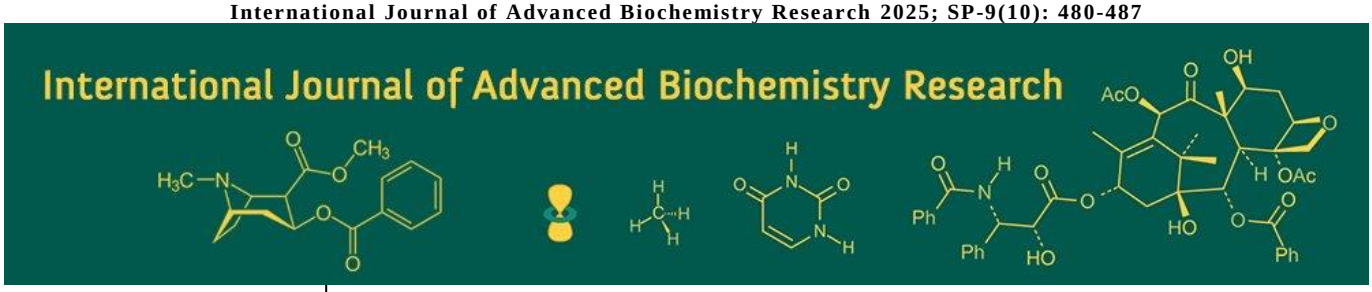

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GC-MS based characterization and physicochemical analysis of essential oils obtained from *Blumea lacera* at different growth stages

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Abstract
In the present investigation essential oil yield, physicochemical properties, and chemical constituents of *Blumea lacera* by using gas chromatography coupled with mass spectrometry (GC-MS) were studied at three phenological stages viz, vegetative, mature green, and flowering. The mature green stage produced the maximum essential oil yield (0.233%). This stage also yielded optimum results for specific gravity (0.994 g/cm³), refractive index (1.494), optical density (0.694), viscosity (12.350 cP), and ester value (69.570 mg KOH/g), indicating high oil quality. GC-MS analysis revealed 72 chemicals throughout all stages, including caryophyllene, alpha-pinene, camphene, linalool, and gamma-terpinene, as well as (3,5-heptadienal, 2-ethylidene-6-methyl-), which was discovered primarily in the mature green stage (39.32%). These findings show that harvesting at the mature green stage maximizes essential oil yield and bioactive chemical concentration, offering important insights into medicinal and aromatic benefits of *Blumea lacera*.

Keywords: *Blumea lacera*, essential oil, growth stages, GC-MS analysis

Introduction
Blumea lacera (Burm. f.) DC. is a notable herbaceous plant in the Asteraceae family that is well known for its ethnobotanical and medicinal value. This plant is also called as *Kukkuradru* in Sanskrit and *Karanda Janglimuli* in Hindi. In Marathi locally, it is called as *Bhamrud* or *Bhamburdi*. It is also known as *Kakaronda*, *Siyalmutra*, and *Susksampatra* (Goti and Desai, 2020) [8]. About 100–120 species belong the entirety of the Blumea genus, which is a member of the Asteraceae family and is mostly found in tropical Asia, Australia, and Africa. In China, India and Southeast Asia, it is taxonomically diverse, with some species having ethnomedical value. *Blumea lacera*, *Blumea balsamifera*, *Blumea mollis*, *Blumea laciniata*, and *Blumea eriantha* comprise the majority of species (Chatterjee & Maurya, 2024) [4]. In tropical and subtropical climes, Blumea species are common and thrive in semi-arid areas, roadside habitats and degraded soils. Over 50 different species can be found in China and India combined, with the Western Ghats and the foothills of the Himalayas having the highest biodiversity (Sherwani, 2020) [24].
Blumea lacera is an annual herbaceous plant that can reach a height of 50-120 cm, with a bushy look and a taproot system. The stems are erect, branching and glazed in short, rough hairs. The leaves are lanceolate to oblong, with irregular serration and when crushed, they emit a characteristic camphor-like odor (Chatterjee & Maurya, 2024) [4]. *Blumea lacera* grows most effectively in semi-arid to tropical regions, preferring well-drained sandy to loamy soils with moderate fertility. It is appropriate to places with low-to-moderate rainfall (500-1200 mm/year) and tolerates high temperatures (up to 40 °C) (Sherwani, 2020) [24].
This plant grows in the plains of North-west India, reaching elevations of up to 2,900 meters. According to Bhaavaprakaasha (16th century CE), the herb can treat fever, respiratory infections, and vitiated blood. It has long been used as a styptic and anti-inflammatory medication, both internally and externally. Additionally, this herb is used as an anthelmintic, especially for threadworm. The roots and leaves have diuretic, antipyretic and astringent properties. Fresh juice or extract can also be used to treat bruises and ulcers. (Dubey *et al*.

