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Essential Oil Constituent, Antimicrobial Activity, and Mosquito Larvicidal Activity of *Murraya glabra* (Guillaumin) Swingle from Vietnam

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Abstract: The present result showed that sesquiterpene hydrocarbons (78.3%) were the main class of compounds present in the essential oil hydrodistilled from the leaves of *Murraya glabra* (Guillaumin) Swingle from Vietnam. The major sesquiterpene compounds of the essential oil are *cis*-β-elemene (47.3%) and bicyclogermacrene (11.6%). In addition, *E*-caryophyllene (5.7%), (*E*, *E*)-α-farnesene (3.4%), ar-curcumene (3.3%) and α-zingiberene (3.0%) were the other sesquiterpenes present in sizeable amount. Oxygenated monoterpenes were not identified in the essential oil. The essential oil from the leaves of *M. glabra* displayed antibacterial activity against *Enterococcus faecalis* ATCC 29212, *Staphylococcus aureus* ATCC 25923, *Bacillus cereus* ATCC 14579, and *Pseudomonas aeruginosa* ATCC 27853, as well as anti-candidal action against *C. albican*s ATCC 10231, each with Minimum Inhibitory Concentration (MIC) value of 64.0 µg/mL. The corresponding median inhibitory concentration (IC_{50}) values were 32.56 µg/mL, 32.58 µg/mL, 32.99 µg/mL, 32.45 and 32.44 µg/mL, respectively. Essential oil from the leaf of *M. glabra* exhibited larvicidal activity against *Aedes aegypti* and *Culex quiquefasciatus* with median lethal concentrations (LC_{50}) values of 20.86 µg/mL and 24.46 µg/mL, at 24 h, respectively. The lethal concentration required to kill 90% of population exposed (LC_{90}) values at the same test periods were 37.90 µg/mL and 56.79 µg/mL, respectively. The essential oils may be further considered and investigated as a source of natural products.

Keywords: *Murraya glabra;* gram-positive bacteria: gram-negative bacteria: *Aedes aegypti: Culex uinquefasciatus*.

1. Introduction

The genus *Murraya* are an important member of the family Rutaceae. *Murraya glabra* (Guillaumin) Swingle (syn. *Micromelum glabrum* Guillaumin is known in Vietnamese as Vương tùng [1]. In the present communication, essential oils were obtained by hydrodistillation of the leaves of *M. Glabra* collected from Châu Lý Commune, Pù Huống Natural Reserve (Herbarium number: HNU

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770). The essential oil was then analyzed by gas chromatography (GC) and gas chromatography-mass spectrometry (GC/MS) techniques, and subsequently screened for *in vitro* antimicrobial and mosquito larvicidal activities. Extracts from *M. glabra* leaf previously ameliorate infections from microorganisms in ethnomedicine [1]. The authors could not find any information on the compositions and pharmacological potentials of *M. glabra*. Literature reports revealed the published information on the chemical compositions and tested activities of essential oils from several *Murraya* plants of Vietnam and other parts of the world. More so factors including age of plants, soil and climatic conditions, harvesting season, processing technique are responsible for the change in the chemical composition, biological actions and yield of essential oils of *Murraya* plants. The essential oils of *M. koenigii* from Vietnam [2] obtained by hydrodistillation contained large amounts of α-pinene (19.03%), β-phellandrene (18.22%) and *trans*-β-caryophyllene (27.24%), while oil from microwave-assisted hydrodistillation was rich in α-pinene (29.81%), β-phellandrene (25.62%) and *trans*-β-caryophyllene (17.09%). The major constituents of *M. paniculata* from Nigeria [3] include β-cyclocitral (22.9%), methyl salicylate (22.4%), (*E*)-nerolidol (11.7%), while the oil from Nepal [4] had abundant of methyl palmitate (11.1%), isospathulenol (9.4%). The sample analysed from Bangladesh [5] consists of caryophyllene oxide (16.6%), β-caryophyllene (11.8%), and spathulenol (10.2%). This information shows there is existence of both intra-species and inter-species variations in *Murraya* essential oils. Foremost, this paper provides for the first time information on the chemical constituents, antimicrobial and larvicidal properties activities of the Vietnamese plant, *M. glabra*.

