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THE PHYSICOCHEMICAL COMPONENTS AND CHARACTERISTIC FROM ESSENTIAL OILS OF FOREST CLOVES *SYZYGIUM AROMATICUM* (MYRTACEAE) IN MALUKU PROVINCE, INDONESIA

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Abstract

Forest clove (*Syzygium aromaticum* (L.) Merr. & L. M. Perry.) is a type of wild clove from the Myrtaceae family which is an indigenous plant of Indonesia with a distribution limited to the northern and central Maluku Islands and Papua, Indonesia. In Maluku, this species is known as the forest clove and is only utilized as dried clove buds. Utilization in the form of volatile oil is uncommon; therefore, information about the composition of forest clove volatile oil is not yet available. The present study aimed to determine the chemical composition of six hydrodistillation volatile oils from different morphological parts of the forest clove. Samples were collected from two areas in Maluku and followed the standard laboratory analysis. The samples were extracted using the hydrodistillation method under atmospheric pressure using a modified Clevenger-type apparatus. A total of 68 components were identified from all of the volatile oils, consisting of 30 volatile oil components from Ambon Island forest clove and 38 components from Seram Island forest cloves. The main component of clove oil from Ambon Island is germacrene-D (15.49%) which was identified in the bud oil, while the main component of clove bud oil from Seram Island is α-cubebene (20.55%). The soil factor had a very strong influence on the concentration of forest clove volatile oil components and oil content (yield), while the climate factor had more influence on the wet clove bud production weight.

***Key words*:** cloves germplasm, maluku, non-aromatic cloves, *Syzygium aromaticum*, volatile oil, wild tipe cloves.

Introduction

Syzygium is one of the largest genera of the Myrtaceae family which consists of 1200 species with the center of diversity in Southern Asia, Southeast Asia, Malesian, Australian, and New Caledonian regions (Tuiwawa *et al.,* 2013). One of the economically valuable species of the *Syzygium* genus is clove. The scientific name of clove is *Syzygium aromaticum*, classified as the *Syzygium* genus, Syzygieae family, and Myrtoideae subfamily from the Myrtaceae family (Hossain *et al.* 2012). Clove is an indigenous plant of Indonesia from the Maluku Islands and is a plant that produces volatile oils (Milind & Deepa, 2011) and has been cultivated in Madagascar, Sri Lanka, Indonesia, Southern China and has spread to other countries such as Bangladesh, Burma, Thailand, and Malaysia (Hossain *et al.,* 2012). In Maluku, there is a wild clove species known as the forest clove. The forest clove has a different morphology from the cultivated clove. Forest clove is characterized by a sturdy tree, rounded canopy, larger and thicker leaves, less tapered leaf tips, and low branching in the main trunk (Koemiati, 1997). In addition, the forest clove is less aromatic in its flowers and leaves. The distribution of forest clove is limited to the Northern and Central Maluku Islands and Papua. In the central Maluku Islands, the forest clove is commonly found on Ambon Island and Seram Island (Milind & Deepa 2011).

The forest clove production is currently limited to utilization of the dried clove buds even though the utilization of this clove in the form of its essential oils (volatile oils) and oleoresin are more commercial (Riyanto *et al.,* 2016; Gaspar *et al.,* 2018). So far the composition of Maluku forest clove volatile oils is not known for sure, especially that of the bud oil, stem oil, and leaf oil. The composition and concentration of the volatile oil produced will differ depending on the plant species and the part analyzed (Oniga *et al.* 2010; *Amini et al.* 2016).

Oil clove is classified as an essential oil (volatile oil) and can be extracted from the flower, leaf, and stem, producing bud oil, leaf oil, and stem oil (Widayat *et al.,* 2014; Riyanto *et al.,* 2016; Nejad *et al*., 2017; Uddin *et al.,* 2017). Information of the volatile oil components of the bud oil, stem oil, and leaf oil of clove is important because they have been reported to be utilized in pharmaceuticals, aromatherapy, cosmetics, foods, agriculture, and other industries (Jentzsch *et al*., 2017; Rathinam & Viswanathan, 2018). The purpose of this study is to determine the relationship of the composition and concentration of the bud oil, stem oil, and leaf oil of the forest clove from two of its distribution locations in Maluku, Indonesia.

