversity of the original population, the greater the chance for successful selection. In other words, the chance to get a better genotype through selection is getting more prominent [8]. If genetic diversity is narrow, the population is relatively uniform; thus, the selection for trait improvement is less effective [9].

According to Goldschmidt [10], to select mother trees with high productivity and quality, criteria to determine high production and quality need to be considered. Besides that, the criteria for high yielding crops and how to calculate production should be determined. Plant production can be calculated based on the unit area and individual plant⁻¹ unit time⁻¹ [11]. In clove, the selection of high production tree is carried out based on individual tree performance production. In *Melaleuca* species, seeds from high productive mother trees can increase production by 17% [12]. The purpose of this study was (1) to select highly productive clove mother trees, (2) to observe their morphological characters to help in determining the clove type and plant description, and (3) to analyze the quality of clove buds from selected highly productive mother trees.

2. Materials and method
The research was conducted on the island of Siantan, Anambas Islands Regency, Riau Islands Province, from 2015 to 2019.

2.1. Selection of clove population
The highly productive population belongs to a farmer located in the Samak hill valley, Tiangau village, South Siantan. The criteria to select clove population refers to the guidelines for selecting a highly productive population, including land area, the number of trees in the population, plant age, average production tree⁻¹ (30 kg fresh flowers tree⁻¹ at 15 years old) equivalent to 60 kg fresh flowers at 30 years old, and agroecological condition suitable for clove [13]. The characters observed were yielding tree⁻¹ and yield components, namely the number of flower bud inflorescence⁻¹ and individual flower bud weight.

2.2. Selection of high yielding trees
In selecting high-yielding trees (HYTs), observations were made in each flowering season around February-April each year, from 2015 to 2019. Yield observation was carried out following the Indonesian Ministry of Agriculture [13], which requires observing the production of at least three years of harvest. The criteria for the selected trees are those that have a large number of inflorescence tree⁻¹
and a large number of flowers inflorescence\(^1\) (>15) with production tree\(^1\) 40 kg fresh clove at 15 years old [13], equivalent to tree yield (80 kg) at 30 years old. Production tree\(^1\) was determined by harvesting all the flowers from the trees that match the criteria [13], and the flower yield tree\(^1\) was weighed using a scale.

2.3. Observation of morphological characters
Observation on morphological characters was undertaken on plant habits, leaves, flowers, fruits, and seeds to make plant descriptions and determine clove types. The morphological observation followed clove morphological description Kementerian Pertanian [14] and IPGRI [15] modified for cloves. Observation or measurement of each character was carried out on 20 samples tree\(^1\). These means and standard deviation were calculated from the data of 20 samples tree\(^1\). The coefficient of variation (CV) of the character was calculated according to [16].

2.4. Chemical analysis of clove buds
Chemical analysis was undertaken on harvested clove buds that have been sun-dried. Samples were collected from 20 selected HYTs. Essential oil content was extracted by steam distillation of 300 g of dried flower for 8 hours, which was conducted at the Indonesian Spice and Medicinal Crops Research Institute Laboratory, Bogor. Chemical compounds in essential oil were determined by GCMS and conducted at the Health Laboratory of the Government of DKI Jakarta. The analysis used a DB-5MS capillary column, having an inner diameter of 0.25 mm and a film thickness of 0.25 µm. Helium was used as carrier gas with a pressure of 100 kpa. The volume of sample injected was 2 µl. Identification of chemical components was conducted by comparing the fractions of compounds detected with the National Institute of Standards and Technology (NIST) library based on LRI (Linear Retention Indices) values.

3. Results and discussion
3.1. Selection of clove population
Clove plantations in Anambas are managed in limitation and fertilization is very rarely given. The plants begin to flower at the age of 3.5-4 years and still produce until now. The clove plants in Indonesia still produce flowers until more than 100 years. In India, the clove tree begins flowering in about seven years and continues flowering up to 80 years or more [17].

