Identification of Volatile Compounds of Oil Palm Flower (*Elaeis guineensis* Jacq.) with Gas Chromatography and Mass Spectrometry Based on the Difference in Time

Fizrul Indra Lubis[1,2], Sudarjat Sudarjat[3], Ichsan Nurul Bari[3], and Unang Supratman[4*]

[1]*Agricultural Science, Faculty of Agriculture, Universitas Padjadjaran, Jl. Raya Bandung-Sumedang Km. 21, Jatinangor, Sumedang 45363, Indonesia*

[2]*Sulung Research Station, PT Sawit Sumbermas Sarana Tbk. Citra Borneo Indah Group, Jl. H. Udan Said No. 47, Pangkalan Bun 74113, Indonesia*

[3]*Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Padjadjaran, Jl. Raya Bandung-Sumedang Km. 21, Jatinangor, Sumedang 45363, Indonesia*

[4]*Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Jl. Raya Bandung-Sumedang Km. 21, Jatinangor, Sumedang 45363, Indonesia*

** Corresponding author:*

email: unang.supratman@unpad.ac.id

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Abstract: *The pollination process in oil palm is assisted by the insect* Elaeidobius kamerunicus*, which occurs when male and female flowers bloom producing volatile compounds that act as attractants. This study aims to identify volatile compounds in oil palm flowers based on differences in times with gas chromatography mass spectrometry (GC-MS). The research steps include determining the time of the release of volatile compounds in oil palm flowers, extracted using steam distillation, and identification by GC-MS. There are different times of the release of volatile compounds for each type of oil palm flower. Three times by male flowers, at 08:00 am, 11:00 am and 14:00 pm, with the highest volatile compounds at 14:00 pm. Meanwhile, female flowers occurred at 09:00 am, 12:00 am and 15:00 pm, with the highest volatile compounds at 12:00 am. The results of the GC-MS analysis showed that 21 and 19 volatile compounds were identified, with a total of 38 different types. Estragole compounds were dominant in both types of flowers and did not show significant differences in the area sum values at each time of observation. These results indicated the importance of estragole compound for the pollination process in oil palm.*

Keywords: Elaeis guineensis Jacq.*; estragole; palm oil; volatile compounds*

■ INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is one of the plantation commodities that has an important role in economic development and is a source of foreign exchange for the country. The productivity and land area of oil palm continues to increase every year, from 22.5 million and 4.5 million tons in 2010 to 44.8 million and 8.9 million tons in 2020 [1]. The development of oil palm area and productivity in Indonesia is influenced by several factors, one of which is the role of the oil palm pollinating insect (SPKS) *Elaeidobius kamerunicus* Faust which was introduced in March 1983. In general, there was an increase in pollination efficiency, so the fruit set value increased from 11.27 to 75.56%, and there was an increase in other production components such as bunch weight and crude palm oil per Ha [2].

The pollination process by *E. kamerunicus* occurs when male and female flowers bloom, producing volatile compounds that act as attractants. Several studies reported that the volatile compound that acts as an attractant for *E. kamerunicus* is estragole [3-5]. Estragole is an allylphenol derivative compound formed through the shikimate (phenylpropanoid) pathway. In addition to estragole, it is suspected that there are other volatile

compounds that act as attractants. Anggraeni et al. [3] analyzed the volatile compounds of male oil palm flowers at the 100% flowering stage. The results showed that there were compounds of palmitic acid, 4-tetradecyl chloroacetate, estragole, and 1-dodecyne. Meanwhile, female flowers contain 4-tetradecyl chloroacetate, palmitic acid, farnesol, and squalene compounds. Muhamad Fahmi et al. [4] identified volatile compounds from oil palm flowers on different soil types. There were 10 compounds identified, estragole was found to be the main compound in sandy soil (37.49%), clay (30.71%), and peat soil (27.79%). Other compounds such as 9,12-octadecadionic acid and *n*-hexadecanoic acid were found as the main compounds in peat (27.18% and 7.45%), sandy soil (14.15% and 9.31%); and clay (30.23% and 4.99%). The interaction between oil palm and *E. kamerunicus* benefits both plants and pollinating insects, *E. kamerunicus* gets food from male flowers and then carries pollen to female flowers [6]. Based on Anggraeni et al. [3], *E. kamerunicus* is active foraging during the day and peaks at 10:00–11:00 am. Until now, there has been no research that has identified the volatile compound content of oil palm flowers at different times, in the morning, afternoon and evening. GC-MS is a powerful instrument for identifying volatile compounds from plants [7-9]. This study aims to identify the content of volatile compounds in male and female flowers of oil palm based on differences in that time with the GC-MS.

■ EXPERIMENTAL SECTION

Materials

The palm flower was collected from the collecting observational data, and research samples were Batu Kotam (111°30'6.1"E2°18'39.9"S) and Rangda area (111°36'59.7664"E 2°18'47.7493"S) in West Kotawaringin, Central Kalimantan, Indonesia. The oil palm flower extraction process was carried out at the Sulung Research Station Laboratory, Central Kalimantan. Analysis of volatile compounds was carried out at the Central Laboratory, Universitas Padjadjaran, Jatinangor, West Java, Indonesia. The materials used were anthesis (≥ 75%), female receptive oil palm flowers (≥ 75%), distilled water, 4-allylanisole (98%, Sigma-Aldrich), *trans*-anethole (99%, Sigma-Aldrich), anisole (99%, Merck), methyl eugenol (98%, Sigma-Aldrich), ethyl oleate (90%, Sigma-Aldrich), and dichloromethane (99.8%, Merck).

