Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol. 5 No. 6 (2024): June 2024 Issue
https://doi.org/10.51168/sjhrafrica.v5i6.1215
Original Article

MORINGA OLEIFERA LEAF POWDER INFLUENCED THE CHEMICAL PROFILE OF *LEONOTIS LEONURUS* ESSENTIAL OILS.

McMaster Vambe[1], Rebecca Zengeni[2], Georgina Arthur[1], Karishma Singh[1], Stephen Amoo[3,4], Kuben Naidoo[1] & Roger. M. Coopoosamy[1]*

[1]Department of Nature Conservation, Mangosuthu University of Technology, Umlazi, Durban, South Africa.
[2]Department of Soil Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa.
[3]Agricultural Research Council – Vegetables, Industrial and Medicinal Plants, Pretoria, Private Bag X293, Pretoria 0001, South Africa
[4]Unit for Environmental Science and Management, North-West University, Potchefstroom South Africa

ABSTRACT

Background:
Leonotis leonurus is used extensively in African herbal medicine to manage several diseases including diabetes mellitus, epilepsy, hypertension, and skin and respiratory infections. Although *L. leonurus*is a valuable medicinal plant in Africa, little has been done to improve the plant's organoleptic and pharmacological properties.
The study evaluated the effects of Moringa (*Moringa oleifera*) leaf powder treatments on the chemical profiles of essential oils from *L. leonurus*.

Methodology:
All trials were conducted in experimental greenhouse tunnels. Six-week-old *L. Leonurus* seedlings were transplanted into individual pots (1 seedling per pot) containing 1kg of GromorTM potting mix (30 dm3) and subjected to varying quantities (0, 1.25, 2.5, 5, 7.5, and 10g) of Moringa leaf powder (MLP) biweekly for eight weeks. Additionally, each seedling received 100 mL of 50 % Hoagland's solution once every 4 weeks and was watered regularly throughout the trial. At the end of the trial, the plant's shoots were harvested and essential oils were extracted from them by steam distillation. The oils' chemical profiles were then determined by Gas Chromatography-Mass Spectroscopy.

Results:
MLP applications caused each treatment to have a distinct chemical profile. Notable variations in oil yield, number, and concentration of compounds per each sample evaluated were observed. Caryophyllene and humulene were among the bioactive compounds whose concentration increased by 4- to 10-fold in treatments, compared to the control. Caryophyllene, β-copaene, humulene, and phytol were among the most dominant compounds in the oil samples.

Conclusions:
MLP induced qualitative and quantitative changes in *L. leonurus* essential oils. The powder could therefore be potentially used to improve the quality and yield of medicinally valuable crucial oils from the plant.

Recommendations:
Future research could focus on maximizing the use of MLP in natural situations. Such field trials should also investigate the powder's possible use in conjunction with other organic fertilizers.

Keywords: *Biostimulants; Essential Oils; Ethnobotany; Gas Chromatography-Mass Spectroscopy; Leonotis leonurus; Moringa leave powder*
Submitted: 2024-06-13   Accepted: 2024-06-25

Corresponding author: *McMaster Vambe*
Email: *Mcmastervambe@gmail.com*
Mangosuthu University of Technology, Umlazi, Durban, South Africa.P. O Box 12363, Jacobs, 4026, South Africa

INTRODUCTION

Leonotis leonurus(L.) R. Br is a soft-stemmed shrub belonging to the Lamiaceae family (Nsuala *et al.*, 2015). The plant is endemic to South Africa where it is locally known as *duiwelstabak*, *wildedagga*(Afrikaans), Leonotis, lion's ear, wild dagga (English), *imvovo*, *umunyamunya*, *utywala-bengucungu* (isiXhosa), *umcwilii*, *munyane*, *umfincane* or

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utshwala-bezinyoni (isiZulu) (Watt and Breyer-Brandwijk, 1962, Hutchings *et al.*, 1996). Wild dagga has a long ethnomedicinal history in southern Africa where it is commonly used to manage bronchitis, coughs, colds, influenza, itchy skin, chest infections, diabetes mellitus, eczema, epilepsy, delayed menstruation, intestinal worms, constipation, scorpion stings, spider and snake bites (Nsuala *et al.*, 2023). Infusions made from the plant seeds, flowers, leaves, and stems are also used as tonics for tuberculosis, high blood pressure, jaundice, muscular cramps, diabetes, diarrhea, viral hepatitis, and dysentery (Nsuala *et al.*, 2015). The water extract from the stem is often used in South African herbal medicine as a blood-purifying agent (Watt and Breyer-Brandwijk, 1962). Its leaves have also been reported to induce mild psychoactive effects similar to those of Cannabis (*Cannabis sativa*) (Kuchta *et al.*, 2013, Wu *et al.*, 2013). The presence of adrenoyl ethanolamine, a cannabinoid-like compound in the plant has also captivated the interest of some researchers worldwide (Hunter *et al.*, 2020a, Hunter *et al.*, 2020b). Owing to their unique interactions with the human endocannabinoid system, cannabinoids are often used as part of the principal active compounds in pharmaceutical drugs used to manage epilepsy, nausea, and weight losses often associated with the human acquired immunodeficiency syndrome (AIDS) (Benbadis *et al.*, 2014, Wong and Wilens, 2017). The presence of cannabinoid-like compounds in *L. Leonotis*could perhaps explains why the plant is commonly used to manage epilepsy in African traditional medicine, as already alluded to above.

Several efforts have been made to scientifically validate the use of the plant in traditional medicine. Crude extracts from the plant, for instance, demonstrated noteworthy antibacterial, antidiabetic, anti-convulsant, anti-inflammatory, antioxidant, anti-HIV and anti-mosquito properties in some scientific studies (Watt and Breyer-Brandwijk, 1962, Oyedeji *et al.*, 2005, Hurinanthan, 2009, Mnonopi *et al.*, 2011, Mnonopi *et al.*, 2012, Hurinanthan, 2013, Tonisi *et al.*, 2020). In addition, the chemical profile and pharmacological properties of essential oils (EOs) from the shrub have been reported (Pedro *et al.*, 1991, Oyedeji *et al.*, 2005).

Essential oils are oil-rich plant extracts that often contain several kinds of redolent phyto-compounds, some of which possess bioactive properties. These odoriferous liquids are an integral part of plant-based natural products that have been studied extensively for novel therapeutic drug discovery and development. Due to their vast chemo diversity, EOs are also used widely in agriculture, aromatherapy, cosmetics, perfumes, and as food preservatives.