Material and Methods

Site and Time Location

Samples of forest clove (*Syzygium aromaticum* (L.) Merr. & L. M. Perry.) of the flower, flower stem, and leaf were collected from the two distribution locations in Maluku, Indonesia: Ambon Island (03°36'21.7" E – 128°11'19.9" S, at an elevation of 186 m) and Seram Island (03°25'42.8" E – 128°38'54.9" S, at an elevation of 21 m), from March to July 2018 during the flowering phase. The samples were selected uniformly from forest cloves that were morphologically large. Herbarium forest clove (*Syzygium aromaticum* (L.) Merr. & L. M. Perry.) specimens were collected by the Herbarium Bogoriense, Research Center LIPI-Cibinong Bogor-Indonesia (BO 1726070). Soil analysis from the forest clove distribution location was conducted by composite as a representation of each area at the Laboratory of Environmental Biotechnology, Bogor-Indonesia. The forest clove distribution location climate data from the two areas were obtained from the Pattimura Meteorological Station, Maluku Province, Indonesia (2018).

Morphological Characteristics

Before the samples for volatile oil isolation were collected, the forest clove trees in their distribution area on

Ambon Island and Seram Island were characterized morphologically. The morphological characterization used productive trees aged > 15 years. Ten trees were chosen from each area, making a total of 20 trees. The observation of morphological characters referred to IPGRI (1980) with modifications. The morphological characters assessed were the leaf, bud, fruit, and seed using a ruler, while the diameter was measured using vernier calipers. The bud, fruit, and seed were weighed using a digital scale, and the color characteristics were evaluated using the RHS color chart (2015).

Isolation of clove oil

The plant materials were distilled at the Spice and Medicinal Crops Research Institute (Balai Penelitian Tanaman Rempah and Obat (BALITTRO), Bogor-Indonesia using the hydrodistillation method for 6 hours at 100 ℃. Anhydrous sodium sulfate (Na_2SO_4) was added to the oils that were produced and then the mixtures were stored in dark-colored bottles and placed in a tight container at 2 ℃ before the next analysis. The clove oil yield (v/w) from different morphological parts from the two locations in Maluku was: Ambon Island 1.33% (bud), 1% (stalk), 0.44% (leaf); Seram Island: 1.30% (bud), 1.2% (stalk), 0.35% (leaf).

GC-MS analysis

The gas chromatography analysis was conducted at the Special Capital Region of Jakarta's Laboratory of Regional Health, Indonesia. The oil was analyzed using an Agilent Technologies 7890 Gas Chromatograph with an autosampler and 5975 mass selective detector and chemistation data system. The data was collected on an HP INNOWAX capillary column (30 m x 0.25 i.d., film thickness 0.25 µm). The equipment conditions were Helium carrier gas, 0.6 mL/min flow, oven temperature: 60 to 150 ℃ at 2 ℃/min, 150 ℃ to 210 ℃ at 20 ℃ /min; injection temperature 250 ℃; ion source temperature 230 ℃, interface temperature 280 ℃; quadrupole temperature 140 ℃; ionization voltage 70 eV; split 250:1.

Identification of essential oil components

The volatile oil components were identified based on the GC retention time on the 5975 mass selective detector fused silica capillary column. The mass spectra were connected to the standard chemistation data system (NIST 2005 v.2.0 and Wiley 7 library 2003 (Hossain *et al*., 2012). The GC-MS analysis result component data was then analyzed with the R Stat 3.1.0 software to create a heatmap profile of the volatile oil classification. The package used was metabolomics, heatmap, shiny heatmaply, and shiny using a complete linkage agglomeration method and Euclidean distance matrix.

The Environmental Physicochemical Characteristic Analysis

Analysis of organic C used the gravimetry method, the Total N used the Kjeldahl method, and P_2O_5 and K_2O used the Olsen/Bray method, moisture content used gravimetry, and soil texture used the Pipette method.

Statistical Analysis

The correlation between environmental factors and the production of forest clove volatile oil was analyzed using the Principal Component Analysis with help from the XLSTAT software version 2019.1.