2. Materials and Methods

2.1. The samples of M. glabra

The plant was harvested from Châu Lý Commune, Pù Huống Natural Reserve (GPS 18°17′15″N, 105°21′39″E), Vietnam, in October 2022, during sunshine. The leaf sample was identified by Dr. Dai, D.N. and voucher specimen VNU 770, was preserved in the plant specimen room, NgheAn College of Economics, NgheAn, Vietnam. In the preparation of the samples for hydrodistillation procedure, unwanted materials were completely removed. Then the material was grinded into a coarse sample (2 kg).

2.2. Extraction Essential oil from the Leaves of M. glabra

For the leaves of *M. glabra*, fresh leaves (2.0 kg each) were subjected to hydrodistillation using a Clevenger-type apparatus. The procedures were described in earlier studies [2]. The pulverized sample of each plant was divided each into three equal parts to enable the distillation of essential oils three times. Each of the samples was packed separately inside a 5-L flask. The samples were submerged completely inside the flask with enough quantity of distilled water (3.5-L), which was connected to the Clevenger-type apparatus. The essential oils were allowed to distill for 3 h after the whole apparatus was connected to a heating mantle maintained at normal pressure according to Vietnamese Pharmacopoeia [6]. On completion, the hydro distilled essential oils were collected separately into clean and previously weighed sample bottles. Following the normal laboratory procedures [7-9], the essential oils were refrigerated at 4^{o}C till the moment of analysis. The yield (%) of the essential oils was calculated separately by dividing the mass (g) of the essential oil over the mass (g) of the pulverized leaves of *M. glabra*, as described previously [7-9].

2.3. The Analysis of Essential oil of M. glabra

In the GC analysis of the essential oils, the Gas chromatograph used was HP 7890A Plus. Among the GC components are the HP-5MS column which has dimension of 30 m x 0.25 mm and a flame ionization detector (FID). The GC column has a film thickness of 0.25 µm. The GC analytical conditions include the injector and detector temperatures set and maintained at 250^{o}C and 260^{o}C, respectively. To commence the analysis, 1.0 µL of diluted essential oil (1% n-hexane) was injected into the GC column which was done by using the split ratio of 10:1 and the inlet pressure of 6.1 kPa. Helium

under the flow rate of 1 mL/min, was used as the carrier gas. The GC analysis performed under normal pressure. The temperature programmed condition commences from 40°C (held isothermally for 2 min) and rises to 220°C (with 10 min hold). The GC analysis was conducted in triplicate. The individual constituents of each essential oil was quantified using the calibration curves generated from the analyses of representative standard compounds from each class, as reported previously [7-9]. The experimental procedure in GC/MS analysis involves a coupling of Gas chromatography described above with a HP 5973 MSD Mass spectrometer. All the analytical conditions described for GC above were also employed for the GC/MS experiment. The MS spectral data in the GC/MS procedure was obtained with the set conditions of ionization voltage (70 eV), emission current (40 mA), acquisitions scan mass range (45-350 amu) and sampling rate (1.0 scan/s) as reported previously [7-9].

2.4. Determination of the Constituents of M. glabra

The last stage of the analysis was the identification of the individual constituents present in Mass spectral of the essential oil generated from GC/MS. This was accomplished by comparison of the retention indices (RI) of each compound of the essential oils with a homologous series of n-alkanes (C_6-C_{40}). Also, the Mass spectral data of each essential oil was compared with MS fragmentation patterns of compounds documented in literature [10-13]. Moreover, the use of co-injection with known compounds under the same GC conditions was also used to identify some compounds [7-9].

2.5. Antimicrobial Activity

The Gram-positive bacteria, Gram-negative bacteria and fungus were all obtained from the Institute of Marine Biochemistry, Vietnam Academy of Science and Technology, Hanoi, Vietnam. The microbes were *Enterococcus faecalis* ATCC 29212, *Staphylococcus aureus* ATCC 25923, *Bacillus cereus* ATCC 14579, *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853, *Salmonella enterica* ATCC 13076 and *Candida albicans* ATCC 10231. The testing medium for the bacteria was double-strength Mueller-Hinton broth, while double-strength Sabouraud dextrose broth was used for the fungus. The procedures employed were described previously in our various reports [7-9,13]. The concentrations of each essential oil of *M. glabra* used for the antimicrobial study was determined according to reports of similar studies [7-9,13]. Essential oils were reported to have displayed antimicrobial activity within the already determined concentration range. The antimicrobial level of the essential oils was evaluated by the microdilution broth susceptibility assay accompanied by the measurement of the minimum inhibitory concentration (MIC) and median inhibitory concentration (IC_{50}) values.