Biostimulants are gaining popularity in sustainable agriculture due to their inherent ability to enhance vegetative growth, water use efficiency, mineral content, gas exchange traits, and yield attributes under stressful environmental conditions (Voko, 2020, Aremu *et al.*, 2022, Vambe *et al.*, 2023). Extensive chemical variability exists among biostimulants, primarily due to their diverse natural sources which include plants, animals, and fungi. Plant-based biostimulants, the main focus of the current study, are often obtained from humidified organic matter, composts, vermicomposts, or extracts of different plant parts. Moringa (*Moringa oleifera*) leaf extract is among several biostimulants that have been extensively researched in recent years (Abd El-Mageed *et al.*, 2017, Mashamaite *et al.*, 2022, Arif *et al.*, 2023). The plant belongs to the monogeneric family Moringaceae and is a native of Asia Minor, Arabia, India, and Northern parts of Africa (Anwar *et al.*, 2007). Although *M.oleifera* is well known for its medicinal values, growing empirical evidence suggests that leaf crude extracts from the plant can also significantly enhance water use efficiency, seed germination, fruit shelf life, shoot and root development in several crops including maize (*Zea mays*), sunflower (*Helianthus annuus*) and squash (*Cucurbita pepo* L.) (Batool *et al.*, 2016, Abd El-Mageed *et al.*, 2017, Iqbal *et al.*, 2020).

Leonotis leonurus is a valuable medicinal plant in southern Africa and the integration of biostimulants into technologies used to cultivate the plant may not only enhance the production and pharmacological properties of the shrub but might also promote socio-economic developments in the region. Although several studies demonstrated the plant biostimulating effects of Moringa crude leaf extracts, the potential use of Moringa leaf powder as a biofertilizer/ biostimulant has not yet been evaluated. The present study aimed to evaluate the effects of Moringa leaf powder application on the chemical profile of *L. Leonurus* essential oils.

METHODS AND MATERIALS

Experimental conditions and design

Leonotis leonurus seeds were purchased from the commercial seed supplier, Mountain Herb Estate (Hercules, Gauteng Province, South Africa), while Moringa leaves were supplied by the Agricultural Research Council (Pretoria, South Africa). All greenhouse experiments were conducted at the University of KwaZulu-Natal, Pietermaritzburg (PMB) Campus, South Africa (29°37'S 30°23'E). During the experiment, relative humidity in the greenhouse was maintained between 50-60%, while day and night temperatures averaged 25 and 15 C, respectively. The photosynthetic photon flux density of day hours (measured at mid-day) in the greenhouse was approximately 450 ± 5 µmol m-2 s-1. On the 5th of October, 2021, *L. Leonurus* seeds were sown in nursery trays containing GromorTM potting mix (30 dm3). The trays were watered regularly and the seedlings were raised under the aforementioned greenhouse conditions. After six weeks, the seedlings were

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transplanted into individual pots (1 seedling per pot) containing 1kg of GromorTM potting mix (30 dm3). The study was conducted using a 7 x 10 factorial experiment layout in a completely randomized design with 10 replicates per treatment, giving a total of 70 experimental plots. The 7 levels denominate a control experiment [sample 1, S1) and 6 Moringa leaf powder (MLP) treatments [1.25g (sample 2, S2), 2.5g (sample 3, S3), 5g (sample 4, S4), 7.5g (sample 5, S5) and 10 g (sample 6, S6)]. The transplanted seedlings were watered once a week, and subjected to varying quantities of the MLP once every 2 weeks. Additionally, the seedlings received 100ml of 50% Hoagland's solution, once every 4 weeks. The trial ran for 8 weeks after which aerial shoots of the plant were harvested and essential oils extracted from them (1 kg fresh weight/ sample) by steam distillation.

Gas Chromatography-Mass Spectroscopy (GC-MS) Analysis

The chemical profiles of the oils were determined by GC-MS analysis at the School of Chemical and Physical Sciences, University of KwaZulu-Natal (PMB), using a Shimadzu QP-2010 SE Gas Chromatography coupled with (an Agilent) 5973 Mass Selective detector and driven by Agilent Chemstation software as previously described by Hübschmann (2015). The capillary column (Zebron ZB-5MSplus) used had an internal diameter of 30 m × 0.25 mm and a film thickness of 0.25 µm. The flow rate and linear velocity of the carrier gas (Ultra-pure helium) during the analysis were maintained at 1.0 mL/min and 37 cm/s, respectively. Three microliters of each analyte were injected into the capillary column, with the injector temperature set at 250 °C. The mass spectrometer was operated in the electron ionization mode at 70 eV and the electron multiplier voltage at 1859 V. The compounds were putatively identified by comparing the mass spectrum of the analyte at a particular retention time to that of reference standards found in the 2011 National Institute of Standards and Technology (NIST) library. The area percentage of each compound was determined by comparing the total area obtained and the compound's average peak area.

RESULTS

The oils distilled from the six samples were all yellow. However, slight variations in the oil yield were observed, with S1 having the highest yield (0.483g), followed by S4 (0.462g), S2 (0.36g), S6 (0.264g), S3 (0.236g) and S5 (0.181g). The total number of compounds identified in the samples also differed, with S1 having the highest number of compounds (105, Table 1), followed by S2, S5, S6 (60 compounds each), S4 (37 compounds) and S3 (34 compounds) (Tables 2-6). The most predominant compound in the control (S1) had an area of 9.25 %, while the area of the most dominant compounds in the treatments (S2-S6) ranged from 30 – 40 % (Tables 1-6). Furthermore, the main compound in sample S1 was 1H-Cycloprop[e]azulen-7-ol, while 1, 6-Cyclodecadiene was the major compound in S2, S4, and S6. Beta-copaene was the most dominant compound in S3 and S5. The combined proportion of compounds with an area >1 % in Samples 1-6 were 35.41, 81.45, 66.93, 90.95, 32.09, and 77.7 %, respectively. Caryophyllene (Area range: 3.06-29.5%) and beta.-copaene (Area range: 1.76-33.78%) was among the most popular major compounds in all the samples, followed by humulene, phytol, and 1,6-Cyclodecadiene to 10-fold, 1-methyl-5-methylene-8- which were present as major compounds in at least three of the six evaluated samples. It was quite interesting to note that the concentration of some bioactive compounds was exceptionally higher in treatments compared to the control. For instance, there was a 4 increase in the concentration of caryophyllene in all treatments compared to the control. Similarly, the proportion of humulene was 1.07 % in the control, while it ranged from 5.5 – 9 % in the treatments. The concentration of phytol in S2-S6 ranged from 2.74 – 9.37 %, while in the control it was only 0.27 %. Another classic example was that of 1, 6 - cyclodecadiene, which was not detected in the control but its proportion ranged from 38 - 49 % in three treatments (S2, S4, and S6).