Instrumentation

Tiger Select Portable VOC Detector (ION Science Ltd.) was performed to analyze volatile compounds in palm flowers and gas chromatography-mass spectrometry (GC-MS) type Agilent 7 890 A was carried out to investigate volatile compounds from extract from steam distillation.

Procedure

This research process goes through several stages. The first stage was observing oil palm flowers in the field to determine the time of the release of volatile compounds. The second step is to extract volatile compounds from oil palm flowers by using a steam distillation technique. The last stage is the identification of the types of volatile compounds by using GC-MS.

Determination of release of volatile compounds

Detection of the level and time of the release of volatile compounds was carried out by using a portable VOC detector on 10 samples of male and female oil palm flowers with blooming criteria ≥ 75%. Portable VOC detectors are used for specific applications for spot-checking and measuring for such a volatile or gas compound. Observations were made on three sample points with an interval of 60 min from 07:00 am–17:00 pm [3].

Extraction of volatile compounds from oil palm flowers

The volatile compounds of oil palm flowers were obtained by using a steam distillation apparatus [7]. Determination of the timing of flower sampling based on the pattern of the release of the highest volatile compounds from the detection results in the field. Distillation materials to obtain volatile compounds were 1 kg of male and female flowers and 4 L of distilled water [10]. The distillation process was carried out for 4 h [7] at room temperature (± 25 °C) and chiller temperature (below 20 °C) [11-12].

Identification of volatile compounds using GC-MS

The results of the distillation were then analyzed using GC-MS to determine the composition of volatile compounds in oil palm flowers [10]. Analysis of the composition of volatile compounds begins with the preparation of the distillate, which is taken as much as 1 mL and injected into the GC-MS with a split ratio of 1:50 using the hot-needle technique. Several dilution experiments were carried out on the sample to be injected so that the compound with the smallest percentage could be read. The temperature of the injection area and the transfer line used at the interface set is 325 °C, with the ion source adjusted to a temperature of 200 °C. The carrier gas used is helium (He 99.99%), with a constant flow rate of 1 mL/min. The initial oven temperature was at 50 °C for 2 min, after which it was raised to 200 °C at 10 °C/min, which was then equilibrated for 3 min, before the next sample injection. The mass spectrum was recorded at one scan per second with a mass detection range of *m/z* 40–470 amu. Chromatograms and mass spectra were evaluated using GC/MSD 5977B with a limit of fit 80%. Data acquisition and processing were carried out using the NIST 17 mass spectral library. The concentration of the studied compound was calculated from the peak area in the total ion chromatogram. The relative abundance was obtained from the electronic integration of the measurements and the average results of three replicates [13].

■ RESULTS AND DISCUSSION

Time Pattern for the Release of Volatile Compounds in Palm Flower

Determination of the time pattern for the release of volatile compounds emitted by male and female flowers of oil palm at 07:00 am to 17:00 pm using the VOC detector showed differences for each type of oil palm flower (Fig. 1). There are three times for the release of volatile compounds by male flowers, namely at 08:00 am, 11:00 am, and 14:00 pm, with the highest release at 14:00 pm. Meanwhile, the three times for the release of volatile compounds in female flowers occurred at 09:00 am, 12:00 am and 15:00 pm. The peak of the release of the highest volatile compounds occurred at 12:00 am. This will be marked by a stronger floral aroma when in the field. The release of volatile compounds in male flowers was higher than that of female flowers, seen at the peak of the release of volatile compounds by male flowers of 0.610 ppm, while in female flowers, it was 0.056 ppm.

Identification of Volatile Compounds in Male Palm Flowers by GC-MS Based on the Time

The results of volatile compounds based on the time of the release of volatile compounds in male flowers were identified using GC-MS. The results of the GC-MS analysis identified 13 compound peaks at 8:00 am (Fig. 2), 7 compound peaks at 11:00 am (Fig. 3) and 14 compound peaks at 14:00 pm (Fig. 4). Based on the detected peaks,