Observation on yield and yield components showed that yield and yield components in the origin population vary more than those in the selected HYTs (Table 1). Yield tree\(^1\) and yield components of HYTs are higher than the original population. Large harvests take place every two years, and among them, small harvests tend to be ignored. Biennial harvest intervals also occur in other regions such as in East Nusa Tenggara (NTT), Maluku, and other clove-producing countries such as Madagascar or Zanzibar [18], where years with high crop yield are followed by years with little or no flowering. Not much researches have been conducted related to irregular bearing, so that factors influence flowering and irregular bearing in cloves are not fully understood [18].

It may be that irregular bearing link with the time needed by the clove plants to undergo plant recovery (with long vegetative phase) after high flowering, in preparation for the next flowering season. The time taken is thought to be influenced by its endogenous hormones, plant nutrition available and environmental condition.
Table 1. Yield and yield components characters of original Anambas population and its 20 high yielding trees

| Characters                          | Original Population | 20 HYTs                  |
|------------------------------------|---------------------|--------------------------|
|                                    | Average | St. dev | CV (%) | Average | St. dev | CV (%) |
| The yield of fresh clove buds tree^{-1} (kg) | 85      | 31.14   | 36.63  | 105.20  | 21.10   | 15.18  |
| The number of flower bud inflorescence^{-1} | 9.71    | 3.10    | 31.94  | 16.54   | 1.86    | 11.25  |
| Individual fresh bud weight (g)      | 0.37    | 0.51    | 13.59  | 0.41    | 0.02    | 5.11   |

3.2. Selection of high yielding trees

Flowering initiation of clove in Anambas Islands Regency occurred in October/November. Fruit harvest is usually taken in March-April. There is variation in yield among the HYTs, ranging from 121 to 192 kg tree^{-1}, equivalent to 38-56 kg tree^{-1} of dry flower (Table 2). The average yield is greater than the average yield of previously released varieties [19].

Table 2. The yield of highly productive clove trees in the Anambas population

| No | Code of HYTs | Yield of fresh flower included stalk (kg tree^{-1}) | Stalk (%) | Average yield (kg) |
|----|--------------|-----------------------------------------------------|-----------|--------------------|
|    |              | 2015 | 2017 | 2019 | Average | Fresh flower | Dried flower |
| 1  | SAG01        | 120  | 134  | 160  | 138.00 | 25.16   | 103.28 | 41.31 |
| 2  | SAG02        | 140  | 156  | 170  | 155.33 | 24.92   | 116.62 | 46.65 |
| 3  | SAG03        | 150  | 152  | 162  | 154.67 | 28.16   | 111.11 | 44.45 |
| 4  | SAG04        | 115  | 125  | 140  | 126.67 | 23.70   | 96.65  | 38.66 |
| 5  | SAG05        | 150  | 160  | 172  | 160.67 | 26.74   | 117.71 | 47.08 |
| 6  | SAG06        | 145  | 150  | 164  | 153.00 | 24.10   | 116.13 | 46.45 |
| 7  | SAG07        | 155  | 165  | 168  | 162.67 | 21.97   | 126.93 | 50.77 |
| 8  | SAG08        | 135  | 141  | 90   | 122.00 | 21.47   | 95.81  | 38.32 |
| 9  | SAG09        | 150  | 165  | 164  | 159.67 | 26.41   | 117.50 | 47.08 |
| 10 | SAG10        | 148  | 160  | 180  | 162.67 | 24.01   | 123.61 | 49.45 |
| 11 | SAG11        | 110  | 120  | 135  | 121.67 | 21.81   | 95.13  | 38.05 |
| 12 | SAG12        | 112  | 124  | 140  | 125.33 | 23.73   | 95.59  | 38.24 |
| 13 | SAG13        | 130  | 141  | 156  | 142.33 | 24.74   | 107.12 | 42.85 |
| 14 | SAG14        | 136  | 144  | 160  | 146.67 | 21.36   | 115.34 | 46.14 |
| 15 | SAG15        | 160  | 171  | 141  | 157.33 | 27.09   | 114.71 | 45.88 |
| 16 | SAG16        | 124  | 139  | 156  | 139.67 | 22.25   | 108.59 | 43.44 |
| 17 | SAG17        | 120  | 132  | 150  | 134.00 | 23.36   | 102.70 | 41.08 |
| 18 | SAG18        | 160  | 170  | 180  | 170.00 | 24.92   | 127.64 | 51.05 |
| 19 | SAG19        | 120  | 123  | 132  | 125.00 | 23.72   | 95.35  | 38.14 |
| 20 | SAG20        | 200  | 187  | 190  | 192.33 | 26.8    | 140.79 | 56.31 |