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Table 1: The chemical profile of essential oils from greenhouse grown *Leonotis leonurus* (control).

Chemical Name	Area %	Retention Time	Similarity Index %	Molecular Formulae	Molecular Weight
1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7-t	9.25	13.666	93	$C_{15}H_{24}O$	220
.beta.-copaene	6.86	11.478	78	$C_{15}H_{24}$	204
Caryophyllene oxide	5.15	13.702	82	$C_{15}H_{24}O$	220
12-Oxabicyclo[9.1.0]dodeca-3,7-diene, 1,5,5,8	3.25	13.940	89	$C_{15}H_{24}O$	220
2-Butenal, 2-methyl-4-(2,6,6-trimethyl-1-cyclohexen-	3.23	16.528	78	$C_{14}H_{22}O$	206
Caryophyllene	3.06	11.883	85	$C_{15}H_{24}$	204
Cubedol	2.37	12.920	87	$C_{15}H_{26}O$	222
Bicyclo[4.3.0]nonane, 7-methylene-2,4,4-trime	2.24	14.543	84	$C_{15}H_{24}$	204
alpha.-Cubebene	1.96	10.976	87	C15H26O	222
Kauran-18-al, 17-(acetyloxy)-, (4.beta.)-	1.83	17.7	77	$C_{22}H_{34}O_3$	346
2-Heptanone, 6-(3-acetyl-1-cyclopropen-1-yl)	1.79	16.368	78	$C_{13}H_{20}O_3$	224
Cycloheptasiloxane, tetradecamethyl-	1.77	12.094	87	$C_{14}H_{42}O_7Si_7$	518
ricyclo[20.8.0.0(7,16)]triacontane	1.7	17.040	78	$C_{30}H_{52}O_2$	444
Bicyclo[5.2.0]nonane, 2-methylene-4,8,8-trime	1.60	14.414	73	$C_{15}H_{24}$	204
.alfa.-Copaene	1.65	11.341	93	$C_{15}H_{24}$	204
Cyclononasiloxane	1.56	15.287	80	$C_{18}H_{54}O_9S_{i9}$	666
4,8,13-Cyclotetradecatriene-1,3-diol, 1,5,9-tri	1.57	15.365	81	$C_{20}H_{34}O_2$	2400
Cubedol	1.46	12.695	87	$C_{15}H_{26}O$	222
3-buten-2-one, 4-(5,5-dimethyl-1-oxaspiro[2.5]	1.41	15.617	75	$C_{13}H_{22}O$	1484
Isoaromadendrene epoxide	1.35	1.35	81	$C_{15}H_{24}O$	220
Caryophyllene oxide	1.32	13.296	82	$C_{15}H_{24}O$	220
Cyclooctasiloxane, hexadecamethyl-	1.29	13.751	82	$C_{16}H_{48}O_8Si_8$	592
But-3-enal, 2-methyl-4-(2,6,6-trimethyl-1-cycl	1.27	17.581	78	$C_{14}H_{22}O$	206
Andrographolide	1.25	15.657	76	$C_{20}H_{30}O_5$	350
1H-Benzocyclohepten-7-ol, 2,3,4,4a,5,6,7,8-octahydro	1.21	14.357	76	$C_{15}H_{26}O$	222

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Table 1: Continued [the chemical profile of essential oils from greenhouse - grown *Leonotis leonurus* (control)].

1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7	1.20	15.413	93	$C_{15}H_{24}O$	220
Benzene, 1-methyl-3-(1-methylethyl)-	1.18	6.882	95	$C_{10}H_{14}$	134
4,8,13-Cyclotetradecatriene-1,3-diol	1.17	16.096	80	$C_{20}H_{34}O_2$	306
Cycloheptane, 4-methylene-1-methyl-2-(2-met	1.1	14.833	80	$C_{15}H_{24}$	204
Alloaromadendrene oxide-(1)	1.08	15.929	71	$C_{15}H_{24}O$	220
Humulene	1.07	12.265	95	$C_{15}H_{24}$	204
Cyclobutane, 1,2-bis(1-methylethenyl)-, trans-	1.02	6.940	93	$C_{10}H_{16}$	136
3-Acetonylcyclohexanone	1.00	16.030	71	$C_9H_{14}O_2$	154
4,14-Dimethyl-11-isopropyltricyclo[7.5.0.0(10	0.98	17.858	78	$C_{19}H_{30}O$	274
(2,2,6-Trimethyl-bicyclo[4.1.0]hept-1-yl)-meth	0.98	16.277	75	$C_{16}H_{26}O_2$	250
4,6,10,10-Tetramethyl-5-oxatricyclo[4.4.0.0(1	0.97	18.219	76	$C_{13}H_{20}O_2$	208
Succinic acid, di(tridec-2-ynyl) ester	0.80	15.078	79	$C_{30}H_{50}O_4$	474
Naphthalene, 1,2,3,4,4a,5,8,8a-octahydro-4a-m	0.89	14.636	90	$C_{15}H_{24}$	204
(1As-(1a.alpha.,4b.beta.,8as)-4a,8,8-trimethylo	0.83	15.720	76	$C_{14}H_{22}O$	206
1,1,4a-Trimethyl-5,6-dimethylenedecahydronap	0.82	14.054	81	$C_{15}H_{24}$	204
Octasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13,1	0.81	17.316	79	$C_{16}H_{50}O_7Si_8$	578
.beta.-copaene	0.78	12.527	85	$C_{15}H_{24}$	204
Bicyclo[5.2.0]nonane, 4-methylene-2,8,8-trime	0.73	14.138	78	$C_{15}H_{24}$	204
2-Oxetanone, 4-(2,6,8-trimethyl-1,5-nonadieny	0.72	15.828	68	$C_{15}H_{24}O_2$	236
9-Isopropyl-1-methyl-2-methylene-5-oxatricyc	0.69	15.557	61	$C_{15}H_{24}O$	220
4,8,13-Cyclotetradecatriene-1,3-diol, 1,5,9-tri	0.69	17.975	84	$C_{20}H_{34}O_2$	306
Andrographolide	0.67	15.245	76	$C_{20}H_{30}O_5$	350
Bicyclo [5.2.0] nonane, 4-methylene-2,8,8-trime	0.67	14.950	78	$C_{15}H_{24}$	204
1H-Cyclopenta[1,3]cyclopropa[1,2]benzene, oc	0.65	11.963	94	$C_{15}H_{24}$	204
2-Cyclohexene-1-methanol, 2,6,6-trimethyl-	0.63	16.715	82	$C_{10}H_{16}O$	152
Cyclohexasiloxane, dodecamethyl-	0.62	10.217	80	$C_{12}H_{36}O_6Si_6$	444
1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7-	0.58	15.121	93	$C_{15}H_{24}O$	220

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Table 1: Continued [the chemical profile of essential oils from greenhouse-grown *Leonotis leonurus* (control)].