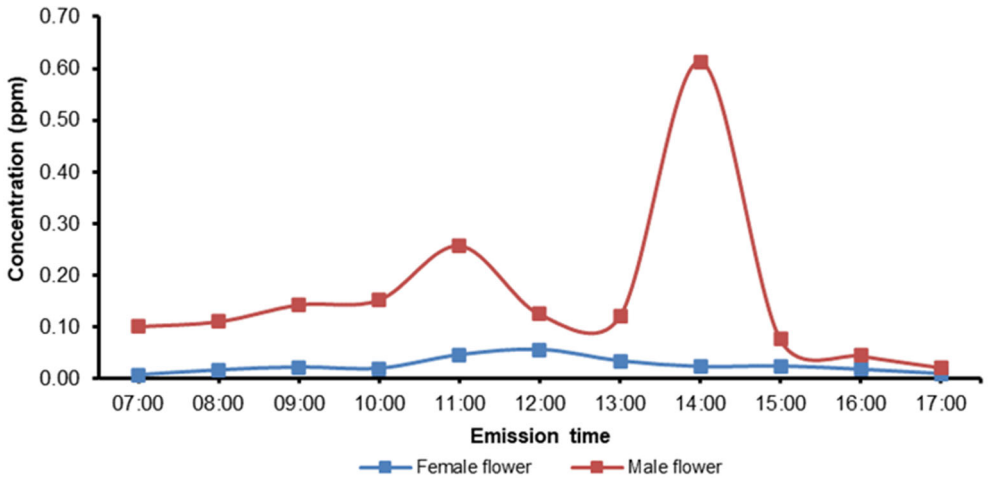

Fig 1. Time pattern for the release of volatile compounds from oil palm flowers

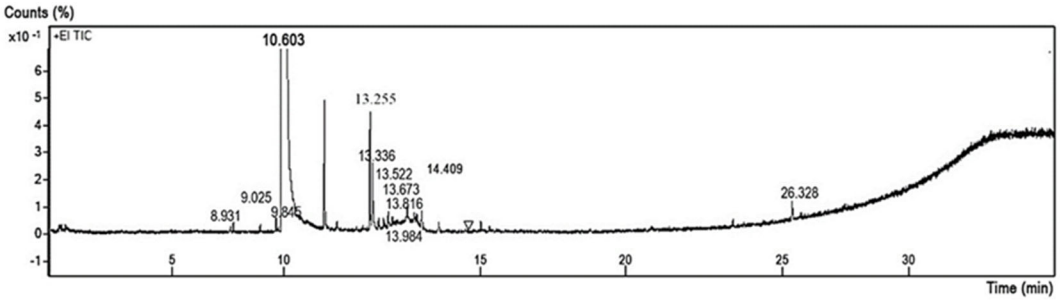

Fig 2. Chromatogram of male flowers at 08:00 am

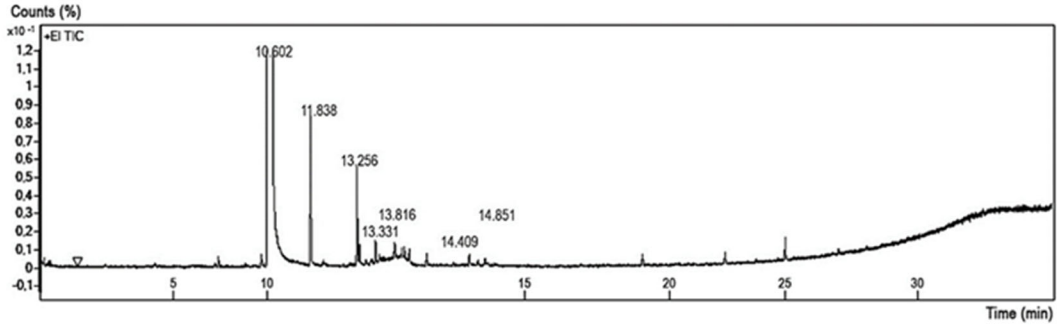

Fig 3. Chromatogram of male flowers at 11:00 am

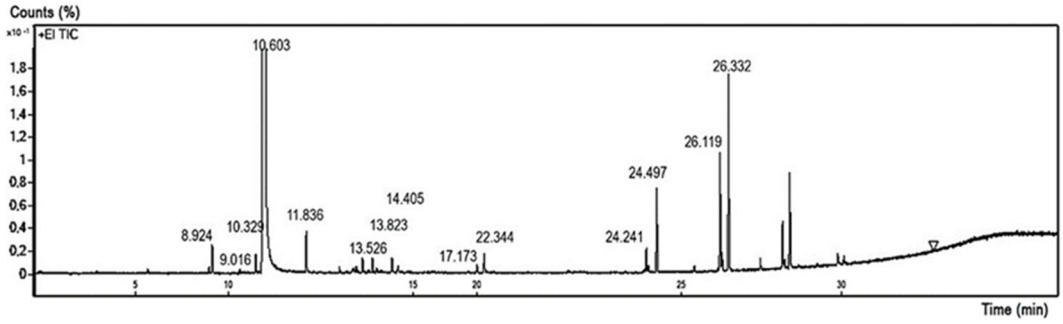

Fig 4. Chromatogram of male flowers at 14:00 pm

the dominant volatile compound in oil palm flowers for all observation times was estragole.

Identification of GC-MS on the sample at 8:00 am obtained the highest peak compound with a retention time (RT) of 10.603 min and a sum area of 99.66, which is suspected to be estragole (Fig. 2). In addition, other peaks were identified, these compounds were 2-propenamide, nonanal, 1-ethenyl-4-methoxybenzene, anethole, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)cyclohexane, methyl eugenol, germacrene D, 3-methyl-6-(1-methyl ethylidene)cyclohexene, γ-elemene, α-farnesene, 1-(2-Acetoxyethyl)-1-(4-methylpent-4-enyl)-2-(1-methyl ethenyl)cyclobutane, and hexamethylcyclotrisiloxane (Table 1).