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2019) [7]. Anti-inflammatory, diuretic, antidiabetic, anthelmintic, antipyretic, antibacterial, anti-atherothrombosis, expectorant and anxiolytic properties are among its most common and widespread uses in allopathy. Muqawwi-e-Aam is the name given to the essential oil utilized in the Unani system. (Singh, 2019) [26].
Chemical composition and bioactive compounds of essential oils extracted from several Blumea species, which are used medicinally in Asia and Africa. Key components such as β-caryophyllene, germacrene D, and borneol, which contribute to remarkable antibacterial, larvicidal, anti-inflammatory, cytotoxic, and fumigant properties, were highlighted in the analysis, which covered 18 species. The oil of the *Blumea lacera* have the potential to treat infections, skin conditions and insect-borne illnesses. For example, *Blumea lacera* oil shown cytotoxicity against cancer cell lines and antimicrobial properties (Nuzul *et al*. 2024) [17].

Material and Methodology

The experiment was conducted at Department of Post-Harvest Management of Medicinal, Aromatic, Plantation, Spices and Forest Crops (MAPSF), Post Graduate Institute of Post-Harvest Technology and Management Killa-Roha, Dist.-Raigad, Maharashtra, India (18° 42'5947" N, 73°17'9361" E) during the year 2023-2024.

Plant material collection and oil extraction: The fresh plant material was collected from campus area of PGI-PHTM, Killa-Roha at different stages and oil was extracted using Clevenger apparatus. The oil was dried over anhydrous sodium sulphate and stored at -4^{0}C for further analysis.

Yield of essential oil: The essential oil was extracted from different maturity stages of fresh plant material (300gm) by hydro distillation method and after that yield was calculated by following formula (Samadi *et al*. 2020) [21]

$$\text{Essential oil (\%)} = \frac{\textit{Volume of oil obtained (ml)}}{\textit{Fresh weight of the plant material (gm)}} \times 100$$

Physicochemical analysis of essential oil

- **Specific gravity of essential oil-** The empty pycnometer (m) Weighed, then pycnometer filled with distilled water. Dipped the pycnometer into a water bath at a temperature of 25±2°C for 30 minutes, then weighed the contents (m1). Emptied the pycnometer, washed and cleaned it, then filled the pycnometer with Bhamrud oil samples, and put it in the bath under the same conditions (Abram *et al*. 2021) [1].
- **Refractive index of essential oil:** After noting the temperature and keeping the refractometer in adequate light, the Abbe refractometer's prism was opened, and cotton dipped in alcohol was used to clean it. The two prisms of the refractometer were gradually brought together and clamped after a drop of the oil sample was applied to the meticulously cleaned fixed prism. Hold off for a while. Using the other eyepiece, the refractive index value of Bhamrud essential oil was displayed directly on the side scale. After the reading, a piece of lens paper was used to properly wipe the prisms (Pallavi, 2006) [18].
- **Optical density of essential oil:** The optical density of the sample was determined by using the spectrophotometer at (488 nm) wavelength (Yanez - Limon *et al*. 2005) [28].
- **Viscosity of essential oil:** The viscosity of essential oil was measured using viscometer Brookfield's standard solutions can be used for calibration (Maneeintr *et al*. 2013) [14].
- **Acid value of essential oil-** The hue and anticipated acid value were used to determine the sample mass of test. In a 250 ml conical flask, weighed 5ml of the cooled oil sample. Then, added 50–100 ml of newly neutralized hot ethyl alcohol and 1 ml of phenolphthalein indicator solution. After five minutes of boiling, titrated the mixture while it was still hot against a standard alkali solution, shaking quickly. The weight of oil used to make the estimate and the strength of the titrating alkali to ensure that the amount of alkali needed for the titration doesn't go over 10 ml (Hamid and Hamid, 2015) [9].