Results

Morphological Characters

Morphological characterization of forest cloves was conducted on samples collected from their two distribution areas in Maluku, on Ambon Island and Seram Island. The morphological characteristics of the leaf, bud, fruit, and seed of forest clove are presented in Table 1.

Table 1: Morphological characters of forest cloves in Maluku

Site	Morphology	Parameters				Amount	Colour
		Shape	Lenght (cm)	Widht (cm)	Weight (g)		
Ambon	Leaf	Oval	20.67±1.61	9.94±0.88	-	-	deep yellowish green (141A)
	Flower bud	Round funnel	2.51±0.10	0.63±0.04	0.84±0.12	19.12±4.40	light yellow green (154D)
	Fruit	Conical	3.21±0.22	1.60±0.21	5.37±1.70	-	dark red (59A)
	Seed	Conical	2.26±0.31	0.96±0.17	1.59±0.53	-	strong purplish red (59D)
Seram	Leaf	Oval	20.15±1.26	9.81±0.93	-	-	deep yellowish green (141A)
	Flower bud	Round funnel	2.35±0.10	0.64±0.05	0.80±0.10	12.83±2.29	light yellow green (154D)
	Fruit	Conical	3.35±0.24	2.10±0.07	9.17±0.95	-	dark red (59A)
	Seed	Conical	2.34±0.20	1.19±0.10	2.26±0.51	-	strong purplish red (59D)

Forest cloves on Ambon Island and Seram Island had similar morphology and color, only differing slightly in the size of the plant morphology. Forest clove leaves in the two locations were oval with obtuse leaf tips; however, the leaves of the forest clove from Ambon Island were slightly larger than those from Seram Island. The forest clove leaves from Ambon Island had an average length of 20.67 cm and width of 9.94 cm. The forest clove flower buds from Ambon Island were also morphologically larger and had a greater number of flowers per cluster than those of the forest clove from Seram Island. The forest clove from Ambon Island had an average flower bud length of 2.51 cm, a width of 0.63 cm, a weight of 0.84 g, and a number of flower buds per cluster of 19.12 buds. Even though it had a slightly larger leaf and flower morphological size, the forest clove from Ambon Island had fruit and seeds that were morphologically smaller than those of the forest clove from Seram Island. The fruit of the forest clove from Seram Island had an average length of 3.35 cm, an average diameter of 2.10 cm, and an average weight of 9.17 g. The seeds of the forest clove from Seram Island had an average length of 2.34 cm, an average diameter of 1.19 cm, and an average weight of 2.26 g.

Distribution

In Maluku, the distribution of forest cloves was most common on Ambon Island (Hitulama, Hitumessing, Mamala, and Morella villages) and on Seram Island (Latu and Hualoy villages). In these areas, cloves are commonly cultivated by farmers because the dried clove buds have commercial value. Forest cloves in these locations are generally found in the mountain forests on Ambon Island and Seram Island. In its distribution area on Ambon Island, this species was commonly found at an altitude of 100-250 m, while on Seram Island it was found at an altitude of 100-500 m..

The Environmental Soil Physicochemical Properties

Forest cloves grow well in Maluku because the soil and agro-climatic factors are suitable. The results of the soil and climate conditions in the two distribution locations in Maluku are presented in Table 2.

Table 2 : The soil conditions in the forest clove distribution areas in Maluku, Indonesia

Parameters	Distribution	
	Ambon	Seram
C organic (%)	2.38	2.79
N-Total (%)	0.25	0.27
P_2O_5 (ppm)	29.87	6.50
K_2O (ppm)	88.52	27.84
Water content (%)	4.40	1.72
pH	6.56	5.36
Sand (%)	48.85	58.65
Silt (%)	33.84	23.35
Clay (%)	17.31	18.00

The results of the soil analysis in the two forest clove distribution locations revealed a near-neutral pH. The forest clove distribution location on Ambon Island had a soil pH of approximately 6.56 and on Seram Island 5.36. The moisture content and available P_2O_5 and K_2O content in the soil in the forest clove distribution areas on Ambon Island were slightly higher than on Seram Island. Besides the soil factor, the climate factor also has an effect on the growth of forest clove trees. The climatic condition on Ambon Island and Seram Island where the forest cloves were found is presented in Figure 1.