Eucalyptol	0.58	6.982	96	$C_{10}H_{18}O$	154
1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7-	0.58	12.33	93	$C_{15}H_{24}O$	220
1-Heptatriacotanol	0.57	18.381	79	$C_{37}H_{76}O$	536
1-(2-Ethyl-1,3-dimethyl-cyclopent-2-enyl)-etha	0.57	14.764	78	$C_{11}H_{18}O$	166
Aromadendrene oxide-(2)	0.54	18.902	80	$C_{15}H_{24}O$	220
Bicyclo[5.2.0]nonane, 4-methylene-2,8,8-trime	0.48	13.470	86	$C_{15}H_{24}$	204
Andrographolide	0.46	16.610	79	$C_{20}H_{30}O_5$	350
eranyl-.alpha.-terpinene	0.46	13.230	78	$C_{20}H_{32}$	272
2-Butanone, 4-(2,6,6-trimethyl-2-cyclohexen-1	0.44	12.352	61	$C_{13}H_{20}O$	192
.beta.-Guaiene	0.44	12.427	87	$C_{15}H_{24}$	204
alfa.-Copaene	0.43	14.196	81	$C_{15}H_{24}$	204
7-Tetracyclo[6.2.1.0(3.8)0(3.9)]undecanol, 4,4	0.43	14.720	69	$C_{15}H_{24}O$	220
1H-Indene, 1-ethylideneoctahydro-7a-methyl	0.43	15.176	78	$C_{12}H_{20}$	164
Cyclohexanecarboxamide	0.43	15.769	64	$C_{12}H_{17}NO_2$	207
4,8,13-Cyclotetradecatriene-1,3-diol, 1,5,9-tri	0.42	19.605	81	$C_{20}H_{34}O_2$	306
(1R)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene	0.42	5.601	95	$C_{10}H_{16}$	136
Aromadendrene oxide-(1)	0.37	16.889	80	$C_{15}H_{24}O$	220
7R,8R-8-Hydroxy-4-isopropylidene-7-methylb	0.36	14.289	76	$C_{15}H_{24}O$	220
Andrographolide	0.34	15.010	76	$C_{20}H_{30}O_5$	350
Cyclopropanecarboxylic acid, 2,2-dimethyl-3-(	0.34	14.240	67	$C_{21}H_{28}O_3$	328
1-Cycloheptene, 1,4-dimethyl-3-(2-methyl-1-pr	0.34	14.887	70	$C_{15}H_{24}$	204
.gamma.-Muurolene	0.34	12.849	88	$C_{15}H_{24}$	204
Cyclopropanecarboxylic acid, 2,2-dimethyl-3-(	0.34	17.379	71	$C_{21}H_{28}O_3$	328
9-(3,3-Dimethyloxiran-2-yl)-2,7-dimethylnona	0.31	18.105	70	$C_{15}H_{26}O_2$	238
Cyclooctasiloxane, hexadecamethyl-	0.31	20.417	80	$C_{16}H_{48}O_8Si_8$	592
2,2,6-Trimethyl-1-(2-methyl-cyclobut-2-enyl)	0.3	18.469	77	$C_{15}H_{22}O$	218
Murolan-3,9(11)-diene-10-peroxy	0.27	13.057	77	$C_{15}H_{22}O$	218
Phytol	0.27	22.051	97	$C_{20}H_{40}O$	296

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Table 1: Continue [the chemical profile of essential oils from greenhouse-grown *Leonotis leonurus* (control)].

Benz[e]azulene-3,8-dione, 3a,4,6a 7,9,10,10a	0.26	16.204	57	$C_{20}H_{28}O_6$	364
Andrographolide	0.24	13.352	79	$C_{20}H_{30}O_5$	350
Diazoprogesterone	0.24	15.51	66	$C_{21}H_{30}N_4$	338
Dihydro-.alpha.-methylionone	0.24	16.573	66	$C_{21}H_{30}N_4$	338
Andrographolide	0.24	15.508	79	$C_{20}H_{30}O_5$	350
.alpha.-Cadinol	0.25	14.222	71	$C_{15}H_{26}O$	222
Ethanone, 1-(1-methyl-2-cyclopenten-1-yl)-	0.23	4.902	82	$C_8H_{12}O$	124
Cyclohexene 3-(tert-butyl)peroxide	0.20	13.380	80	$C_{10}H_{18}O_2$	170
Ethanone, 1-(1-methyl-2-cyclopenten-1-yl)-	0.21	14.091	82	$C_8H_{12}O$	124
Tricyclo[4.4.0.0(2,7)]dec-3-ene-3-methanol, 1	0.21	18.044	75	C15H24O	220
Humulene	0.21	13.800	95	$C_{15}H_{24}$	204
2-Butanol, 4-(2,2-dimethyl-6-methylenecycloh	0.21	16.827	66	$C_{13}H_{22}O$	194
.beta.-copaene	0.16	12.527	87	$C_{15}H_{24}$	204
Bicyclo[6.1.0]nonane, 9-(1-methylethylidene)-	0.16	13.142	79	C12H20	164
Camphor	0.15	8.565	95	$C_{10}H_{16}O$	152
Alloaromadendrene	0.13	12.306	84	$C_{15}H_{24}$	204
Cyclopentasiloxane, decamethyl-	0.13	8.134	66	$C_{10}H_{30}O_5Si_5$	370
Diethylmethyl(2-(3-methyl-2-phenylvaleryloxy)	0.13	17.100	60	$C_{19}H_{32}BrNO_2$	385
Bicyclo[6.3.0]undec-1(8)-en-3-one, 2,2,5,5-tetr	0.12	13.420	71	$C_{15}H_{24}O$	220
(-)-.beta.-Bourbonene	0.11	11.589	66	$C_{15}H_{24}$	204
Aromandendrene	0.09	11.678	84	$C_{15}H_{24}$	204
2H-1-Benzopyran, 3,4,4a,5,6,8a-hexahydro-2,5	0.08	10.317	82	$C_{13}H_{22}O$	194
Cyclopentanecarboxylic acid,	0.07	16.215	68	$C_{14}H_{24}O_2$	224
3-Tetradecene, (Z)-	0.07	9.156	68	$C_{14}H_{24}O_2$	224
Bicyclo[5.2.0]nonane, 2-methylene-4,8,8-trime	0.24	13.5	79	$C_{15}H_{24}$	204

Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol. 5 No. 6 (2024): June 2024 Issue
https://doi.org/10.51168/sjhrafrica.v5i6.1215
Original Article

Table 2: The chemical composition of essential oils from greenhouse - grown *Leonotis leonurus* seedlings treated with 1.25g of *Moringa oleifera*leaf powder biweekly for eight weeks

Chemical Name	Area %	Retention Time	Similarity %	Molecular Formulae	Molecular Weight
1,6-Cyclodecadiene, 1-methyl-5-methylene-8-	37.88	12.59	89	$C_{15}H_{24}$	204
Caryophyllene	27.07	11.910	97	$C_{15}H_{24}$	204
Humulene	8.38	12.284	95	$C_{15}H_{24}$	204
. gamma. -Elemene	4.94	12.703	92	$C_{15}H_{24}$	204
Phytol	3.18	22.095	97	$C_{20}H_{40}O$	296
.beta.-copaene	1.76	11.457	91	$C_{15}H_{24}$	204
Cycloheptasiloxane, tetradecamethyl-	1.35	12.095	87	$C_{14}H_{42}O_7Si_7$	518
. alpha. -Cubebene	1.29	10.974	87	$C_{15}H_{24}$	204
1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)-	1.26	13.266	94	$C_{15}H_{26}O$	222
Cyclooctasiloxane	1.26	13.749	77	$C_{16}H_{48}O_8Si_8$	592
Naphthalene, 1,2,3,4,4a,7-hexahydro-1,6-dimethyl	0.85	13.057	90	$C_{15}H_{24}$	204
. alfa. -Copaene	0.77	11.338	93	$C_{15}H_{24}$	204
Naphthalene, 1,2,3,5,6,8a-hexahydro-4,7-dimet	0.76	12.880	88	$C_{15}H_{24}$	204
Caryophyllene oxide	0.69	13.633	94	$C_{15}H_{24}$	220
Cyclononasiloxane, octadecamethyl-	0.66	15.288	79	$C_{18}H_{54}O_9Si_9$	666
4-(2,2,6-Trimethyl-bicyclo [4.1.0] hept-1-yl)-but	0.65	29.729	80	$C_{14}H_{24}O$	208
1,3,6,10-Dodecatetraene, 3,7,11-trimethyl-, (Z, E	0.51	12.640	92	$C_{15}H_{24}$	204
1-Hydroxy-1,7-dimethyl-4-isopropyl-2,7-cyclo	0.49	13.556	91	$C_{15}H_{26}O$	222
2H-3,9a-Methano-1-benzoxepin, octahydro-2,2,5a	0.46	12.905	81	$C_{15}H_{26}O$	222

Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol. 5 No. 6 (2024): June 2024 Issue
https://doi.org/10.51168/sjhrafrica.v5i6.1215
Original Article

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1H-Cycloprop[e]azulene, 1a,2,3,4,4a,5,6,7b-oc	0.38	12.149	88	$C_{15}H_{24}$	204
1,2,5,5,8a-Pentamethyl-1,2,3,5,6,7,8,8a-octahy	0.36	27.008	85	$C_{15}H_{26}O$	222
Octasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13,1	0.29	17.330	74	$C_{16}H_{50}O_7Si_8$	578
Cyclohexasiloxane, dodecamethyl-	0.27	10.228	78	$C_{12}H_{36}O_6Si_6$	444
. alfa.-Copaene	0.27	12.460	93	$C_{15}H_{24}$	204
1-Naphthalenol, 1,2,3,4,4a,7,8,8a-octahydro-1	0.23	14.197	88	$C_{15}H_{26}O$	222
12-Oxabicyclo [9.1.0] dodeca-3,7-diene, 1,5,5,8-	0.18	13.913	88	$C_{15}H_{24}O$	220
. beta. -copaene	0.15	12.406	91	$C_{15}H_{24}$	204
1,1,6-trimethyl-3-methylene-2-(3,6,9,13-tetram	0.14	25.260	77	$C_{33}H_{56}$	452
Alloaromadendrene	0.13	12.218	86	$C_{15}H_{24}$	204
trans-calamenene	0.13	12.942	89	$C_{15}H_{22}$	202
. alpha. -Cadinol	0.13	14.338	90	$C_{15}H_{26}O$	222
1-Naphthalenepropanol, alpha. -ethenyldecahy	0.12	18.760	81	$C_{20}H_{34}O$	290
1,1,6-trimethyl-3-methylene-2-(3,6,9,13-tetram	0.11	24.361	77	$C_{33}H_{56}$	452
7R,8R-8-Hydroxy-4-isopropylidene-7-methylbi	0.10	14.402	59	$C_{15}H_{24}O$	220
Cyclononasiloxane, octadecamethyl-	0.10	25.421	79	$C_{18}H_{54}O_9Si_9$	666
1.57 Cyclohexane, 1-ethenyl-1-methyl-2-(1-methylethenyl	0.04	10.800	92	$C_{15}H_{24}O$	204

Student's Journal of Health Research Africa
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https://doi.org/10.51168/sjhrafrica.v5i6.1215
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Table 2: Continued (the chemical composition of essential oils from greenhouse - grown *Leonotis leonurus* seedlings treated with 1.25g of *Moringa oleifera* leaf powder biweekly for eight weeks).