The 20 HYTs were a result of a gradual selection from the Anambas population. There have been no reports on performances of progenies in a progeny trial in cloves. In *Melaleuca* sp., seeds from selected trees can increase production up to 17% [12] compared to non-selected ones. In other perennial forest plants, simple recurrent selection produces high-productivity plants [20]. The use of seeds from the selected HYTs is expected to increase field crop production.
3.3. Observation of morphological characters

3.3.1. Plant and leaves. Clove plant habits of 20 selected HYTs are in the medium and large size categories with a trunk circumference of 50-120cm and an average plant height of 15.39m (Table 3). The plant ages are more than 30 years. The calculated coefficient of variation (CV) is less than 20% for these plant and leaf characters, except for the canopy width. These indicate that the plant habits and leaves of HYTs are uniforms. Plant of SAG 020 has the widest canopy width (10m) compared to the others and has the highest yield tree\(^1\).

| Code of HYTs | Circumference (cm) | Height (m) | Canopy (m) | Petiole (cm) | Length (cm) | Width (cm) | Index (L/W) |
|--------------|--------------------|------------|------------|--------------|-------------|------------|-------------|
| SAG 01       | 90.00              | 14.00      | 3.00       | 3.15         | 12.75       | 4.83       | 2.64        |
| SAG 02       | 100.00             | 16.00      | 5.00       | 2.75         | 13.50       | 4.40       | 3.07        |
| SAG 03       | 120.00             | 14.50      | 5.50       | 3.08         | 13.00       | 5.58       | 2.33        |
| SAG 04       | 100.60             | 15.00      | 5.00       | 2.70         | 13.45       | 5.58       | 2.41        |
| SAG 05       | 120.00             | 17.00      | 7.00       | 2.43         | 12.50       | 5.10       | 2.45        |
| SAG 06       | 50.00              | 14.50      | 6.00       | 2.83         | 12.83       | 4.80       | 2.67        |
| SAG 07       | 120.00             | 16.50      | 7.00       | 2.53         | 12.28       | 4.63       | 2.65        |
| SAG 08       | 120.00             | 15.50      | 7.50       | 2.70         | 12.25       | 4.18       | 2.93        |
| SAG 09       | 120.00             | 15.00      | 6.50       | 2.73         | 12.93       | 4.78       | 2.71        |
| SAG 10       | 100.00             | 15.00      | 5.50       | 2.33         | 10.83       | 4.15       | 2.61        |
| SAG 11       | 120.00             | 15.00      | 7.00       | 2.30         | 11.17       | 3.97       | 2.82        |
| SAG 12       | 120.00             | 15.80      | 7.50       | 2.50         | 12.33       | 4.77       | 2.59        |
| SAG 13       | 140.00             | 16.90      | 6.60       | 2.83         | 11.83       | 4.58       | 2.58        |
| SAG 14       | 120.00             | 16.50      | 6.50       | 2.97         | 13.60       | 5.10       | 2.67        |
| SAG 15       | 90.80              | 14.50      | 6.50       | 2.88         | 13.20       | 5.85       | 2.26        |
| SAG 16       | 120.00             | 15.50      | 6.00       | 1.04         | 5.17        | 2.14       | 2.41        |
| SAG 17       | 110.00             | 15.00      | 6.50       | 2.33         | 12.25       | 4.73       | 2.59        |
| SAG 18       | 65.00              | 14.30      | 8.20       | 3.15         | 14.28       | 5.48       | 2.61        |
| SAG 19       | 120.00             | 15.50      | 5.50       | 2.88         | 14.95       | 4.88       | 3.07        |
| SAG 20       | 90.00              | 15.80      | 10.00      | 2.90         | 14.55       | 5.43       | 2.68        |