The bacteria were standardized to 5×10^5 CFU/mL while the fungi strength was 1×10^3 CFU/mL, and each grew in specific media. The stock solutions of each essential oil of M. glabra were prepared in 1% dimethyl sulfoxide from 1.6384 x 10^4 μg/mL to 2^1 μg/mL. The dilute solutions of essential oils and microorganisms were separately placed in 96-well microtiter plates and incubated for 24 h (37 °C). The last row of each plate which has only the serial dilutions of the essential oils was used as the negative (no growth) control. The positive controls are streptomycin for antibacterial and nystatin for anticandidal. After 24 h, the MIC values were evaluated from the wells where the lowest concentration of each of the essential oil completely inhibited the growth of microorganisms, while the IC_{50} values were determined by the percentage of microorganisms that inhibited the microbial growth from the turbidity data of EPOCH2C spectrophotometer (BioTeK Instruments, Inc Highland Park Winooski, VT, USA) and Rawdata computer software (Brussels, Belgium). The data obtained were calculated as described previously [7-9,13].

2.6. Evaluation of Mosquito Larvicidal Potentials

The adults of *Culex quinquefasciatus* and *Aedes aegypti* used in the study of larvicidal activities of the essential oils were collected from Hoa Khanh Nam ward, Lien Chieu District, Da Nang city (16°03'14.9"N, 108°09'31.2"E), Vietnam. The tests were conducted at the Center for Entomology and Parasitology Research, Duy Tan University. The mosquito vectors were maintained under identical

conditions as described previously [1,3,8]. Briefly, *C. quinquefasciatus* and *A. aegypti* were kept in cages (40 X 40 X 40 cm). The adult's mosquito vectors sustained on 10% sucrose solution were fed with blood of mice. Tap water was used to induce hatching of eggs. The resulting larvae were rare in plastic trays (24 X 35 X 5 cm) built for this purpose with temperature conditions sustained at 25 ± 2°C and relative humidity of 65─75%. There are equal 12:12 h light: dark cycles through the duration of the study. Feeds for the larvae include dog biscuits and yeast powder in the ratio of 3:1 as reported earlier [1,3]. The larvicidal activities of the essential oils from the leaves of *M. glabra* were evaluated as previously described following the established protocols [14]. Four different concentrations of the essential oils (12.5, 25, 50, and 100 µg/mL) were used in the experiment. With ethanol (EtOH) used as a negative control, permethrin, a larvicidal drug, was used as a positive control. Prior to analysis, 200 mg of each of the essential oils was dissolved in 20 mL of ethanol which was transferred into different beakers stocked with 20 fourth instar larvae of *C. quinquefasciatus* and *A. aegypti*. The mortality of larvae of *C. quinquefasciatus* and *A. aegypti* was recorded after 24 h and 48 h of exposure to the different concentrations of the essential oils and repeated four times. The mortality rate was calculated using the formula described previously [7-9].

$$M_c = \frac{M_o - M_t}{100 - M_t} x100$$

where,
M_o = mortality in the treated groups, M_t = mortality in the control group and M_c = calculated mortality

2.7. Statistical Analysis

The LC_{50} values, LC_{90} values, and 95% confidence limits and mean of standard deviation (SD, ±) were calculated accordingly [7-9].

3. Results and Discussion

3.1. Constituents Present in M. glabra

The hydro distilled *M. glabra* yielded essential oil of 1.56% (w/w) and light-yellow colored. The instrumental analysis of the essential oil was done through GC and GC/MS. The oxygen-containing monoterpenes class of compounds were absent in *M. glabra* oil. From the analysis of the GC/MS, 23 compounds (93.1% of the whole oil contents), could be identified in *M. glabra* oil. Sesquiterpene hydrocarbon (78.3%) was the most abundant class of compounds identified in the essential oil of *M. glabra* (Table 1 and Figure S1). Monoterpene hydrocarbons (6.1%) and oxygenated sesquiterpenes (1.6%) are present in sizable amounts. The main compounds of the essential oil, mostly sesquiterpene, are *cis*-β-elemene (47.3%) and bicyclogermacrene (11.6%). In addition, *E*-caryophyllene (5.7%), (*E*, *E*)-α-farnesene (3.4%), ar-curcumene (3.3%), α-zingiberene (3.0%) and β-bourbonene were the other sesquiterpenes present in sizeable amount. The monoterpenes (*E*)-β-ocimene (2.1%), β-phellandrene (1.8%) and α-pinene (1.1%) were present in amounts > 1%.