Calculation

$$\textbf{Acid value} = \frac{56.1VN}{W}$$

Where,
V = Volume in ml of standard potassium hydroxide or sodium hydroxide used
N = Normality of the potassium hydroxide solution or Sodium hydroxide solution
W = Weight in g of the sample

Ester value of essential oil- Sifted the sample through a filter paper to remove any contaminants and remaining moisture. Ensured that the sample is totally dried. Mixed the sample thoroughly and transfered 1.5 g of dry sample to a 250 mL Erlenmeyer flask. Pipette 25 mL of alcoholic potassium hydroxide solution into the flask. In addition to the sample, made a blank determination. Connected the sample flasks and blank flask with air condensers, placed them on the water bath, and boiled gently but steadily until saponification is complete, as evidenced by the lack of greasy particles and the appearance of clear solution. Clarity can be attained within an hour after boiling. After the flask and condenser have cooled slightly, washed the inside of the condenser with about 10 ml of hot ethyl alcohol neutral to phenolphthalein. Titrated the excess potassium hydroxide with 0.5N hydrochloric acid, using roughly 1.0 mL of phenolphthalein indicator. (Hamid and Hamid, 2015) [9].

Calculation

$$\text{Ester value} = \frac{56.1\,(B-S)N}{W}$$

Where,
B = Volume in ml of standard hydrochloric acid required for the blank.
S = Volume in ml of standard hydrochloric acid required for the sample
N = Normality of the standard hydrochloric acid and
W = Weight in gm of the oil/fat taken for the test.

GC-MS Profile of essential oil: The gas-liquid chromatography examination of the Bhamrud essential oil samples were performed at Common Facility Centre (CFC),

Sophisticated Analytical Instrumentation Facility (SAIF) Shivaji University, Kolhapur, Maharashtra. The GC-MS analysis was performed using a Shimadzu TQ 8050 operating in electron impact mode (EI, 70 eV). The oven temperature was programmed as 80°C for 1 min, then increased from 80-250°C at 10°C min^{-1}, held at 250°C for 2 min, increased from 250-300°C at 10°C min^{-1}, and finally held for 10 min at 300°C. The injector temperature was 250°C. Helium was used as the carrier gas at a flow rate of 0.8 mL min^{-1}. An Rtx-5 Column (30m x 0.25m x 0.25 µm) was used. The samples were dissolved in ethanol (1 mg of sample in 500 µL of ethanol). All injections were run in split less mode.

Statistical analysis: The data obtained from the experiment was subjected to statistical analysis using OPSTAT software (Python Anywhere) developed by Department of Mathematics & Statistics, CCS HAU, Hisar (Sheoran *et al.*, 1998) [23].

Results and Discussion

- **Yield of essential oil (%):** Yield of essential oil from vegetative stage, flowering stage and mature green plant was recorded to determine recovery behaviour in different stages. The yield of essential oil is observed more in mature green stage of plant. The data related to the yield of essential oil (%) presented in the Table-1 and observed significantly highest yield of essential oil was found in the mature green stage (0.233%) and lowest yield of essential oil was found in the vegetative state (0.165%). Less moisture content and lower activity of some critical enzymes required for manufacture of particular chemicals at the seedling stage led to less essential oil production at the early stages of growth. Plants spend the majority of their produced photosynthetic materials on vegetative organs rather than the synthesis of valuable biological active chemicals in the early stages of their growth, compared to later phases. Hazrati *et al*. (2020) [10] saw the same behavior generated varying yield of essential oil at different phases of growth in *H. percisicus*. Similarly, Daghbouche *et al*. (2020) [5] observed that, vegetative stage had least yield of essential oil in *C. triflorus.* The types and amounts of chemical components found in essential oils vary depending on their level of development. The essential oil composition varies, as a result of the metabolic activities taking place in the plant at various phases of growth. Mature or senescent organs of plant can differ greatly in the presence of particular chemicals. The essential oil is stored in oil glands of plant during mature green stage. After the maturity of plant, the amount of essential oil in it gradually decreases due to expansion of cells and tissue of plant organ like leaves and stems. Tripathi and Hazarika (2014) [27], Yuan *et al*. (2016) [29], and Pourabdal *et al*. (2021) [20] studied same behavior in their investigations.