Cyclooctasiloxane, hexadecamethyl-	0.21	20.457	86	$C_{16}H_{48}O_8Si_8$	592
1H-Cyclopenta[1,3]cyclopropa[1,2]benzene,	0.2	11.970	94	$C_{15}H_{24}$	204
cis-1,2-Cyclododecanediol	0.2	14.776	85	$C_{12}H_{24}O_2$	200
6,11-Undecadiene, 1-acetoxy-3,7-dimethyl-	0.2	23.990	81	$C_{16}H_{28}O_2$	252
2,7:3,6-Dimethano-2H-1-benzopyran, octahydr	0.16	25.130	54	$C_{11}H_{16}O$	164
Octadec-9-enoic acid	0.12	23.259	82	$C_{18}H_{34}O_2$	282
4-(2-Amino-6-methoxy-9H-purin-9-yl)cyclopen	0.12	25.151	52	$C_{11}H_{13}N_5O_2$	247
2-Pentadecanone, 6,10,14-trimethyl-	0.09	16.265	93	C18H36O	268
Isoaromadendrene epoxide	0.09	13.865	81	$C_{15}H_{24}O$	220
Octasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13,1	0.09	17.330	80	$C_{16}H_{50}O_7Si_8$	578
Toluene-4-sulfonic acid, 2,7-dioxatricyclo[4.3.1	0.09	25.190	57	$C_{15}H_{18}O_5S$	310
Aromadendrene oxide-(2)	0.08	14.656	79	C15H24O	220
(E,E)-7,11,15-Trimethyl-3-methylene-hexadeca	0.07	17.499	79	C20H32	272
n-Hexadecanoic acid	0.07	18.385	81	$C_{16}H_{32}O_2$	256
Corymbolone	0.06	14.510	71	$C_{15}H_{24}O_2$	236
3.alpha.,4.alpha.,9.beta.,11-Diepoxymuurolan	0.06	25.238	47	$C_{15}H_{24}O_3$	252
Naphthalene, decahydro-1,6-bis(methylene)-4-(	0.04	12.218	77	$C_{12}H_{22}O$	182
Adamantane-2-carbonitrile, 4-(4-nitrophenylsul	0.04	14.724	59	$C_{17}H_{18}N_2O_5S$	362
.beta.-copaene	0.06	12.760	91	$C_{15}H_{24}$	204
Octadecane	0.06	14.569	77	$C_{18}H_{37}Cl$	288
Cubenol	0.05	14.053	78	$C_{15}H_{26}O$	222
Spiro[5.5]undec-8-en-1-one	0.03	25.045	52	$C_{11}H_{16}O$	164
Cinnamic acid	0.02	14.696	53	$C_{31}H_{40}O_{15}$	652
5-Isopropenyl-1,2-dimethylcyclohex-2-enol	0.02	25.250	40	$C_{11}H_{18}O$	166

Student's Journal of Health Research Africa
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Vol. 5 No. 6 (2024): June 2024 Issue
https://doi.org/10.51168/sjhrafrica.v5i6.1215
Original Article

Table 3: The chemical composition of essential oils from greenhouse - grown *Leonotis leonurus* seedlings treated with 2.5 g of *Moringa oleifera* leaf powder biweekly for eight weeks.

Chemical Name	Area %	Retention Time	Similarity %	Molecular Formulae	Molecular Weight
.beta.-copaene	33.78	12.528	89	$C_{15}H_{24}$	204
Caryophyllene	11.860	15.93	97	$C_{15}H_{24}$	204
Phytol	7.07	22.045	97	$C_{20}H_{40}O$	296
Chloroacetic acid, dodecyl ester	2.43	23.217	68	$C_{14}H_{27}ClO_2$	262
Humulene	6.31	12.258	95	$C_{15}H_{24}$	204
Cyclohexane, 1-ethenyl-1-methyl-2-(1-methyle	4.85	12.674	92	$C_{15}H_{24}$	204
1-Heptatriacotanol	1,67	25.110	55	$C_{37}H_{76}O$	536
1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)-	1.66	13.261	92	C15H26O	222
2-Cyclohexene-1-carboxaldehyde, 2,6,6-trimeth	1.59	22.625	54	$C_{10}H_{16}O$	152
4(1H)-Isobenzofuranone, hexahydro-3a,7a-dim	1.36	23.245	52	$C_{10}H_{16}O_2$	168
Tetracontane-1,40-diol	1.17	29.640	51	$C_{40}H_{82}O_2$	594
Azulene, 1,2,3,5,6,7,8,8a-octahydro-1,4-dimeth	1.09	25.199	55	$C_{15}H_{24}$	204
.beta.-copaene	1.02	11.447	89	$C_{15}H_{24}$	204
(5R,8R,8aS)-5,8-Dipropyl-1,2,3,5,8,8a-hexahy	1.01	25.055	54	$C_{14}H_{25}N$	207
2-Propanehydroperoxide, 1-bromo-2-cyclopropyl-	0.98	0.50	56	$C_6H_{11}BrO_2$	194
cubedol	0.92	12.897	76	$C_{15}H_{26}O$	222
Naphthalene, 1,2,3,5,6,8a-hexahydro-4,7-dimet	0.91	12.867	88	C15H_{24}	204
Piperazine, 1-(1-methyl-4-piperidyl)-	0,87	23.430	53	$C_{10}H_{21}N_3$	183
Caryophyllene oxide	0.84	13.624	53	$C_{15}H_{24}O$	220
.alfa.-Copaene	0.83	11.33	92	$C_{15}H_{24}$	204
Tetracosa-2,6,14,18,22-pentaene-10,11-diol, 2,	0.81	25.235	51	$C_{30}H_{52}O_2$	444
1H-Benzocyclohepten-7-ol, 2,3,4,4a,5,6,7,8-oc	0.81	29.669	53	$C_{15}H_{26}O$	222
Fumaric acid, propyl tetradec-3-enyl ester	0.69	25.270	53	$C_{19}H_{30}O_4$	322
2(1H)-Naphthalenone, octahydro-4a-methyl-7-(1	0.63	25.170	56	$C_{14}H_{24}O$	208

Student's Journal of Health Research Africa
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Vol. 5 No. 6 (2024): June 2024 Issue
https://doi.org/10.51168/sjhrafrica.v5i6.1215
Original Article

Table 3: Continued (the chemical composition of essential oils from greenhouse - grown *Leonotis leonurus* seedlings treated with 2.5 g of *Moringa oleifera* leaf powder biweekly for eight weeks).

1,3,6,10-Dodecatetraene, 3,7,11-trimethyl-, (Z,	0.62	12.636	81	$C_{15}H_{24}$	204
6-Hydroxy-7-methyl-9-oxabicyclo[3.3.1]nonan	0.60	19.655	56	$C_9H_{14}O_3$	170
Butyl 4-ethyloctanoate	0.52	18.361	52	$C_{14}H_{28}O_2$	228
Adipic acid, .beta.-citronellyl decyl ester	0.33	22.545	50	$C_{26}H_{48}O_4$	424
Allylphenyl sulfide	0.38	26.955	49	$C_9H_{10}S$	150
Methanol, [6,8,9-trimethyl-4-(2-furyl)-3-oxabic	0.72	22.590	47	$C_{16}H_{22}O_3$	262
[1,1'-Bicyclohexyl]-3-ol	0.46	22.600	46	$C_{12}H_{22}O$	182
6,11-Undecadiene, 1-acetoxy-3,7-dimethyl-	1,78	23.943	77	$C_{16}H_{28}O_2$	252
Succinic acid	0,64	25.144	50	$C_{16}H_{28}O_4$	284
l-Gala-l-ido-octose	0.19	25.385	39	$C_8H_{16}O_8$	240

Student's Journal of Health Research Africa
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https://doi.org/10.51168/sjhrafrica.v5i6.1215
Original Article

Table 4: The chemical profile of essential oils from greenhouse - grown *Leonotis leonurus* seedlings treated with 5g of *Moringa oleifera* leaf powder biweekly for eight weeks.