The identified compositions of *M. glabra* were compared with data available on the constituents of other *Murraya* essential oils the world over. The available evidence indicated that varieties of monoterpenoids and sesquiterpenoids were identified and reported previously from *Murraya* species. These terpenoids differ from one species to another. Moreover, there are both intra-species and inter-species in their various chemical constituents. For example, α-pinene, β-phellandrene and *trans*-β-caryophyllene were the main compounds of *M. koenigii* from Vietnam [2] and Malaysia [15], while β-caryophyllene and β-gurjunene are the main compounds from sample analysed from London [16]. However, δ-carene being the most singly abundant compound in a sample from Bangladesh [17]. While the sample of essential oils of *M. paniculata* from Nigeria contained β-cyclocitral, methyl salicylate and

(*E*)-nerolidol [3], methyl palmitate and isospathulenol make up the composition of Nepal sample [4]. However, large amounts of β-caryophyllene along with one or two other sesquiterpenes featured prominently in the essential oils of *M. paniculata* from Bangladesh [5], China [17] and Cuba [18]. The sesquiterpenes spathulenol featured in the essential oils of *M. exotica* from China [19], (*E*)-nerolidol occurred prominently from samples of India origin [20]. The compounds limonene and perillaldehyde were found in *M. crenulata* [21] and *M. euchrestifolia* [22].

Table 1. Constituents of the leaf essential oils of *M. glabra*

Compound[a]	**RI (Exp.)**	**Range of RI[a-c]**	**Percent Composition[d]**
α-Pinene	937	924-941	1.1
Sabinene	979	944-980	0.7
β-Phellandrene	1032	1026-1032	1.8
Limonene	1034	1028-1038	0.4
(*E*)-β-Ocimene	1049	1041-1052	2.1
2-Nonanone	1093	1088-1094	0.4
(E)-4,8-Dimethylnona-1,3,7-triene	1118	1116-1120	0.5
δ-Elemene	1347	1335-1352	0.4
β-Bourbonene	1399	1381-1401	2.9
cis-β-Elemene	1404	1385-1407	47.3
α-Santalene	1431	1421-1438	1.8
β-Caryophyllene	1437	1416-1451	5.7
9-*epi*-(*E*)-Caryophyllene	1479	1457-1480	1.2
β-Chamigrene	1490	1488-1493	0.4
Germacrene D	1498	1471-1500	3.0
α-Zingiberene	1504	1498-1510	3.0
E, E)-α-Farnesene	1513	1507-1523	3.4
Bicyclogermacrene	1513	1483-1525	11.6
δ-Cadinene	1537	1516-1547	0.4
ar-Curcumene	1540	1532-1548	3.3
(*E*)-α-Bisabolene	1543	1541-1558	1.6
(*E*)-Nerolidol	1570	1549-1569	0.5
Spathulenol	1598	1571-1601	1.1
			93.1
Monoterpene hydrocarbons			**6.1**
Sesquiterpene hydrocarbons			**1.6**
Oxygenated sesquiterpenes			**0.9**
Non-terpenes			

[a] Order of elution on GC column; RI (Exp.), Experimental retention indices on GC column; RI[a-c]: [10], b: [11], c: [12] (Literature retention indices on HP-5MS column as seen in NIST [d] Standard deviation were insignificant; Unidentified are (i) RI 1547, *m/z*: 93, 220; (ii) RI 1593, *m/z*: 81, 218

Considering the analysis above, *M. glabra* essential oil compositional pattern differs from other *Murraya* species so far analysed in the literature. Essential oils from *Murraya* species which has large quantities of *cis*-β-elemene and bicyclogermacrene as seen in *M. glabra* was not found in literature from other parts of the world. One of the factors mentioned above may have been responsible for these variations in the compositional patterns of *Murraya* essential oils [22].