Average: 106.82, 15.39, 6.17, 2.65, 12.48, 4.75, 2.64
St.dev: 20.95, 0.85, 1.66, 0.45, 1.96, 0.78, 0.21
CV (%): 19.61, 5.50, 26.89, 16.93, 15.68, 16.38, 7.97

The canopy shape of 20 selected HYTs is slender conical, similar to those of Tuni Bursel and Gorontalo varieties. This shape is different from Afo, with a wide canopy with a large trunk circumference [21]. The leaves' shape is generally broad-lanceolate with the widest part towards the tip, almost similar to the Afo variety. This shape differs from that of the Zanzibar variety, characterized by slender lanceolate and symmetrical when folded. This result is in accord with [22] that several morphological differences were found among different varieties.

The color of the young leaves of HYTs is reddish-green and turned to dark green on mature leaves. The leaf margin is entirely wavy, and the leaf surface is smooth, with quite clear vena. Leaf venation of the other varieties such as Afo, Gorontalo, and Tuni Bursel are different. Venation in Afo variety is less clear, in contrast to the Tuni Bursel and Gorontalo have very clear vena, with pinnate type [17].

The 20 selected HYTs have relatively stiff leaves. Based on plants character, the leaves and flowers of 20 HYTs are closed to those of Tuni Bursel, similar to those of Siputih type cloves. Leaf characters are useful in distinguishing varieties [22]. In North Maluku, there are several cultivated cloves, namely Zanzibar, Afo, and Siputih, and other indigenous clove variants. These clove types can be distinguished.
from several main characters, especially from the shape of the canopy and leaves, flowers at young, and the ripe picking stage [23].

3.3.2. Flowers. Cloves inflorescences grow at the terminal shoots. HYTs have the medium type of stalks, indicated by the average height of inflorescence (6cm), differ from those of Tuni Bursel with short stalks (average height less than 4cm), and Zanzibar Karo with long stalks. The number of clove buds in inflorescence ranged from 15-22 (Table 4) fullfil the guidance provided for selecting highly productive clove trees [13].

The clove bud's weight is relatively heavy (0.41 g) (Table 4), almost similar Tuni Bursel. The size of individual bud is medium, and relatively smaller than Tuni Bursel, but bigger than Zanzibar Karo. The flower bud is easily separated from the stalks. This character is of interest to farmers because it is easy to separate flower buds from their stalks during harvesting and processing. The Zanzibar clove usually has a lighter clove bud weight, as was shown by Gorontalo [19] and Afo [21]. Afo is thought to be the origin of Zanzibar cloves [22].

The shape of individual flower bud dominantly slim cone, although some showed parallel shape. According to Pool et al. [22] there were three kinds of flower bud shape in clove: slim cone, waisted, and parallel shape. Variation in flower bud shape within population also reported [22], this may be due to that the population developed from seeds resulted from cross pollination. The colour of young flower bud is light green and changes to a slightly reddish beige when reaching the harvesting stage. Flower bud colour in clove differ among varieties. Zanzibar variety generally has red flower bud at the right harvesting stage, while Siputih or Tuni Bursel is light beige to slightly reddish.