Chemical Name	Area %	Retention Time	Similarity %	Molecular Formulae	Molecular Weight
1,6-Cyclodecadiene, 1-methyl-5-methylene-8-(	36.25	12.640	88	$C_{15}H_{24}$	204
Caryophyllene	29.5	11.948	96	$C_{15}H_{24}$	204
1,6-Cyclodecadiene, 1-methyl-5-methylene-8-	12.64	36.25	90	$C_{15}H_{24}$	204
cis-.alpha.-Bisabolene	10.27	12.308	89	$C_{15}H_{24}$	204
gamma.-Elemene	5.39	12.738	92	$C_{15}H_{24}$	204
Phytol	2.74	22.109	97	$C_{20}H_{40}O$	296
.beta.-copaene	2.73	11.460	92	$C_{15}H_{24}$	204
.alpha.-Cubebene	1.74	10.974	87	$C_{15}H_{24}$	204
Naphthalene, 1,2,3,4,4a,7-hexahydro-1,6-dimet	1.14	13.061	88	$C_{15}H_{24}$	204
.alfa.-Copaene	1.05	11.337	81	$C_{15}H_{24}$	204
1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)-	0.94	13.262	93	$C_{15}H_{26}O$	222
Caryophyllene oxide	0.8	13.634	93	$C_{15}H_{24}O$	220
Naphthalene, 1,2,3,5,6,8a-hexahydro-4,7-dimet	0.79	12.886	87	$C_{15}H_{24}$	204
1-Hydroxy-1,7-dimethyl-4-isopropyl-2,7-cyclod	0.77	13.585	90	$C_{15}H_{26}O$	222
1H-Cycloprop[e]azulene, 1a,2,3,4,4a,5,6,7b-oc	0.66	12.161	91	$C_{15}H_{24}$	204
1-Hydroxy-1,7-dimethyl-4-isopropyl-2,7-cyclod	0.65	13.556	90	$C_{15}H_{26}O$	222
2H-3,9a-Methano-1-benzoxepin, octahydro-2,2	0.60	12.908	79	$C_{15}H_{26}O$	222
6,11-Undecadiene, 1-acetoxy-3,7-dimethyl-	0.41	23.971	79	$C_{16}H_{28}O_2$	252
5-(1-Isopropenyl-4,5-dimethylbicyclo[4.3.0]nona	0.34	25.11	82	$C_{22}H_{36}O_2$	332
1,2,5,5,8a-Pentamethyl-1,2,3,5,6,7,8,8a-octahy	0.31	26.981	84	$C_{15}H_{26}O$	222
Pentadecanal-	0.29	14.765	90	$C_{15}H_{30}O$	226

Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol. 5 No. 6 (2024): June 2024 Issue
https://doi.org/10.51168/sjhrafrica.v5i6.1215
Original Article

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6,11-Undecadiene, 1-acetoxy-3,7-dimethyl	0.27	29.671	79	$C_{16}H_{28}O_2$	252
12-Oxabicyclo[9.1.0]dodeca-3,7-diene, 1,5,5,8	0.23	13.910	89	$C_{15}H_{24}O$	220
1H-Cycloprop[e]azulene, decahydro-1,1,7-trim	0.23	14.187	85	$C_{15}H_{24}$	204
1H-Cyclopenta[1,3]cyclopropa[1,2]benzene, oc	0.21	11.986	91	$C_{15}H_{24}$	204
trans-calamenene	0.20	12.945	91	$C_{15}H_{22}$	202
6,11-Eicosadienoic acid, methyl ester	0.20	29.685	59	$C_{21}H_{38}O_2$	322
1H-3a,7-Methanoazulene, octahydro-3,6,8,8-te	0.20	14.515	83	$C_{15}H_{26}$	206
.beta.-copaene	0.19	12.412	92	$C_{15}H_{24}$	204
Naphthalene, decahydro-1,1,4a-trimethyl-6-me	0.16	18.738	84	$C_{20}H_{32}$	272
9,12,15-Octadecatrien-1-ol, (Z,Z,Z)-	0.13	17.094	93	$C_{18}H_{32}O$	264
.alpha.-Cadinol	0.11	14.329	91	$C_{15}H_{26}O$	222
Andrographolide	0.11	14.645	82	$C_{20}H_{30}O_5$	350
2-Pentadecanone, 6,10,14-trimethyl-	0.11	16.254	94	$C_{18}H_{36}O$	268
Globulol	0.10	13.861	91	$C_{15}H_{26}O$	222
1-Naphthalenol, decahydro-1,4a-dimethyl-7-(1-	0.10	14.396	80	$C_{15}H_{26}O$	222
.beta.-ylangene	0.09	12.782	86	$C_{15}H_{24}$	204

Student's Journal of Health Research Africa
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https://doi.org/10.51168/sjhrafrica.v5i6.1215
Original Article

Table 5: The chemical composition of essential oils from greenhouse - grown *Leonotis leonurus* seedlings treated with 7.25g of *Moringa oleifera* leaf powder biweekly for eight weeks.