The climatic condition in the two forest clove distribution areas in Maluku revealed that the precipitation rate in Ambon Island was 453 mm/month with an average monthly temperature of 27.03 ^{o}C and humidity of around 86%. On Seram Island, the precipitation rate was around 238.64 mm/month with an average temperature of 26.99 ^{o}C and humidity of 87.60%.

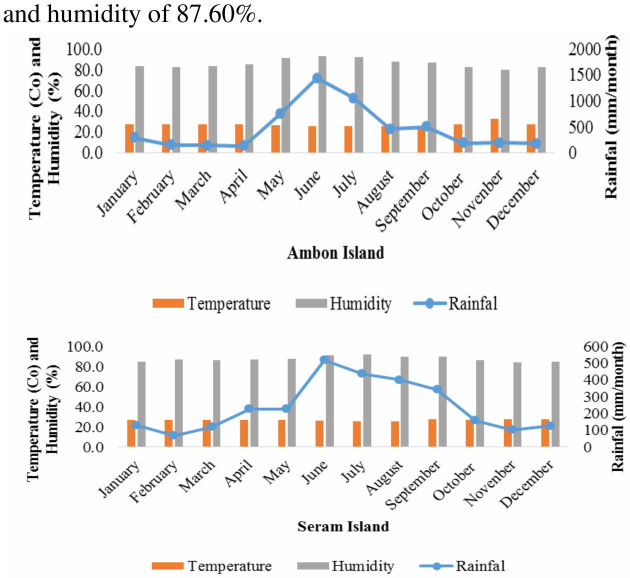

Fig. 1: The climatic condition on Ambon Island and Seram Island where the forest cloves

Volatile oil components of forest cloves

The hydrodistillated oils followed up with GC-MS analysis identification resulted in the names of the components, retention time (RT), quality (Q), and percentage of concentration which are presented in Table 3. Identification of the components was conducted by comparing the mass spectrometry data with the library 7 information in the equipment. Volatile oils from the two locations in Maluku, Indonesia consisted of 68 components, 30 components from volatile oils from Ambon Island and 38 components from volatile oils from Seram Island. The volatile oils from Ambon Island were identified as 13 components in the bud oil, 11 components in the stem oil, and 6 components in the leaf oil, whereas those from Seram Island were identified as 12 components in the bud oil, 10 components in the stem oil, and 16 components in the leaf oil. The highest concentration of volatile oil components in the results from the two areas were: Ambon Island: bud oil, germacrene-D (15.49%); stem oil, ageratochromen (56.430%); leaf oil, 2,3',4-trimethyldiphenylmethane (80.39%), while Seram Island: bud oil, α-cubebene (20.55%); stem oil, pyrimidine, 1,4,5,6-tetrahydro-1methyl-2-[2-(thyeny)ethenyl]-, E (35.98%); leaf oil, methyleugenol (18.44%).

All the volatile oil components of forest cloves from Maluku, Indonesia from the two locations demonstrated variations in the identifying components in each morphological part using the heatmap analysis which are presented in Figure 1. The identifying component is signified by a bright green color in the heatmap profile. The identifying compounds in the forest cloves from Ambon Island were bud oil, 4,10 (14)-muuroladien-8.beta-ol (1.47%) and 4,11-dioxa-3,5-dimethyl-3-methoxytetracycloundecane cage compound (9.62%); stem oil, cadina-1,4-diene (1.18%), germacrene (15.12%), myristcin (1.30%); leaf oil, 2,3',4-trimethyldiphenylmethane (80.39%). The identifying compounds in the forest cloves from Seram Island were bud oil, caryophyllene oxide (1.19%), trans-beta-ocimene (1.82%), humulene (3.06%); stem oil: pyrimidine,1,4,5,6-tetrahydro-1methyl-2-[2-(thyeny)ethenyl]-,(E) (35.98%); leaf oil: β-bourbonene (6.29%), cadina-4-diene (2.45%), trans-methyl-isoeugenol (1.05%), 4,4-dimethyl-3-(3-methyl-3-buten-1-yliden0-2-methylidenbicyclo[4.1.0] heptane (1.00%), endo-8-hydroxy cycloisolongifolene (1.19%).