**Table 4.** Flower characteristics of high yielding trees in Anambas population

| Code of HYTs | Inflorescence | Clove bud |
|--------------|---------------|-----------|
|              | Length (cm)   | Width (cm) | Height (cm) | Number of flower | Weight (g) | Length (mm) | Corolla width (mm) | Tube width (mm) |
| SAG 01       | 6.11          | 4.15       | 6.24        | 15.7            | 0.39       | 18.90       | 4.85           | 3.75          |
| SAG 02       | 6.20          | 4.12       | 5.92        | 18.2            | 0.41       | 18.26       | 5.10           | 3.73          |
| SAG 03       | 6.77          | 4.71       | 6.80        | 15.4            | 0.44       | 18.73       | 5.08           | 3.49          |
| SAG 04       | 6.78          | 5.19       | 6.19        | 15.1            | 0.40       | 20.54       | 6.21           | 4.93          |
| SAG 05       | 6.47          | 4.12       | 6.62        | 20.1            | 0.40       | 20.63       | 5.96           | 4.74          |
| SAG 06       | 5.57          | 3.60       | 5.78        | 15.9            | 0.42       | 20.14       | 6.01           | 5.22          |
| SAG 07       | 6.97          | 4.51       | 6.27        | 16.7            | 0.42       | 19.92       | 6.06           | 5.26          |
| SAG 08       | 6.80          | 4.64       | 6.02        | 15.4            | 0.42       | 20.40       | 6.46           | 5.27          |
| SAG 09       | 6.93          | 4.65       | 6.34        | 17.2            | 0.39       | 20.22       | 6.11           | 5.02          |
| SAG 10       | 7.00          | 5.34       | 6.24        | 15.4            | 0.39       | 19.41       | 6.10           | 4.90          |
| SAG 11       | 6.22          | 3.92       | 6.25        | 15.2            | 0.43       | 20.38       | 6.99           | 4.98          |
| SAG 12       | 6.22          | 3.92       | 6.25        | 16.1            | 0.43       | 20.38       | 6.99           | 4.98          |
| SAG 13       | 7.05          | 4.35       | 6.60        | 16.5            | 0.39       | 20.08       | 6.09           | 5.20          |
| SAG 14       | 6.25          | 3.85       | 5.40        | 15.1            | 0.40       | 20.38       | 6.30           | 5.17          |
| SAG 15       | 6.70          | 4.65       | 6.95        | 22.1            | 0.40       | 20.60       | 6.18           | 5.62          |
| SAG 16       | 4.30          | 3.2        | 5.63        | 19.0            | 0.39       | 19.58       | 6.27           | 5.39          |
| SAG 17       | 6.25          | 3.95       | 5.45        | 15.3            | 0.38       | 20.01       | 6.78           | 5.38          |
| SAG 18       | 5.87          | 3.55       | 5.70        | 15.8            | 0.46       | 19.64       | 6.26           | 5.62          |
| SAG 19       | 6.50          | 4.00       | 6.25        | 15.1            | 0.43       | 19.43       | 5.76           | 5.01          |
| SAG 20       | 6.50          | 4.00       | 6.25        | 15.5            | 0.43       | 19.43       | 5.76           | 5.01          |
| Average      | 6.37          | 4.22       | 6.16        | 16.54           | 0.41       | 19.85       | 6.07           | 4.93          |
| St.dev       | 0.61          | 0.52       | 0.41        | 1.86            | 0.02       | 0.65        | 0.55           | 0.58          |
| CV (%)       | 9.64          | 12.39      | 6.62        | 11.25           | 5.11       | 3.28        | 9.10           | 11.81         |
The corolla has a lightly red spot, with a dome shape. This shape differs from Afo [21] and Zanzibar Karo [24] varieties, which have a triangular shape and prominent red spot. Differences in flower bud characters between HYTs with other clove varieties are in accord with Pool et al. [22] that flower bud characters can be used to differentiate between varieties/populations.

3.3.3. Fruits and seeds. The morphological appearance of the fruit can be used as a distinguishing feature between varieties in other crops. In cloves, there are still no apparent differences between varieties. Fruit shapes in HYTs from the Anambas population are mainly cylindrical or elongated conical, similar to all clove varieties released, with an average fruit index of nearly two. The average fruit weight of HYTs is 2.98 g lighter than Tuni Bursel and Afo but heavier than Zanzibar Karo and Zanzibar Gorontalo (Table 5).