- **Specific gravity of essential oil (g/cm^3):** The significantly maximum specific gravity was found in mature green plant (0.994 g/cm^3) followed by flowering stage (0.974 g/cm^3). The minimum mean was found in vegetative state (0.958 g/cm^3) shown in Table-1. The essential oil produced from *Blumea lacera* was found to have a higher specific gravity in the mature green stage. The specific gravity of the oils suggested higher molecular weight fatty acids. The specific gravity of essential oil is increased as changes in phenological growth of plant. The chemical compound in oil affects the specific gravity of oil. Younger i.e. vegetative plant had lower specific gravity than mature plant because of modifications to large molecular mass molecules and long carbon chains. Equivalent effect found in the investigation of Alfikri *et al*. (2020) [3] with the oil of *Syzygium aromaticum* L. Khandekar *et al*. (2013) [13] and Afriani *et al*. (2024) [2] investigated identical results with *Blumea lacera* and Sembung (*Blumea balsamifera*) essential oil respectively.

- **Refractive index of essential oil (g/ml @ 20 ℃):** The high refractive index of essential oil among the three stages as shown in Table-1 was in the mature green stage of plant i.e. 1.494 g/ml, while flowering stage has low refractive index (1.474 g/ml) followed by vegetative state (1.458 g/ml). The quality and degree of purity of the oil is frequently evaluated using the refractive index. Since oil color affects refractive index, higher oil clarity results in a higher refractive index. Alfikri *et al*. (2020) [3] found comparable findings from research on *Syzygium aromaticum* L. oil showed that the average refractive index of the oil from young plants was less than the older ones i.e. mature plant.

- **Optical density of essential oil (g/ml at 20 ℃):** The essential oil from mature green stage of plant has a more optical density (0.694 g/ml) than flowering stage (0.674 g/ml) and vegetative state (0.658 g/ml) presented in Table-1. A particularly transparent material has a feature known as optical density, which is an inverse measure speed of light passing through it. The refractive index of the material increases as increase in optical density. Since optical density is inversely proportional to the speed of light in the medium, more optical density results in slower light and a higher refractive index.

- **Viscosity of essential oil (cP):** The viscosity of essential oil in vegetative stage of plant was high (14.278 cP) as compared to essential oil from flowering stage (13.268 cP) followed by mature green stage (12.35 cP) evaluated in Table-1. Viscosity of oil measures the how much oil is thicker than the water or liquid. The viscosity decreases as the volatile component proportion increases. The volatile chemical compounds in essential oil affects the viscosity of essential oil. Silva *et al*. (2017) [25] found that, the main component of essential oils is β-caryophyllene, which also affects viscosity. The exponential equation revealed a significant inverse relationship between β-caryophyllene content and viscosity. It was discovered that the β-caryophyllene content decreased with increasing viscosity, and the viscosity decreased with increasing β-caryophyllene content. Mishra *et al*. 2012 [15] investigated identical value of viscosity from essential oil of *Calendula officinalis* L. (Asteraceae).

- **Acid value of essential oil (mg of KOH/g):** The essential oil from flowering stage of plant shows the

highest acid value (7.515 mg of KOH/g) than that of vegetative state (6.932 mg of KOH/g) followed by mature green stage (6.353 mg of KOH/g). The acid value of essential oil represents the free-fatty acids in essential oil. The purpose of calculating the acid number is to ascertain the acidity index of an oil. The low acid number indicates the low acid content present in oil. The low number of acid implicated low free or fatty acids in essential oil. (Afriani *et al*. 2024) [2]. The high acid value shows the rancidity or oxidation of essential oil. The identical value of acid value was obtained from Sembung (*Blumea balsamifera*) essential oil by Afriani *et al*. (2024) [2].

- **Ester value of essential oil (mg of KOH/g):** Ester value of essential oil from mature green stage (69.570 mg of KOH/g) was high as compared to essential oil from flowering stage (68.850 mg of KOH/g) followed by vegetative stage (66.720 mg of KOH/g). The existence of an ester number in an oil indicates its pleasant aroma. When an oil is dissolved in ethanol and a base is added, a huge number of triglyceride esters develop saponification, which accounts for the high content of esters in an oil. (Afriani *et al*. 2024) [2]. Hence the higher number of esters imply good quality of essential oil. The identical value of ester value was obtained from Sembung (*Blumea balsamifera*) essential oil by Afriani *et al*. (2024) [2].