The dominant estragole compound was identified at 11:00 am with RT 10.602 min and area sum 99.65 (Fig. 3). Six other compounds identified were anethole, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)cyclohexane, methyl eugenol, 4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-2-butanone, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl) cyclohexane, and 1,5-dimethyl-8-(1-methylethenyl)-1,5-cyclodecadiene (Table 2). There are 14 peaks at 14:00 am, with the highest peak at RT 10.603 min and a sum area of 98.33 which is suspected to be estragole compound (Fig. 4). Meanwhile, other peaks are linalool, nonanal, 1-methoxyadamantane, (1*S*,2*E*,6*E*,10*R*)-3,7,11,11-tetramethylbicyclo[8.1.0]-undeca-2,6-diene, 2-butanone, 4-(2,6,6-trimethyl-1-cyclohexen-1-yl),

Table 1. List of volatile compounds of male flowers samples at 08:00 am

Peak	Compound	Start	RT (min)	End	Height	Area	Area sum	%Area
1	2-Propenamide	8860	8.931	8952	963	1851	0	0.00
2	Nonanal	8976	9.025	9057	1833	3201	1	0.01
3	1-Ethenyl-4-methoxybenzene	9826	9.845	9899	1295	2063	1	0.01
4	Estragole	10450	10.603	11066	4730275	39799003	10000	99.66
5	Anethole	11800	11.840	11888	22181	35322	9	0.09
6	1-Ethenyl-1-methyl-2,4-bis(1-methylethenyl)cyclohexane	13220	13.255	13298	20171	30331	8	0.08
7	Methyl eugenol	13304	13.336	13390	10844	18611	5	0.05
8	Germacrene D	13482	13.522	13565	1893	3928	1	0.01
9	3-Methyl-6-(1-methylethylidene)cyclohexene	13649	13.673	13705	1849	3080	1	0.01
10	γ-Elemene	13792	13.816	13870	2725	5612	1	0.01
11	α-Farnesene	13924	13.948	13983	1644	3558	1	0.01
12	1-(2-Acetoxyethyl)-1-(4-methylpent-4-enyl)-2-(1-methylethenyl)cyclobutane	14358	14.409	14436	2707	5769	1	0.01
13	Hexamethylcyclotrisiloxane	26293	26.328	26371	3452	6965	2	0.02

Table 2. List of volatile compounds of male flowers samples at 11:00 am

Peak	Compounds	Start	RT (min)	End	Height	Area	Area sum	%Area
1	Estragole	10458	10.602	11125	4710964	37728112	10000	99.65
2	Anethole	11806	11.838	11890	39044	63305	17	0.17
3	1-Ethenyl-1-methyl-2,4-bis(1-methylethenyl)cyclohexane	13226	13.256	13288	24758	36233	10	0.10
4	Methyl eugenol	13313	13.331	13361	4119	5843	2	0.02
5	4-(2,6,6-Trimethyl-1-cyclohexen-1-yl)-2-butanone	13792	13.816	13876	5811	10247	3	0.03
6	1-Ethenyl-1-methyl-2,4-bis(1-methylethenyl) cyclohexane	14339	14.409	14474	3911	8957	2	0.02
7	1,5-Dimethyl-8-(1-methylethenyl)-1,5-cyclodecadiene	14824	14.851	14902	3489	6125	2	0.02

trans-β-Ionone, pentadecanal, nonadecane, 1-docosene, nonadecane, and 5-eicosene (Table 3).

The interpretation of the main peak of the mass spectrum in the male flower sample at 8.00 am was obtained at a retention time of 10.603 min. The mass spectrum of the compound at the main peak *m/z* = 148, the molecular ion is thought to have fragmented with the release of ($C_2H_3^{\bullet}$), yielding (M-27) at *m/z* = 146. The peak at *m/z* = 77 probably appears due to the loss of the group ($CH_3O^{\bullet}$) produce (M-31). The compound is thought to be estragole (Fig. 5).

Meanwhile, the chromatogram peak in male flower samples at 11.00 am with a retention time of 10.602 min was a compound with the molecular formula $C_{10}H_{12}O$. The mass spectrum showed that the molecular mass of the compound was 148 and showed a molecular ion peak at *m/z* 148 followed by fragments at *m/z* 148, 121, 77, 65, and 51 (Fig. 6). The peak of the chromatogram on male flower samples at 14:00 pm obtained a retention time of 10.603 min is suspected to be estragole compounds. The mass spectrum showed molecular ion peaks at *m/z* 148 with fragments at *m/z* 148, 121, 77, and 51 (Fig. 7).

Identification of GC-MS Volatile Compounds Based on Time of the Release of Female Palm Flowers

The results of the samples that have been isolated by steam distillation technique are separated between the oil and water phases, then identified using GC-MS to determine the content of volatile compounds. The results of GC-MS showed that 10 compound peaks were identified in the female flower sample at 9:00 am (Fig. 8), 14 compound peaks at 12:00 am (Fig. 9) and 9 compound peaks at 15:00 pm (Fig. 10).

Table 3. List of volatile compounds of male flowers samples at 14:00 pm

Peak	Compounds	Start	RT (min)	End	Height	Area	Area sum	%Area
1	Linalool	8898	8.924	8957	2266	3720	1	0.01
2	Nonanal	8981	9.016	9054	11440	17638	6	0.06
3	1-Methoxyadamantane	10297	10.329	10370	7462	14154	5	0.05
4	Estragole	10465	10.603	10874	4731972	27998331	10000	98.33
5	Estragole	11806	11.836	11887	16406	27216	10	0.10
6	(1*S*,2*E*,6*E*,10*R*)-3,7,11,11-Tetramethylbicyclo[8.1.0]undeca-2,6-diene)	13489	13.526	13575	5832	10301	4	0.04
7	4-(2,6,6-Trimethyl-1-cyclohexen-1-yl)-2-butanone	13772	13.823	13869	5902	9793	3	0.03
8	*trans*-β-Ionone	14351	14.405	14448	6037	11085	4	0.04
9	Pentadecanal	17117	17.173	17214	7956	13300	5	0.05
10	Nonadecane	22301	22.344	22389	34569	61392	22	0.22
11	1-Docosene	24195	24.241	24276	47492	77535	28	0.27
12	Nonadecane	24467	24.497	24553	80103	139741	50	0.49
13	5-Eicosene	26092	26.119	26143	17311	24950	9	0.09
14	Nonadecane	26299	26.332	26369	38549	63429	23	0.22