| Code of HYTs | Fruit Weight (g) | Fruit Length (mm) | Fruit Width (mm) | Fruit Index (l/w) | Seed Weight (g) | Seed Length (mm) | Seed Width (mm) | Seed Index (l/w) |
|--------------|------------------|-------------------|------------------|------------------|----------------|------------------|----------------|----------------|
| SAG 01       | 2.91             | 27.88             | 13.16            | 2.12             | 1.27           | 18.78           | 9.55           | 1.97           |
| SAG 02       | 2.89             | 26.93             | 13.74            | 1.96             | 0.95           | 15.61           | 8.42           | 1.85           |
| SAG 03       | 2.82             | 26.12             | 14.70            | 1.78             | 0.88           | 16.54           | 8.63           | 1.92           |
| SAG 04       | 2.98             | 26.19             | 13.90            | 1.88             | 0.90           | 16.02           | 8.97           | 1.79           |
| SAG 05       | 3.47             | 28.24             | 13.87            | 2.04             | 1.11           | 19.36           | 9.08           | 2.13           |
| SAG 06       | 2.45             | 26.82             | 12.46            | 2.15             | 0.70           | 15.64           | 8.27           | 1.89           |
| SAG 07       | 2.97             | 26.52             | 13.70            | 1.94             | 1.00           | 17.11           | 9.32           | 1.84           |
| SAG 08       | 2.90             | 27.21             | 13.50            | 2.02             | 0.86           | 16.51           | 8.80           | 1.88           |
| SAG 09       | 4.55             | 25.07             | 12.85            | 1.95             | 0.95           | 16.77           | 8.59           | 1.95           |
| SAG 10       | 3.33             | 28.21             | 14.02            | 2.01             | 1.16           | 18.47           | 9.18           | 2.01           |
| SAG 11       | 3.21             | 25.99             | 14.58            | 1.78             | 1.06           | 17.82           | 9.48           | 1.88           |
| SAG 12       | 2.73             | 25.55             | 12.84            | 1.99             | 1.00           | 17.71           | 9.42           | 1.88           |
| SAG 13       | 2.43             | 24.95             | 12.37            | 2.02             | 0.95           | 17.38           | 9.06           | 1.92           |
| SAG 14       | 2.65             | 25.67             | 13.74            | 1.87             | 0.70           | 15.11           | 8.34           | 1.81           |
| SAG 15       | 2.67             | 25.68             | 13.28            | 1.93             | 0.75           | 15.55           | 7.92           | 1.96           |
| SAG 16       | 2.52             | 26.13             | 13.08            | 2.00             | 1.07           | 17.12           | 9.45           | 1.81           |
| SAG 17       | 2.41             | 24.49             | 13.10            | 1.87             | 0.88           | 17.62           | 8.83           | 2.00           |
| SAG 18       | 3.43             | 25.98             | 14.36            | 1.81             | 1.23           | 19.66           | 9.70           | 2.03           |
| SAG 19       | 3.21             | 29.16             | 12.76            | 2.29             | 0.97           | 19.92           | 8.33           | 2.39           |
| SAG 020      | 3.02             | 26.35             | 14.10            | 1.87             | 1.05           | 19.18           | 9.02           | 2.13           |
| **Average**  | **2.98**         | **26.46**         | **13.51**        | **1.96**         | **0.97**       | **17.39**       | **8.92**       | **1.95**       |
| **St.dev**   | **0.48**         | **1.17**          | **0.66**         | **0.12**         | **0.15**       | **1.43**        | **0.49**       | **0.14**       |
| **CV (%)**   | **16.05**        | **4.42**          | **4.88**         | **6.29**         | **15.74**      | **8.21**        | **5.44**       | **7.06**       |

Clove fruits commonly reach maturity three months after anthesis, indicated by the color change. The skin color of clove fruit is green when young and becomes purplish-red when mature, with no clear distinction in fruit color among varieties. However, the color of the fruit is commonly used as an indicator of physiological maturity. The seeds' physiological ripening phase can be determined using the age indicator after the anthesis and using fruit size indicators and color [25]. The mature clove fruits turned to red, indicating physiological maturity, and have a vigor index value of 73.75% [26].

HYTs seeds' shape is narrow cylindrical or elongated conical with an average seed index of almost two, the same as the shape of seeds of other clove varieties. The colour of the seed varies, from reddish-green to red. The development of seeds is better when fruits have fully mature, indicated by purplish
skin color. In *Syzygium polyanthum*, the clove-related species within the Myrtaceae, seeds' physiological maturity is at the pre-ripe stage, characterized by the fruit's reddish-green skin color and has the highest germination [27].