Table-1: Physicochemical properties of essential oil obtained from *Blumea lacera* at different growth stages

Physico-chemical parameters of essential oil	Vegetative stage	Mature green stage	Flowering stage	S. Em±	CD at 5%
Yield of essential oil (%)	0.165	0.233	0.217	0.001	0.002
Specific gravity of essential oil (g/cm³)	0.958	0.994	0.974	0.001	0.003
Refractive index of essential oil (g/ml @ 20 ℃)	1.458	1.494	1.474	0.001	0.003
Optical density of essential oil (g/ml at 20 ℃)	0.658	0.694	0.674	0.001	0.003
Viscosity of essential oil (cP)	14.278	12.350	13.268	0.010	0.029
Acid value of essential oil (mg of KOH/g)	6.932	6.353	7.515	0.034	0.102
Ester value of essential oil (mg of KOH/g)	66.720	69.570	68.850	0.009	0.028

GC-MS Profile of essential oil-

In oil obtained from three different growth stages of *Blumea lavera*, 72 chemical compounds were found. The area (%) of each compound at the vegetative, mature green and flowering stages is listed in the Table No.2, along with a note indicating whether or not it appears consistently throughout all stages. Several chemicals were exclusive or dominating at specific stages, whereas others were found in two or all three growth stages.

Common chemicals found at all stages include alpha-Pinene, Camphene, D-Limonene, Caryophyllene, Caryophyllene oxide, Linalool, and gamma-Terpinene. Only the vegetative stage contained compounds such methyl (E)-dec-2-en-4,6-diynoate, benzoene, 1,2,3-trimethyl-, and only the mature green stage exhibited the presence of 3,5-hexadienal, 2-ethylidene-6-methyl-, and kessane. The highest quantity of "Bicyclo[3.1.1]hept-2-en-6-one, 2,7,7-trimethyl" was found during the vegetative (51.56%) and flowering (39.42%) stages, however it was not present during the mature green stage. Additional important components included 4,7,7-Trimethylbicyclo [4.1.0] hept-3-en-2-one (4.18% to 11%), 2,2-dimethyl-3- (varying from 10.46% to 17.33% over three stages), and cyclopropanecarboxylic acid. The only mature green stage showed a distinct dominant presence of (3,5-Heptadienal, 2-ethylidene-6-methyl-) at 39.32%.

The common chemical compound found in essential oil from all three stages with different type of plant material through analysis are Bicyclo[3.1.1]hept-2-en-6-one, 2,7,7-trimethyl (chrysanthenone), Cyclopropanecarboxylic acid, 2,2-dimethyl-3 (chrysanthemic acid) and Caryophyllene. Similar compounds are found in investigation of Satyal *et al*. (2015) [22] in the analysis of chemical profiling of essential oil from *Blumea lacera*, Joshi *et al*. (2023) [12] Identified potentially bioactive compounds from *Blumea lacera* essential oil by gas chromatography-mass spectroscopy and Dinde *et al*. (2018) [6] analyzed characterization of essential oil from *Blumea oxyodonta.* Most of essential oils from different growth stages contain a high concentration of bicyclo [3.1.1] hept-2-en-6-one derivatives. This is generally consistent with earlier reports that identified caryophyllene, germacrene D, and Z lachnophyllum ester as the main terpenoid components. The extraction technique, location, and plant stage may have an impact on the specific compound dominance (Satyal *et al*. 2015) [22]. As the composition of essential oil profiles from *Blumea lacera* from Nepal, India, and other Southeast Asian countries has varied, the current findings are supported by the frequent identification of caryophyllene, germacrene D, 1,8-cineole, myrcene, Z lachnophyllum ester, and other sesquiterpenes (Satyal *et al*. 2015; Hoi *et al*. 2023) [22, 11]. The major chemical compound found in oil of mature green plant of fresh plant material is 3,5Heptadienal, 2-ethylidene-6-methyl. The presence of this aldehyde is further supported by essential oil chemical profiling of *Chrysanthemum indicum*, several Citrus species, and *Artemisia baldshuanica*, which highlights its contribution to the distinctive aroma and possible bioactivity of these oils (NCBI, 2025) [16].