The heatmap profile also revealed the classification of all the components into major and minor components. The major components were: α-cubebene, δ-cadinene, eugenol, germacrene-D, α-copaene, α-cadinol, caryophyllene, while the minor components were: methyleugenol, ageratochromen, myristcin, cadina-1,4-diene, methyl 2-(3',3'-dimethyl-1butynl'-yl)-1-cyclohexenecarbohylate,trans-Caryophyllene,γ-Muurolene,β-bourbonene, endo8-hydroxy-cycloisolongifolene, trans-methyl-isoeugenol,4,4-dimethyl-3-(3-methyl-3-buten-1-yliden0-2-methylidenbicyclo[4.1.0]heptane, 2,3',4-trimethyldiphenylmethane, 2,3',4-trimethyldiphenylmethane, naphtalene, 1,2,3,4,4a,7-hexahydro-1,6-dimethyl-4-(1-methylethyl),4,11-dioxa-3,5-dimethyl-3-methoxytetracycloundecane cage compund, 4,10 (14)-muuroladien-8 beta.-ol, α-amorphene, humulene, trans-beta-ocimene, caryophyllene oxide. In the heatmap profile, the stem oil from Ambon Island had a separate classification from the other volatile oils because germacrene-D and α-copaene were not discovered. The major components of the bud oil, stem oil, and leaf oil as a whole for the forest clove from Ambon Island were α-cubebene (12.42%, 2.13%, 4.24%), δ-cadinene (9.85%, 5.14%, 4.19%), eugenol (10.60%, 11.35%, 1.29%), germacrene-D (15.49%, - , 1.79%), α-copaene (9.40%, - , 3.65%), α-cadinol (3.45%, 1.96%, -), caryophyllene (4.30%, - , -), and from Seram Island α-cubebene (20.55%, 6.98%, 7.31%), δ-cadinene (10.52%, 4.20%, 9.70%), eugenol (1.23%, 0.66%, 0.66%), germacrene-D (16.62%, 24.87%, 9.81%), α-copaene (13.24%, 3.93%, 5.80%), α-cadinol (2.25%, 1.14%, 3.52%), caryophyllene (16.64%, 12.75%, 4.10%).

Table 3: Composition and concentration of essential oils of forest clove (*Syzygium aromaticum* (L.) Merr. & L. M. Perry.) from Maluku-