The average seed weight of HYTs is 0.97 g (Table 5). The weight of seeds in cloves varies depending on the varieties, from less than 1 g to more than 2 g, with Tuni Bursel has the highest seed weight. The average seed weight of HYTs is similar to Zanzibar Karo and Zanzibar Gorontalo.

Seed weight correlates with quality in other plant species. In clove, it is not directly correlated with seed quality and germinability. Field experience also showed that seed size in clove is not a determining factor of seed viability. However, seed weight above 1 g is considered good quality seeds that will germinate three weeks after sowing [28]. In Rubiaceae species, small coffee seeds will sprout and grow fast and simultaneously in coffee, and the germination is faster than large and medium-size seeds [29]. The research results on a forest tree *Intsea palembanica*, seed weight has a positive effect on germination. Weighted seeds provide a better germination response compared to medium-weight and light-weight seeds [30].

### 3.4. Chemical analysis of cloves

Essential oil levels and eugenol levels are quality criteria for cloves. Indonesian National Standard (INS) and European Spice Association (ESA) standards require minimum clove essential oil content to be 12%. Essential oil levels and high levels of eugenol are widely requested in the pharmaceutical and cigarette industries. These industries generally accept clove with a minimum content of eugenol 70%. Standards of total eugenol based on the INS standard is 80-95%, 80.5 - 85.1% [31] and 75-88% [32].

The clove bud oil content of HYTs is 12.94-20.01%, with total eugenol 74-86%, true eugenol 70.40-78.16%, β-caryophyllene 13.71-23.68%, humulene 1.18-2.56% and eugenol acetate 0-10.95% (Table 6). In terms of clove bud oil, all the HYTs fulfill the INS. Although most HYTs do not fulfill the eugenol's total content as determined by INS but fulfill [32] and industries requirements.

Compared with the released varieties, the essential oil and eugenol contents of the HYTs are lower than that of Zanzibar Gorontalo, with oil content ranged from 19.94-23.00% and total eugenol content of 87.45 - 93.00% [19]. However, in the eugenol content, the oil of HYTs corresponds to Tuni Bursel 79.82% [33]. In Ambon, the clove essential oil content reported 7.05%, much lower than HYTs but has higher eugenol levels 81.13 - 84.44% [34].

The average content of β-caryophyllene of 20 HYTs (20.26 %) is much higher than Afo (16.5%) [21], Tuni Bursel (14.91%) [33] and Gorontalo varieties (11.27%) [19], also from Tuni (12.68%) [33] and Zanzibar (19.3%) cloves from Ambon [35] and the Zanzibar clove grown in East Jawa [36], and cloves planted in Jawa and Manado [37]. Eugenol acetate is another component in clove oil detected from this study, and the value ranged from 0-10.95 %. There are seven HYTs which eugenol acetate levels are not detected, maybe influenced by genetic rather environmental factors, because all the HYTs are grown in the same environmental condition. Eugenol acetate in HYTs is similar to cloves oil from Ambon, namely in Tuni 6.23% and much less than in Zanzibar clove 19.15% [22]. The eugenol acetate levels from this study are also much lower than clove oil grown in Jawa (20.54%) but almost similar to cloves grown in Manado at 8.70% [37]. For humulene content, results from this study are 1.18-2.56%, which is in accord with clove grown in Jawa and Manado [37].

The secondary metabolites production is highly influenced by the genetic and environment and genetic x environmental interaction. Those differences in essential oil content and components among clove reported by several researchers may be attributed to those factors. The differences were probably due to differences in the stage of flowers harvested [36] or oil extraction method [17]. In this study, the oil quality is analyzed from the mature clove buds, marked by the reddish beige buds' color, with the flower crown still intact and not yet anthesis/bloom. The oil was produced from a water/steam distillation.
Table 6. Essential oils and major chemical components of highly productive clove trees in the Anambas population