3.2. Antimicrobial Activity

The MIC value of 64.0 µg/mL was recorded against each of the microorganisms, *E. faecalis* ATCC 29212, *S. aureus* ATCC 25923, *B. cereus* ATCC 14579, and *P. aeruginosa* ATCC 27853, by *M. glabra* leaf oil (Table 2). The corresponding IC_{50} value was 32.56 µg/mL, 32.58 µg/mL, 32.99 µg/mL, and 32.4532.56 µg/mL, respectively. In addition, *M. glabra* oil showed anti-candidal action against *C. albican*s ATCC 10231, with MIC value of 64.0 µg/mL, as well as IC_{50} value of 32.44 µg/mL. The essential oil, however, did not exhibit any antibacterial potential towards *E. coli* ATCC 25922 and *S. enterica* ATCC 13076. This first report, overall, showed that *M. glabra* exhibited promising antimicrobial activity.

Literature information revealed that *Murraya* essential oils exhibited selective microbial inhibition towards different microorganisms. Therefore, microbial activity of *M. glabra* looks similar to available data from other *Murraya* plants through selective activity. Previous reports revealed that *M. koenigii* extracted by microwave-assisted hydrodistillation displayed antimicrobial activity towards *S. aurues,* and *B. cereus* [2]. *M. paniculata* [4] did not inhibit the growth of several bacteria but showed antifungal activity against *Aspergillus niger* (MIC = 313 µg/mL). However, essential oil of *M. paniculata* from Cuba also displayed different inhibitory effects against *Klebsiella pneumoniae* and *B. subtilis* [17]. Likewise, the oils from Egypt, whose major compound was α-pinene displayed strong antifungal activity against *C. albicans* and showed a modest antibacterial activity against *E. coli*, *P. aeruginosa*, *S. aureus* and *Sarchina lutea* [23]. Also, *M. paniculata* from Brazil with high contents of β-caryophyllene, α-zingiberene and β-cubebene was active against *Sclerotinia sclerotiorum* [25]. Regarding the antimycobacterial activity, essential oils from *M. paniculata* ripe (β-caryophyllene, α-ylangene and germacrene-D) and unripe fruits (sesquithujene, α-zingiberene, germacrene-D and α-copaene) were active against *Mycobacterium kansasii* (MIC = 250 µg/mL), moderately active against *M. tuberculosis* (MIC = 500 µg/mL) and inactive against *M. avium* (MIC = 2000 µg/mL) [26].

In principle, *M. glabra* oil had a different chemical compositional pattern with concomitant influence on the antimicrobial actions. The promising *in vitro* antimicrobial activity of essential oil from *M. glabra* leaves may be justified by its major chemical constituents, i.e., *cis*-β-elemene, and bicyclogermacrene. The synergistic effects of some minor compounds such as *E*-caryophyllene, α-pinene amongst others, might also influence the antimicrobial activity. It is relevant, taking into account that they have already had their antimicrobial activity reported by the literature. The sesquiterpene bicyclogermacrene is an important agent *S. aureus* and *E. coli* [26], while β-caryophyllene demonstrated selective antibacterial activity against *S. aureus* [27] and antifungal effect [28]. The monoterpene, α-pinene was found to possess potent activity against a variety of microorganisms [29].

Table 2. Antimicrobial activity of the leaf essential oil of *M. glabra*

Microorganisms	**MIC (µg/mL)**[a,]	IC_{50} **(µg/mL)** [a]
Enterococcus faecalis ATCC299212	64.00 ± 0.01 [b]	32.56 ± 0.50 [c]
Staphylococcus aureus ATCC25923	64.00±0.14 [d]	32.58 ± 0.51 [e]
Bacillus cereus ATCC14579	64.00 ± 0.00 [f]	32.99 ± 0.50 [f]
Pseudomonas aeruginosa ATCC27853	64.00 ± 0.10 [g]	32.45± 0.50 [f]
*Candida albican*s ATCC10231	64.00 ± 0.10 [h]	32.44 ± 0.12 [h]
Escherichia coli ATCC25922	NA	NT
Salmonella enterica ATCC13076	NA	NT

[a] Mean value of three replicate assays; [b,c,d,e,f] Streptomycin, MIC values of 0.21 µg/mL, 1.07 µg/mL, 1.16 µg/mL, 2.20 µg/mL, and 0.18 µg/mL, respectively; [h] Cycloheximide, MIC of 0.46 µg/mL; NA: No activity; NT: Not tested