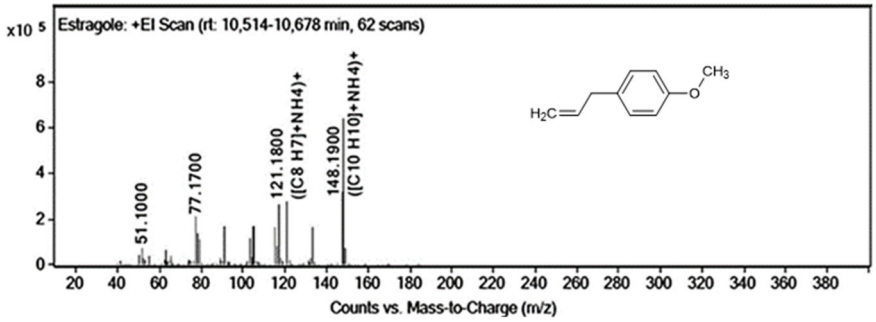

Fig 5. Mass spectrum and structure of estragole in male flower samples at 08:00 am

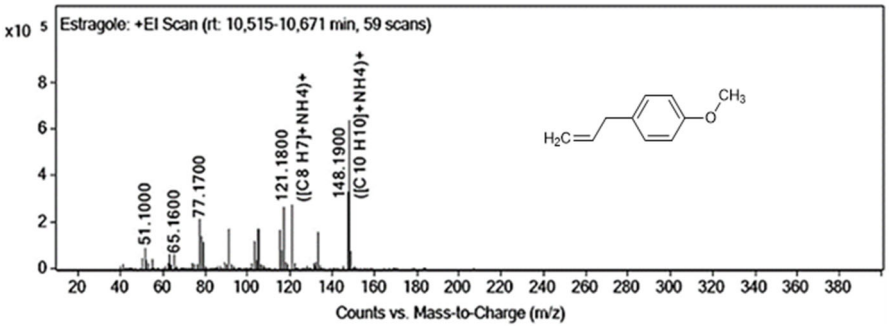

Fig 6. Mass spectrum and structure of estragole in male flowers samples at 11:00 am

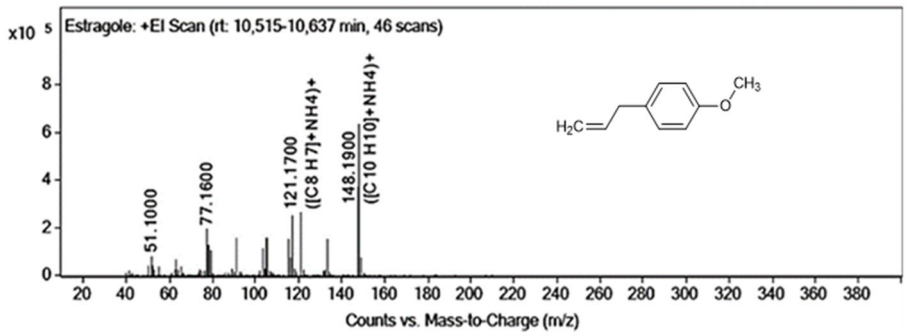

Fig 7. Mass spectrum and structure of estragole in male flowers samples at 14:00 pm