Location	Bud oil					Stem oil					Leaf oil				
	Components[1]	**Class[2]**	**RT[3]**	**Q[4]**	**Conc. (%)[5]**	**Components[1]**	**Class[2]**	**RT[3]**	**Q[4]**	**Conc. (%)[5]**	**Components[1]**	**Class[2]**	**RT[3]**	**Q[4]**	**Conc. (%)[5]**
Ambon Island	Germacrene-D	S	34.116	99	15.49	Ageratochromen	S	56.430	90	30.67	2,3',4-Trimethyldiphenylmethane	A	56.706	90	80.39
	Ageratochromen	S	56.421	90	12.58	Methyleugenol	PP	47.787	98	23.34	α-cubebene	S	21.144	99	4.24
	α-cubebene	S	21.149	99	12.42	Germacrene	S	34.078	99	15.12	δ-cadinene	S	36.821	99	4.19
	Eugenol	PP	50.059	98	10.60	Eugenol	PP	50.059	99	11.35	α-copaene	S	23.020	99	3.65
	δ-cadinene	S	36.830	99	9.85	δ-cadinene	S	36.835	99	5.14	Germacrene-D	S	34.063	99	1.79
	α-copaene	S	23.006	99	9.40	Trans-Caryophyllene	S	28.144	94	2.45	Eugenol	PP	50.059	99	1.29
	4,11-Dioxa-3,5-dimethyl-3-methoxytetracycloundecane Cage Compund	A	56.588	90	9.62	α-cubebene	S	21.120	99	2.13					
	Caryophyllene	S	28.225	99	4.30	α-cadinol	S	51.211	99	1.96					
	α-cadinol	S	51.211	91	3.45	γ-Muurolene	S	33.216	99	1.59					
	Methyleugenol	PP	47.764	98	3.30	Myristcin		51.564	99	1.30					
	α-amorphene	S	33.216	99	2.64	Cadina-1,4-diene	S	48.787	95	1.18					
	Naphtalene, 1,2,3,4,4a,7-hexahydro-1,6-dimethyl-4-(1-methylethyl)	S	48.792	84	2.07										
	4,10 (14)-Muuroladien-8.beta.-ol		53.273	48	1.47										
Seram Island	α-cubebene	S	22.50	99	20.55	Pyrimidine, 1,4,5,6-tetrahydro-1methyl-2-[2-(thyeny) ethenyl]-, E	A	56.43	87	35.98	Methyleugenol	PP	47.78	98	18.44
	Caryophyllene	S	28.27	99	16.64	Germacrene-D	S	34.13	99	24.87	Methyl 2-(3',3'-dimethyl-1butynl'-yl)-1-cyclohexenecarbohylate	A	56.41	90	16.84
	Germacrene-D	S	34.10	99	16.62	Caryophyllene	S	28.23	99	12.75	Germacrene-D	S	34.08	99	9.81
	α-copaene	S	23.03	99	13.24	α-cubebene	S	21.12	99	6.98	δ-cadinene	S	36.83	99	9.70
	δ-cadinene	S	42.81	99	10.52	δ-cadinene	S	36.83	99	4.20	β-Bourbonene	S	24.28	97	6.29
	Methyl 2-(3',3'-dimethyl-1butynl'-yl)-1-cyclohexenecarbohylate	S	56.41	83	8.75	α-copaene	S	22.96	99	3.93	α-copaene	S	22.96	99	5.80
	Humulene	S	31.89	83	3.06	Naphtalene, 1,2,3,4,4a,7-hexahydro-1,6-dimethyl-4-(1-methylethyl)	A	48.78	83	1.22	Trans-caryophyllene	S	28.19	97	4.83
	α-amorphene	S	33.22	99	2.60	Methyleugenol	PP	47.76	98	1.20	Caryophyllene	S	28.25	95	4.10
	α-cadinol	S	50.87	98	2.25	α-cadinol	S	51.20	98	1.14	α-cubebene	S	21.15	99	7.31
	Trans-beta-ocimene	M	9.80	96	1.82	Eugenol	PP	50.06	99	0.66	Eugenol	PP	50.06	99	3.79
	Eugenol	PP	50.05	98	1.23						α-cadinol	S	50.54	94	3.52
	Caryophyllene oxide	S	46.88	95	1.19						γ-Muurolene	S	33.2199	99	2.54
											Cadina-4-diene	S	48.78	92	2.45

Remarks : [1]Component of GC-MS analysis. [2] **S**=sesquiterpenoids, **PP**=phenilpropanoids, **A**=Aliphatics, **M**=Monoterpenoids. [3] **RT**=retention time. [4] **Q**=Quality. [5] **Conc.**= Concentration of components. Data were obtained from six essential oils from diverent morphology of forest clove from March to July 2018.