Table 2: Chemical compounds found in essential oil from three growth stages of Bhamrud (*Blumea lacera*)

Sr. No.	Compound Name	Area% Vegetative Stage	Area% Mature Green stage	Area% Flowering stage	Common to All Stages
1	Benzene, 1,3-dimethyl-	0.21	0.00	0.17	No
2	Bicyclo[3.1.0]hex-2-ene, 2-methyl-5-(1-methy	0.23	0.17	0.43	Yes
3	alpha. -Pinene	1.01	0.98	2.99	Yes
4	Camphene	0.28	0.26	0.67	Yes
5	Bicyclo[3.1.0]hexane, 4-methylene-1-(1-meth	0.74	0.68	0.24	Yes

6	1-Octen-3-ol	0.28	0.39	0.15	Yes
7	1,3-Cyclopentadiene, 1,2,5,5-tetramethyl-	0.45	0.46	1.05	Yes
8	Benzene, 1,2,3-trimethyl-	0.19	0.00	0.00	No
9	Decane	0.13	0.00	0.00	No
10	alpha. -Phellandrene	0.16	0.16	1.10	Yes
11	o-Cymene	0.72	0.53	1.52	Yes
12	D-Limonene	0.53	0.47	0.78	Yes
13	gamma. -Terpinene	0.18	0.20	0.49	Yes
14	Undecane	0.26	0.00	0.21	No
15	Linalool	0.66	0.96	0.55	Yes
16	methyl (E)-dec-2-en-4,6-diynoate	9.96	0.00	0.00	No
17	Bicyclo[3.1.1]hept-2-en-6-one, 2,7,7-trimethy	0.70	0.00	0.61	No
18	Isochrone	0.21	0.28	0.15	Yes
19	Bicyclo[3.1.1]hept-2-en-6-one, 2,7,7-trimethyl	51.56	0.00	39.42	No
20	3,3-Dimethyl-6-methylenecyclohexene	0.75	1.08	0.65	Yes
21	endo-Borneol	0.21	0.00	0.00	No
22	3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl	0.63	0.95	0.00	No
23	Bicyclo[3.1.0]hexane, 6-isopropylidene-1-met	0.31	0.00	0.00	No
24	Dodecane	0.36	0.36	0.30	No
25	(3E,5E)-2,6-Dimethylocta-3,5,7-trien-2-ol	0.16	0.27	0.00	No
26	(E)-2,6-Dimethylocta-2,5,7-trien-4-one	0.29	0.50	0.00	No
27	2-Cyclohexen-1-one, 3-methyl-6-(1-methyleth	1.21	1.87	1.28	Yes
28	Thymol	0.42	0.52	0.28	Yes
29	Trimecaine	0.53	0.00	0.44	No
30	1,3-Cyclopentadiene, 5,5-dimethyl-1-ethyl-	0.13	0.26	0.00	No
31	1,3-Cyclopentadiene, 5,5-dimethyl-1-ethyl-	0.17	0.44	0.00	No
32	Cyclopropane carboxylic acid, 2,2-dimethyl-3-	11.08	17.33	10.46	Yes
33	4,7,7-Trimethylbicyclo[4.1.0]hept-3-en-2-one	6.64	11.00	4.18	Yes
34	3-Methyl-2-butenoic acid, oct-3-en-2-yl ester	0.26	0.36	0.00	No
35	Caryophyllene	2.98	5.11	5.43	Yes
36	Seychelle	0.27	0.00	0.34	No
37	1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-	0.27	0.42	0.46	Yes
38	beta. -copaene	0.33	0.64	0.00	No
39	Naphthalene, decahydro-4a-methyl-1-methyle	0.18	0.37	0.23	No
40	Pentadecane	0.17	0.00	0.00	No
41	2-Oxooctanoic acid	0.40	0.77	0.31	Yes
42	Caryophyllene oxide	0.85	1.19	0.70	Yes
43	Kauran-18-al, 17-(acetyloxy)-, (4. beta.)-	0.29	0.58	0.00	No
44	1,4-Dimethyl-7-(prop-1-en-2-yl)decahydroazu	0.55	0.89	0.37	Yes
45	(1,4,4-Trimethyl-cyclohex-2-enyl)-acetic acid	0.28	0.59	0.32	Yes
46	Allyl nonanoate	0.44	0.00	0.32	No
47	Cyclohexane, 1,1-dimethyl-	0.00	0.00	0.32	No
48	Cyclopentane, 1-ethyl-2-methyl-, cis-	0.00	0.00	0.37	No
49	Heptane, 2,4-dimethyl-	0.00	0.43	2.43	No
50	Cyclohexane, 1,3-dimethyl-, cis-	0.00	0.00	0.25	No
51	Octane, 2-methyl-	0.00	0.00	0.34	No
52	1,6-Dimethylhepta-1,3,5-triene	0.00	0.25	1.45	No
53	Ethylbenzene	0.00	0.00	0.47	No
54	o-Xylene	0.00	0.00	1.42	No
55	1,5-Heptadiene, 2,6-dimethyl-	0.00	0.00	0.23	No
56	1,3-Cyclohexadiene, 1-methyl-4-(1-methyleth	0.00	0.00	0.24	No
57	2,6,6-Trimethylbicyclo [3.2.0] hept-2-en-7-one	0.00	0.00	12.45	No
58	Terpinen-4-ol	0.00	0.00	0.65	No
59	trans-Ocimenol	0.00	0.00	0.22	No
60	Azulene, 1,2,3,5,6,7,8,8a-octahydro-1,4-dimet	0.00	0.00	0.24	No
61	Naphthalene, 1,2,3,4,4a,5,6,8a-octahydro-7-m	0.00	0.00	0.18	No
62	Naphthalene, 1,2,3,5,6,8a-hexahydro-4,7-dime	0.00	0.00	0.33	No
63	3,5-Heptadienal, 2-ethylidene-6-methyl-	0.00	39.32	0.00	No
64	Bicyclo[2.2.1]heptan-2-ol, 1,7,7-trimethyl-, (1	0.00	0.38	0.00	No
65	Bicyclo[2.2.1]heptane, 7,7-dimethyl-2-methyl-	0.00	0.50	0.00	No
66	Bicyclo[3.1.1]hept-3-en-2-one, 4,6,6-trimethyl	0.00	0.18	0.00	No
67	Kessane	0.00	0.16	0.00	No
68	2H-3,9a-Methano-1-benzoxepin, octahydro-2,	0.00	0.20	0.00	No
69	Caryophylla-4(12),8(13)-dien-5.alpha.-ol	0.00	0.81	0.00	No
70	Hexanoic acid, 3,5,5-trimethyl-, oct-3-en-2-yl	0.00	0.81	0.00	No
71	Propanoic acid, 2-methyl-, 2-[3-[(acetyloxy)m	0.00	0.21	0.00	No
72	(1R,7S,E)-7-Isopropyl-4,10-dimethylenecyclo	0.00	0.19	0.00	No