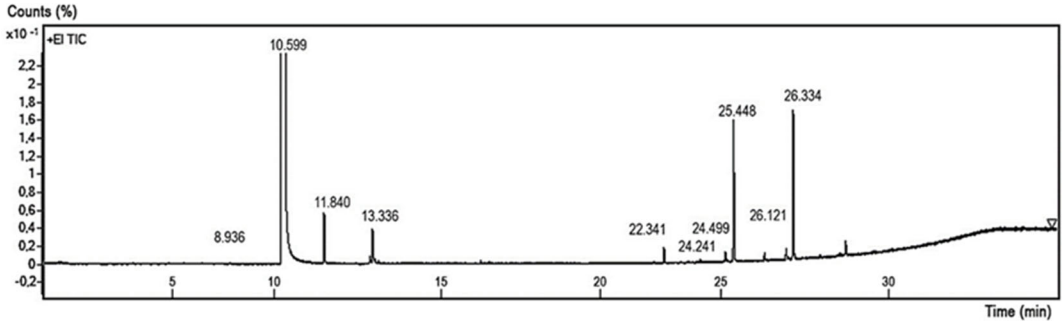

Fig 8. Chromatogram of female flowers at 09:00 am

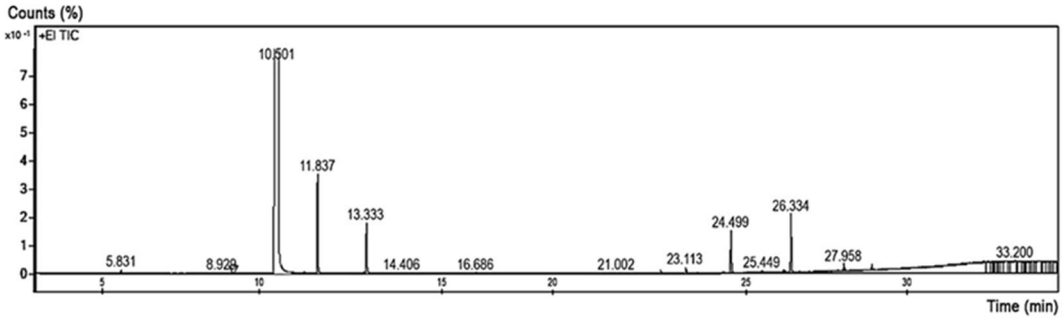

Fig 9. Chromatogram of female flowers at 12:00 am

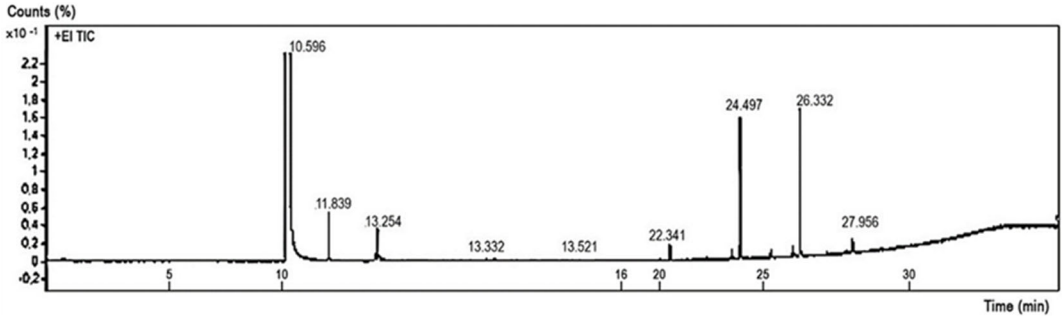

Fig 10. Chromatogram of female flowers at 15:00 pm

The peaks found in female flower samples at 09:00 am occurred at a retention time of 10.599 min with a sum area of 98.91 (Fig. 8). The results of the identification of the peaks are suspected to be estragole compounds. Other compounds identified based on the peak formed included 2-propenamide, anethole, methyl eugenol, hexadecane, 1,1'-(2-methyl-1,3-propanediyl)biscyclohexane, nonadecane, and 1,2,4-benzenetricarboxylic acid, 1,2-dimethyl ester (Table 4).

An increase in the number of peaks was identified at

12:00 am. There are 14 peaks, with the peaks occurring at a retention time of 10.608 min and a sum area of 97.74 which is suspected to be estragole. Other peaks besides estragole are thought to be volatile compounds, namely anisole, 2-propenamide, anethole, methyl eugenol, 2-methyl-3-(3-methyl-but-2-enyl)-2-(4-methyl-pent-3-enyl)-oxetane, 1-butanamenite, hexadecane, ethyl 9-octadecenoate, hexamethylcyclotrisiloxane, nonadecane, and di-*n*-decylsulfone (Table 5).

The peak at 15:00 pm occurred with a retention value of 10.596 min, an area sum of 99.22, and it was suspected that the compound was estragole. Estragole is the dominant compound found in female flowers. Meanwhile, other compounds identified were anethole, 1,5-dimethyl-8-(1-methylethenyl)-1,5-cyclodecadiene, methyl eugenol, 2-(4a,8-dimethyl-2,3,4,5,6, 7-hexahydro-1*H*-naphthalen-2-yl)propan-2-ol, hexadecane, nonadecane, and hexamethylcyclotrisiloxane (Table 6).

Table 4. List of volatile compounds of female flowers at 09:00 am

Peak	Compounds	Start	RT (min)	End	Height	Area	Area sum	%Area
1	2-Propenamide	8890	8.936	8955	699	1536	0	0.00
2	Estragole	10468	10.599	10958	4755799	34816630	10000	98.91
3	Anethole	11805	11.840	11878	26397	43320	12	0.12
4	Methyl eugenol	13309	13.336	13463	17428	35926	10	0.10
5	Hexadecane	22314	22.341	22381	8225	13302	4	0.04
6	1,1'-(2-Methyl-1,3-propanediyl)biscyclohexane	24197	24.241	24273	4871	7830	2	0.02
7	Nonadecane	24456	24.499	24537	74102	127162	37	0.36
8	1,2,4-Benzenetricarboxylic acid, 1,2-dimethyl ester	25407	25.448	25477	4092	6843	2	0.02
9	1,1'-(2-Methyl-1,3-propanediyl)biscyclohexane	26081	26.121	26145	6193	10764	3	0.03
10	Nonadecane	26288	26.334	26390	78296	136393	39	0.39