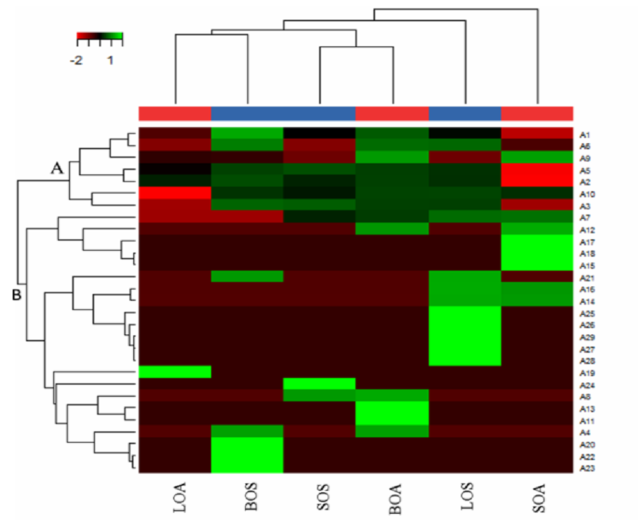

Fig. 2: Heatmap grouping of essential oils. (A) main components ; (B) minor components. (A1-A29) Essential oil components. Essential oil from different part of morphologies from two distribution areas, (BOA) bud oil-Ambon; (SOA) stem oil-Ambon; (LOA) leaf oil-Ambon, (BOS) bud oil-Seram, (SOS) stem oil-Seram, (LOS) leaf oil-Seram.

The correlation between forest clove volatile oil and environmental factors

The correlation between forest clove volatile oil and the conditions of the environment where it grows was analyzed using PCA (Figure 3). The result was two eigenvalues. The first PCA had 15.24 eigenvalues (80.21% variability), the second 2.48 (13.08% variability). The two eigenvalues reflected a 93.29% variation in the data (% cumulative/total variant). The results of the Principal Component Analysis (PCA) revealed a correlation between the concentration of volatile oil components in the bud oil, stem oil, leaf oil, and oil yield from the forest clove bud, stem, and leaf and the environmental conditions. The analysis results demonstrated that in the forest clove distribution areas in Maluku, the soil factor strongly influenced the concentration of forest clove's volatile oil components and oil content. Soil factors such as P_2O_5 and K_2O, moisture content, and pH had a positive correlation with the volatile component concentration in the bud oil, stem oil, leaf oil, and oil content of the leaf and bud of the forest clove. The higher the available phosphorus, potassium, and moisture content combined with a near-neutral pH would increase the concentration of the volatile oil components and oil content in forest cloves.

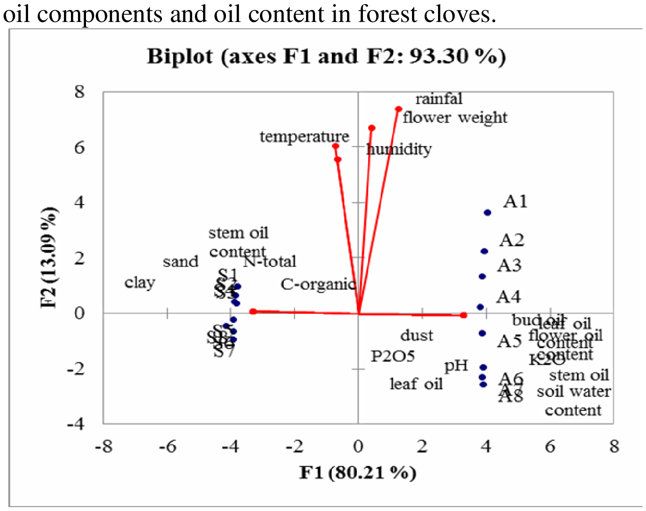

Fig. 3: Principal Component Analysis for discovering the correlation between forest clove volatile oil and the environmental factors.

Discussion

In general, the characteristics of the forest cloves in the two locations had large morphological sizes with specific characters. Koemiati (1997) stated that the forest clove is classified as a wild type clove with a larger leaf size with an obtuse end, low branching on the main trunk, a slightly rounded canopy, more disease resistant, and less aromatic. Forest cloves are numerous in these two areas because it is the natural distribution area. Koemiati (1997) had mentioned before that wild-type forest cloves are numerous on the Maluku Islands and part of Papua. Maluku is known as the center of origin of spices, especially cloves (Millind & Deepa, 2011), and is rich in the clove germplasm, including forest cloves. As a whole, the soil and climate conditions in the two locations were suitable for the optimum growth of clove trees. In general, cloves demand fertile soil conditions which are rich in organic materials, a thick solum, and an optimum pH of 5.5-6.5. The ideal precipitation rate is an evenly distributed 500-3,500 mm/year, the optimum temperature 22-32 C^{o}, and optimum humidity of 60-80%.