| Code of HYTs | Numbers of component | Essential oils (%) | Total eugenol (%) | True eugenol (%) | Caryophyllene (%) | Humulene (%) | Eugenol acetate (%) |
|--------------|----------------------|-------------------|------------------|------------------|------------------|--------------|---------------------|
| SAG 01       | 5                    | 15.68             | 74               | 77.10            | 18.64            | 2.00         | 1.67                |
| SAG 02       | 6                    | 16.97             | 79               | 75.79            | 19.92            | 2.10         | 1.33                |
| SAG 03       | 7                    | 12.94             | 76               | 72.16            | 22.14            | 2.37         | 1.90                |
| SAG 04       | 6                    | 15.42             | 76               | 74.06            | 21.72            | 2.31         | 1.10                |
| SAG 05       | 5                    | 16.5              | 86               | 73.46            | 13.71            | 1.50         | 10.95               |
| SAG 06       | 8                    | 17.33             | 79               | 73.41            | 20.68            | 2.20         | 2.05                |
| SAG 07       | 7                    | 15.67             | 78               | 74.36            | 20.03            | 2.15         | 2.20                |
| SAG 08       | 5                    | 17.34             | 78               | 76.91            | 19.77            | 2.16         | 0.00                |
| SAG 09       | 5                    | 17.32             | 80               | 76.93            | 18.65            | 2.01         | 1.96                |
| SAG 010      | 5                    | 16.3              | 82               | 78.16            | 18.21            | 2.02         | 1.12                |
| SAG 011      | 7                    | 17.03             | 77               | 73.47            | 21.44            | 2.30         | 1.64                |
| SAG 012      | 5                    | 20.01             | 76               | 75.82            | 20.53            | 1.18         | 0.00                |
| SAG 013      | 7                    | 16.53             | 79               | 75.53            | 20.36            | 2.19         | 0.00                |
| SAG 014      | 6                    | 18.07             | 76               | 74.78            | 21.49            | 2.29         | 0.00                |
| SAG 015      | 7                    | 18.15             | 76               | 74.12            | 21.91            | 2.33         | 0.00                |
| SAG 016      | 7                    | 18.99             | 79               | 75.17            | 15.60            | 1.71         | 5.78                |
| SAG 017      | 8                    | 17.36             | 77               | 74.02            | 21.06            | 2.23         | 1.07                |
| SAG 018      | 7                    | 15.33             | 70               | 70.40            | 23.62            | 2.56         | 1.88                |
| SAG 019      | 6                    | 18.5              | 76               | 74.17            | 22.12            | 2.34         | 0.00                |
| SAG 020      | 4                    | 19.49             | 75               | 73.33            | 23.68            | 2.54         | 0.00                |
| Average      | 6.15                 | 17.05             | 77.45            | 74.66            | 20.26            | 2.12         | 2.66                |
| St.dev       | 1.59                 | 3.14              | 1.79             | 2.38             | 0.33             |              |                     |
| CV (%)       | 9.33                 | 4.05              | 2.4              | 11.74            | 15.53            |              |                     |

The highest oil and eugenol levels are obtained from flowers that have bloomed where the stamens and crowns have fallen off (over matured buds) [36]. On the contrary, our study results show that eugenol's highest content is obtained from mature clove buds (fully developed flowers with the crown still intact, not yet bloom). The difference may be attributed to differences in variety and environmental conditions of the plants grown.

The extraction method influenced eugenol content. Extraction of clove bud using methanol produced eugenol in Zanzibar Gorontalo, Afo, and Tuni Bursel varieties, differed from those reported by Supriadi et al. [19], Departemen Pertanian [21], and Bermawie et al. [33]. Besides that, plant age also influences oil and eugenol contents. The oil content of clove buds harvested from young clove plants (aged 4-5 years) was higher than that from old clove plants (aged 45 years) [36]. On the other hand, eugenol and β-cis-caryophyllene contents are higher in old plants than in young plants. The clove plants age used in this study was over 30 years old, this may be why oil and eugenol content was low, and β-cis-caryophyllene are high, compared to the other varieties.

4. Conclusions

Highly productive trees were selected from the Anambas population with an average yield of over 100 kg tree⁻¹. The overall morphological characteristics are not the same as those of the released varieties but have their characteristics. Essential oil content, total eugenol, and true eugenol levels were in accord with the Indonesian National Standard. β-caryophyllene levels were higher than the superior clove varieties. The selected mother trees may be recommended for further studies for use as seed sources.
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