Table 5. List of volatile compounds of female flowers at 12:00 am

Peak	Compounds	Start	RT (min)	End	Height	Area	Area sum	%Area
1	Anisole	5786	5.831	5870	7120	13291	4	0.04
2	2-Propenamide	8909	8.928	8939	961	1991	1	0.01
3	Estragole	10489	10.501	10683	4752892	34492145	10000	97.74
4	Anethole	11791	11.837	11896	168108	271686	79	0.77
5	Methyl eugenol	13290	13.333	13411	84818	140562	41	0.40
6	2-Methyl-3-(3-methyl-but-2-enyl)-2-(4-methyl-pent-3-enyl)-oxetane	16654	16.687	16733	2031	3351	1	0.01
7	*N*,3-dimethyl-1-butanamenite	20965	21.006	21038	1418	2832	1	0.01
8	Hexadecane	22305	22.343	22391	6243	10796	3	0.03
9	Ethyl 9-octadecenoate	23079	23.114	23178	9513	15750	5	0.04
10	Hexamethylcyclotrisiloxane	23450	23.469	23507	1169	2020	1	0.01
11	Nonadecane	24445	24.499	24563	71008	122503	36	0.35
12	Nonadecane	26271	26.333	26401	98126	175607	51	0.50
13	Di-*n*-decyl sulfone	27930	27.960	27998	11336	20054	6	0.06
14	Hexamethylcyclotrisiiloxane	28779	28.819	28873	8327	15989	5	0.05

Table 6. List of volatile compounds of female flowers at 15:00 pm

Peak	Compounds	Start	RT (min)	End	Height	Area	Area sum	%Area
1	Estragole	10435	10.596	11343	4735482	38092950	10000	99.22
2	Anethole	11796	11.839	11928	31757	50578	13	0.13
3	1,5-Dimethyl-8-(1-methylethenyl)-1,5-cyclodecadiene	13214	13.254	13281	5543	9149	2	0.02
4	Methyl eugenol	13295	13.332	13443	43300	80864	21	0.21
5	2-(4a,8-Dimethyl-2,3,4,5,6,7-hexahydro-1*H*-naphthalen-2-yl)propan-2-ol	13489	13.521	13567	1821	3275	1	0.01
6	Hexadecane	22301	22.341	22382	6666	11918	3	0.03
7	Nonadecane	24462	24.497	24562	38908	66014	17	0.17
8	Nonadecane	26275	26.332	26410	41806	71474	19	0.19
9	Hexamethylcyclotrisiloxane	27918	27.956	28015	3540	6889	2	0.02

The mass spectrum for all-time peaks of the release of volatile compounds in female flowers that occurred at 09:00 am, 12:00 am, and 15:00 pm obtained the main peak *m/z* = 148 which was suspected to be estragole. The fragmentation pattern that occurs based on the mass spectrum for the female oil palm flower samples at 09:00 am, 12:00 pm is *m/z* 148, 121, 77, 51 (Fig. 11 and 12) and the fragmentation pattern for the female oil palm flower at 15:00 pm fragments occurred at *m/z* 148, 121, 77, 65 and 51 (Fig. 13).

Estragole or 1-allyl-4-methoxybenzene is an oxygenated volatile organic compound (OVOC) with the molecular formula $C_{10}H_{12}O$, molecular weight 148.20 g/mol, boiling point 216 °C at 760 mmHg, density 0.946 g/cm^3, liquid at room temperature room, and is optically inactive. Estragole is not classified as a terpenoid compound because it is produced by the phenylpropanoid pathway instead of the terpenoid pathway. Estragole is