Forest clove (*Syzygium aromaticum* (L.) Merr. & L. M. Perry.) volatile oils from the two distribution areas in Maluku, Indonesia from different morphological parts demonstrated a varied component profile. The components identified as a whole demonstrated that even though the components in the forest clove volatile oil were extremely varied, the sesquiterpene fraction was the most predominant (Chaverri & Cicció, 2015; 2017; Amini *et al.,* 2016). The variations in the amount of this component were determined by the part of the plant analyzed even though they came from different species, in addition to being influenced by other factors such as the environment, genetics, and ontogenetic (Priya *et al.,* 2015).

Forest clove volatile oils from the two locations in Maluku, Indonesia demonstrated a variety of identifying components in each morphological part. The differences in a plant's identifying component depend on the morphological part analyzed (Sohilait, 2015; Chaverri & Cicció, 2017). The forest clove had main components consisting of α-cubebene, δ-cadinene, eugenol, germacrene-D, α-copaene, α-cadinol, and caryophyllene The main components were more numerous than the results of a previous study on cultivated clove which were only eugenol, caryophyllene, and eugenyl acetate (Atanasova *et al.,* 2017; Uddin *et al.,* 2017; Gaspar *et al.,* 2018). The differences in the main components were determined more by the differences in the plant species (Amini *et al.* 2016).

The forest clove contained eugenol, similar to the commonly cultivated clove, but the concentration was very low in all the morphological parts (1.23-11.35%). Cultivated clove in a previous study had a high concentration of eugenol in all the morphological parts, ± 70-90% (Jentzsch *et al.* 2017; Nejad *et al.,* 2017; Uddin *et al.,* 2017). The low concentration of eugenol is the reason why forest clove does not have a spicy fragrance because the spicy fragrance in cloves is determined by their eugenol content (Nejad *et al.,* 2017). Eugenol is a phenylpropanoid which is pale yellow and contributes the fresh and spicy fragrance to cloves and is commonly used in pharmaceuticals as an antimicrobe, antioxidant, and anticancer, whereas in agriculture it is used as a food preservative, pesticide, fumigant, and also as a flavoring in food, cosmetics, and other industries (Bendre *et al*., 2016; Nejad *et al.,* 2017).

Phosphorous is a component needed in large amounts during the flowering phase because of its role in the plant's metabolic activity (Hasanudin, 2003), while potassium has a major role in transporting the assimilated products to the plant's tissues (Dascota *et al.,* 2017). As the pH increases closer to neutral and the soil moisture content increases, the quality and quantity of the volatile oil also increase. The optimum pH plays a role in increasing the absorption of soil nutrients, especially phosphorous; therefore, it can improve the plant's metabolic processes. Optimum soil moisture content acts as a solvent for soil nutrients to aid absorption by the plant and improves the transport of products of photosynthesis from the source to the sink (Salisbury & Ross, 1997).

Results of the analysis revealed that the oil yield of forest clove buds had a positive correlation with organic C, total N, and the clay and sand texture. The soil's organic materials play a role in the carbon and nutrient cycles and fluctuations in the soil pH, whereas nitrogen is needed for the plant's vegetative growth and for increasing chlorophyll production (Darlita *et al.,* 2017). The sand fraction in the soil texture facilitates root penetration, while the clay fraction aids water binding by the micropores (Darlita *et al.,* 2017).

The climatic factor in this study only revealed a positive correlation to the forest clove's bud production. The climatic factor, in this case the precipitation rate, had a positive correlation with the weight of the ready-to-harvest clove buds. A higher precipitation rate and temperature would result in a higher weight in the ready-to-harvest clove buds. Ruhnayat & Wahid (2007) stated that optimum precipitation and temperature conditions fulfill the plant's water requirements and create a humid environment which improves the plant's growth.

Conclusion

The main components in forest clove such as α-cubebene, δ-cadinene, germacrene-D, α-copaene, α-cadinol, caryophyllene are compounds classified as sesquiterpenoids which are commonly used as a phytoalexin, an antibiotic for plants' defense against microbes and herbivores (antifeedants). The soil factor in the forest clove distribution areas in Maluku had a correlation with the concentration of the forest clove's volatile oil and oil yield, whereas the climatic factor had more influence on clove bud weight.

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