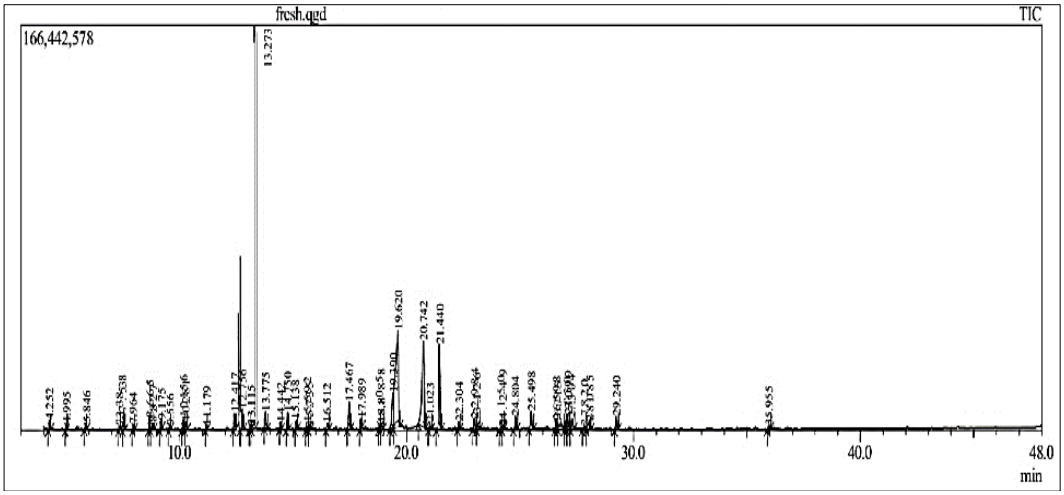

Fig 1: GC-MS chromatograph of essential oil obtained at vegetative stage of *Blumea lacera*