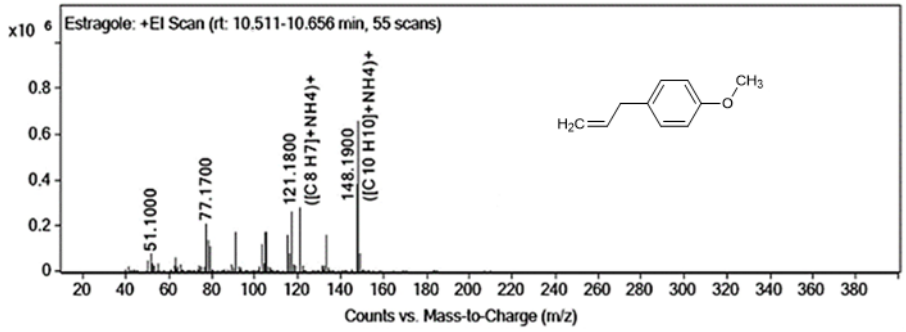

Fig 11. Spectrum and structure of estragole in female flower samples at 09:00 am

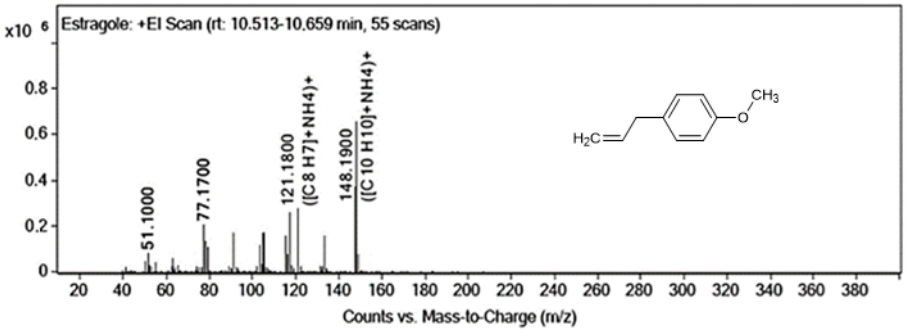

Fig 12. Spectrum and structure of estragole in female flower samples 12:00 am

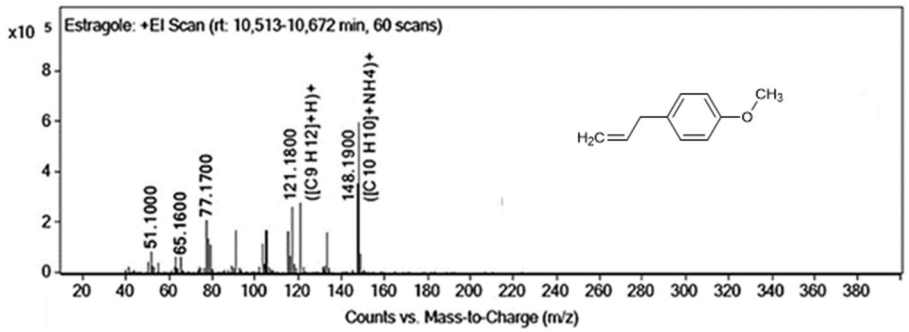

Fig 13. Spectrum and structure of estragole in female flower samples 15:00 pm

found in the essential oils of tarragon and basil plants. Estragole exhibits a carcinogenic effect in mice and can covalently modify DNA. Estragole produced by oil palm plays a role in attracting *E. kamerunicus*. The study conducted by Swaray et al. [14] showed that the stronger aroma of estragole/*p*-methoxyally benzene had the effect of increasing the population density of *E. kamerunicus*.

Anethole is a compound produced through the phenylpropanoid pathway and is an isomer of estragole which has a characteristic anise aroma. Phenylpropene is a class of volatile compounds found in gymnosperms and angiosperms. When removed from flowers, these compounds serve as attractants for pollinators who will detect these compounds through their olfactory system. At high concentrations, this compound shows toxicity to cells which is useful as a defense compound [15].

Anisole is a monomethoxybenzene in which the benzene ring is substituted by a methoxy group. Anisole is a plant metabolite found in *Peristeria elata* and *Ocium gratissimum* plants. Anisole and its derivatives (e.g. *p*-vinyl-anisole, *p*-ethyl-anisole, and *p*-ethylene-anisole) were detected in the rainforest canopy using PTR-MS [16].

Ethyl oleate is a long-chain fatty acid ethyl ester resulting from the formal condensation of the carboxy group of oleic acid with the hydroxy group of ethanol. This compound acts as plant metabolite and acaricide. Ethyl oleate is a natural constituent that can be found in cottonseed oil, linseed oil, peanut oil, coconut oil, and palm kernel oil [17].

Methyl eugenol ($C_{12}H_{24}O_2$) is a phenylpropanoid group compound which is a derivative of eugenol, the shikmiate secondary metabolite biosynthesis pathway between L-phenylaalnine and L-tyrosine [18-19]. This compound is found in several types of plants, including *Melaleuca bracteate*, *O. minimum, O. sanctum,* and *O. tenuiflorum*. According to Kardinan's study [20], methyl eugenol was used as an attractant to attract fruit flies *Bactocera* spp. According to Russo et al. [21] and Jankowska et al. [22], methyl eugenol as an attractant is classified as a "food lure" which attracts male flies for food needs and after consumption it will be synthesized in the body of male fruit flies into pheylpropanoid and coniferyl alcohol compounds which are used as sex pheromones to attract female fruit flies during mating. Methyl eugenol belongs to kairomones which can attract fruit flies *Bactrocera* spp. The male sex is then consumed and processed in the body to produce sex pheromones as a substance that attracts female fruit flies in the mating process [23].

In their life activities, insects communicate them through chemicals called semiochemicals which are divided into two, namely pheromones for communication between individuals within one species and allelochemicals for communication between individuals in different species [24]. Pheromones are divided into several types, such as sex pheromones or sexual stimulation to call the opposite sex; i.e., aggregation pheromones to gather or combine, alarm pheromones that are a sign of danger and alert, epideictic pheromones to indicate the laying area of eggs for female insects to other female insects, territorial pheromones to indicate the territory of certain organisms, and trail pheromones to provide information to the group and other pheromones [25-26]. Allelochemicals consist of allomones (organisms that

release chemical compounds benefit, while those that receive chemical compounds are harmed), kairomones (organisms that release chemical compounds are harmed, while those who receive the benefit), and synomones (organisms that release and receive chemical compounds are equally benefited). Plants produce a bewildering variety of VOCs comprising a great diversity of chemical structures. In addition, diverse metabolic path paths produce various alkanes and low-molecular ethylene, acetaldehyde, acetone, or methanol [25-29]. Volatile compounds from oil palm flowers are thought to belong to the allelochemical type of synomones. The insect *E. kamerunicus* gets food from oil palm flowers and benefits oil palm flowers because it acts as a pollinator that carries pollen from male flowers to female flowers [6].

■ CONCLUSION

Observation of the release pattern of volatile compounds was carried out at 07:00 am–17:00 pm. The results showed that there were three times of release by male flowers, namely at 08:00 am, 11:00 am and 14:00 pm, with the highest peak release at 14:00 am, while the three peak times for the release of volatile compounds in female flowers occurred at 09:00 am, 12:00 am, and 15:00 pm with the highest peak of the release of volatile compounds occurred at 12:00 am. These results suggest that sunlight effect the volatile compounds release. The results of the GC-MS analysis showed that 21 and 19 volatile compounds were identified from male and female flower samples with a total of 38 different types of compounds. Estragole compounds were dominant in both types of flowers and did not show significant differences in the area sum values at each time of observation. Other compounds identified were consistently present in both types of flowers, namely anetol, 2-propenamide, nonadecane, and methyl eugenol, although with different sum area values.

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