3.2. Mosquito Larvicidal Activity

From Table 3, *M. glabra* leaf essential oil exhibited larvicidal activity towards *C. quinquefasciatus* with LC_{50} value of 24.46 µg/mL (21.87-27.34) with LC_{90} value of 56.79 µg/mL (48.61-69.41) at 24 h. The LC_{50} value at 48 h was 13.15 µg/mL (11.77-14.64), while the LC_{90} value was 27.21 µg/mL (23.41-33.47). Also, the leaf essential oil of *M. glabra* showed larvicidal action against *Ae. aegypti* with the lower LC_{50} value of 20.86 µg/mL (18.92-22.98) and LC_{90} value of 37.90 µg/mL (33.25-

45.32) at 24 h, respectively. At 48 h, the essential oil displayed lower LC_{50} and LC_{90} values of 14.64 µg/mL (13.15-16.27) and 29.64 µg/mL (25.58-36.26), respectively (Table 3). This activity can be compared with Permethrin, a larvicidal drug which displayed good activity against *C. quinquefasciatus* and *A. aegypti* with LC_{50} values in the range 2.19─3.43 µg/mL. The larvicidal effect of essential oil of *M. glabra* in this present study will be considered from previous procedures [7-9] where the substances with LC_{50} > 100 µg/mL were considered not active, substances with LC_{50} between 100 µg/mL─50 µg/mL were considered active and those with LC_{50} < 50 µg/mL were considered highly active. Overall, the results in this study showed that essential oil of *M. glabra* (LC_{50} < 50 µg/mL) may be considered to exhibit a good level of activity against *Ae. aegypti* and *C. quinquefasciatus*.

Table 3. Mosquito larvicidal activity of the leaf essential oil of *M. glabra*

	Minimum lethal concentration (µg/mL)			
	LC_{50}	**LC_{90}**	**$\chi 2$**	***p***
C. quinquefasciatus				
24 h	24.46 (21.87-27.34)	56.79 (48.61-69.41)	6.546	0.088
48h	13.15 (11.77-14.64)	27.21 (23.41-33.47)	10.783	0.013
Ae. aegypti				
24 h	20.86 (18.92-22.98)	37.90 (33.25-45.32)	2.048	0.562
48 h	14.64 (13.15-16.27)	29.64 (25.58-36.26)	0.770	0.857

[a] Permethrin, the standard drug used as positive control displayed larvicidal activity against *C. quinquefasciatus* and *A. aegypti* with LC_{50} values in the range of 2.19 - 3.43 µg/mL.

This is the first report on the larvicidal activity of essential oil from *M. glabra*. The antimicrobial activity of *M. glabra* leaf essential oil was comparable to data available on the activity of essential oils from other *Murraya* plants. The essential oils of some other *Murraya* essential oil have shown larvicidal activities. The leaf essential oil of *M. exocita* displayed larvicidal activities after 24 h of exposure period with LC_{50} = 35.8 and LC_{90} = 85.4 ppm (*Ae. aegypti*), and LC_{50} = 43.2 and LC_{90} = 103.2 ppm (*C. quinquefasciatus*) [30]. From the foregoing, it can be deduced that *M. glabra* essential produced better larvicidal activity than *M. exocita* when LC_{50} and LC_{90} data where compared. The larvicidal activity of *M. glabra* may be correlated with the concentration of some compounds identified in the essential oil. For example, *E*-caryophyllene, had previously shown *Ae. aegypti* larvicidal activities with LC_{50} value of 88.3 µg/mL [31]. Thus, essential oils of *M. glabra* and their constituents may be considered among the most promising alternatives to synthetic chemicals.

In conclusion, the main compounds of essential oil distilled from the leaves of *M. glabra* are *cis*-β-elemene (47.3%) and bicyclogermacrene (11.6%). The essential oil displayed antimicrobial activity against *E. faecalis*, *S. aureus*, *B. cereus*, *P. aeruginosa* and *C. albican*s, with MIC value of 64.0 µg/mL. Also, *M. glabra* essential oil exhibited larvicidal activity towards *C. quinquefasciatus* (LC_{50} value of 24.46 µg/mL) and *Ae. aegypti* (LC_{50} value of 20.86 µg/mL) at 24 h. The essential oil of *M. glabra* and its several major compounds may have potential for use in the control of infectious diseases, malaria mosquitoes and may be useful to produce natural antimicrobial and larvicidal agents.

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Supporting Information

Supporting information accompanies this paper on http://www.acgpubs.org/journal/records-of-natural-products

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