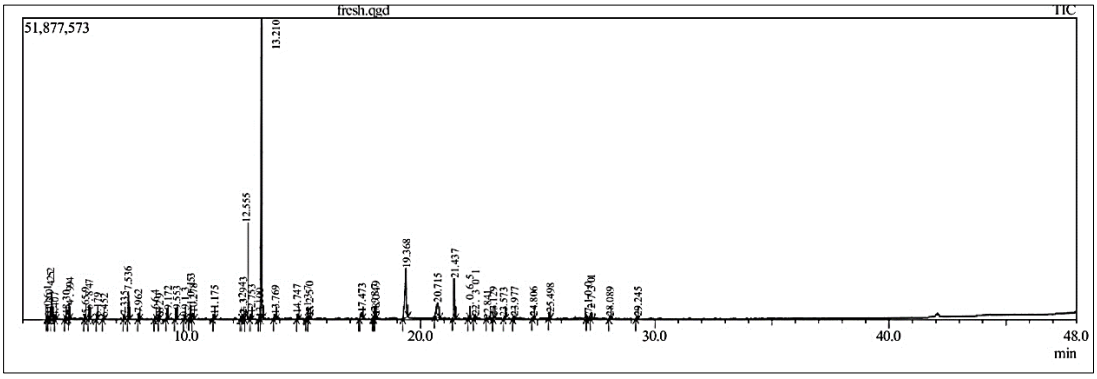

Fig 2: GC-MS chromatograph of essential oil obtained at mature green stage of *Blumea lacera*

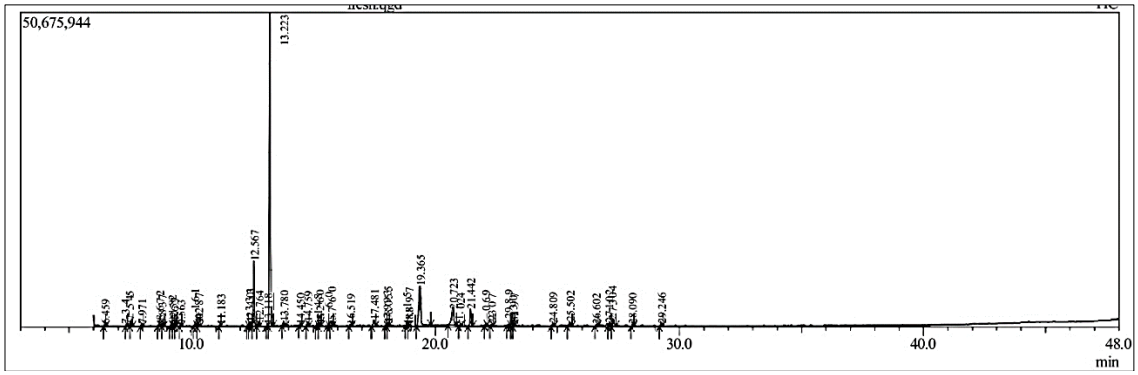

Fig 3: GC-MS chromatograph of essential oil obtained at flowering stage of *Blumea lacera*

Conclusion

The current study thoroughly examined the essential oil yield, physicochemical qualities and chemical makeup of *Blumea lacera* during three phenological stages viz, vegetative, mature green and flowering. The results indicate that the mature green stage produces the more essential oil content as well as the best values for specific gravity, refractive index and ester value, implying that oil quality is greater at this stage. GC-MS profiling revealed a wide variety of 72 compounds, with caryophyllene, chrysanthenone and chrysanthemic acid consistently present at all stages, whereas specific aldehydes and ketones showed stage-dependent occurrence and abundance. The pharmacological and aromatic relevance of essential oil is based on its predominant sesquiterpenes and aldehydes composition. These findings emphasize the importance of harvest timing in maximizing productivity and quality, with implications for the medicinal, aromatic and essential oil sectors, as well as future phytochemical and pharmacological studies of *Blumea lacera*.

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