Chemical Name	Area %	Retention Time	Similarity Index (%)	Molecular Formulae	Molecular Weight
beta. -copaene	30.53	12.54	92	$C_{15}H_{24}$	204
Caryophyllene	27.67	11.87	97	$C_{15}H_{24}$	204
Humulene	9.02	12.26	95	$C_{15}H_{24}$	204
gamma. -Elemene	4.61	12.68	92	$C_{15}H_{24}$	204
Phytol	3.33	22.05	96	$C_{20}H_{40}O$	296
2,5,5,8a-Tetramethyl-6,7,8,8a-tetrahydro-5H-chr	2.54	25.19	58	$C_{13}H_{20}O_2$	208
17.alfa.,21. beta. -28,30-Bisnorhopane	1.79	25.12	60	$C_{28}H_{48}$	384
beta. -copaene	1.56	11.45	86	$C_{15}H_{24}$	204
Butanoic acid	1.18	22.5	54	$C_{15}H_{26}O_2$	238
2,5-Methanopyrano[3,2-b] pyrrole, hexahydro-1-methyl	1.35	22.66	51	$C_9H_{15}NO$	153
1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)-	0.86	13.26	92	$C_{15}H_{26}O$	222
. alpha.-Cubebene	0.83	10.965	95	$C_{15}H_{24}$	204
Naphthalene, 1,2,3,4,4a,7-hexahydro-1,6-dimeth	0.79	13.05	91	$C_{15}H_{24}$	204
Naphthalene, 1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1- (	0.72	12.87	91	$C_{15}H_{24}$	204
Caryophyllene oxide	0.63	13.62	95	$C_{15}H_{24}O$	220
1,2,5,5,8a-Pentamethyl-1,2,3,5,6,7,8,8a-octahyd	0.62	26.967	82	$C_{15}H_{26}O$	222
2,7-Octadiene-1,6-diol, 2,6-dimethyl-	0.6	22.311	47	$C_{10}H_{18}O_2$	170
4-(2,2,6-Trimethyl-bicyclo [4.1.0] hept-1-yl)-but	0.6	23.961	80	$C_{14}H_{24}O$	208

Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol. 5 No. 6 (2024): June 2024 Issue
https://doi.org/10.51168/sjhrafrica.v5i6.1215
Original Article

Table 5: Continued (the chemical composition of essential oils from greenhouse - grown *Leonotis leonurus* seedlings treated with 7.25g of *Moringa oleifera* leaf powder biweekly for eight weeks).

Pentadecanal-	0.56		14.772	94	C15H30O	226
.alfa.-Copaene	0.53		11.55	94	$C_{15}H_{24}$	204
Cyclohexene, 1-formyl-2-phenylsulfinylmethyl	0.53		29.677	61	$C_{16}H_{20}O_2S$	276
1,3,6,10-Dodecatetraene, 3,7,11-trimethyl-, (Z,E)-	0.51		12.637	89	$C_{15}H_{24}$	204
Bicyclo[4.3.0]nonan-7-one, 1-(2-methoxyvinyl	0.51		25.160	54	$C_{12}H_{18}O_2$	194
Cubedol	0.49		12.896	78	$C_{15}H_{26}O$	222
1-Hydroxy-1,7-dimethyl-4-isopropyl-2,7-cyclodeca	0.48		13.547	84	$C_{15}H_{26}O$	222
Octadecane, 1-chloro-	0.48		12.42	77	$C_{18}H_{37}Cl$	288
Cyclopropane, 1-(5-hexenyl)-2-iodo-	0.47		22.582	56	$C_9H_{15}I$	250
Oxirane, 2,2-dimethyl-3-(3,7,12,16,20-pentamethyl	0.42		19.661	61	$C_{30}H_{50}O$	426
Cyclohexene, 1-formyl-2-phenylsulfinylmethyl	0.41		29.650	61	$C_{16}H_{20}O_2S$	276
Methyl 5,9-tetracosadienoate	0.40		22.555	58	$C_{25}H_{46}O_2$	378
2,6,10-Cycloundecatrien-1-one, 2,6,9,9-tetramethyl-,	0.38		22.620	48	$C_{15}H_{22}O$	218
cis,cis,cis-7,10,13-Hexadecatrienal	0.24		17.11	86	$C_{16}H_{26}O$	234
1H-Cycloprop[e]azulene, 1a,2,3,4,4a,5,6,7b-octahydro	0.23		12.13	86	$C_{15}H_{24}$	204
8a(2H)-Phenanthrenol, 7-ethenyldodecahydro-1,1,4a	0.22		18.743	78	$C_{22}H_{36}O_2$	332
2-Isopropenyl-4,4,7a-trimethyl-2,4,5,6,7,7a-hexa	0.21		19.790	54	$C_{14}H_{22}O_2$	222
2-Cyclohexyl-4-methylene-octahydro-benzo[e][1,	0.21		20.385	49	$C_{16}H_{24}N_2O$	260
(-)-Isolongifolol, trimethylsilyl ether	0.21		20.441	46	$C_{18}H_{34}OSi$	294
E-10,13,13-Trimethyl-11-tetradecen-1-ol acetat	0.21		22.420	56	$C_{19}H_{36}O_2$	296
2-methylhexacosane	0.17		14.54	83	$C_{27}H_{56}$	380
Sulfurous acid, octadecyl 2-propyl ester	0.17		22.180	63	$C_{21}H_{44}O_3S$	376
Naphthalene, 1,2,3,4-tetrahydro-1,6-dimethyl-4-(	0.17		12.94	85	$C_{15}H_{22}$	202
1,4-Methanoazulen-3-ol, decahydro-1,5,5,8a-tetramethyl-	0.16		20.460	44	$C_{15}H_{26}O$	222
Cyclobuta[1,2-d:4,3-d']dipyrimidine-2,4,5,7(3H,6	0.16		22.385	56	$C_{14}H_{20}N_4O$	308

Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol. 5 No. 6 (2024): June 2024 Issue
https://doi.org/10.51168/sjhrafrica.v5i6.1215
Original Article

Table 5: Continued (the chemical composition of essential oils from greenhouse-grown *Leonotis leonurus* seedlings treated with 7.25g of *Moringa oleifera* leaf powder biweekly for eight weeks).

i-Propyl 5,9-hexacosadienoate	0.16	22.805	51	$C_{29}H_{54}O_2$	434
(1R)-(+)-Camphanic acid	0.15	22.354	49	$C_{10}H_{14}O_4$	198
1,1,3,6-tetramethyl-2-(3,6,10,13,14-pentamethy	0.15	27.689	54	$C_{32}H_{64}$	448
Ppropiolic acid, 3-(1-hydroxy-2-isopropyl-5-m	0.14	27.610	50	$C_{13}H_{20}O_3$	224
alpha. -Cadinol	013	14.198	56	$C_{15}H_{26}O$	222
12-Oxabicyclo [9.1.0] dodeca-3,7-diene, 1,5,5,8	0.13	13.908	85	$C_{15}H_{24}O$	220
Acetic acid, 7-oxa-2-thiatricyclo [4.3.1.0(3,8)]	0.13	27.655	43	$C_{10}H_{14}O_3S$	214
9-Eicosyne	0.12	19.590	43	$C_{10}H_{14}O_3S$	214
1-Heptatriacotanol	0.12	19.710	55	$C_{37}H_{76}O$	536
1-Pyrazineacetic acid, hexahydro-4-(2-pyrimidinyl)-,	0.11	22.835	41	$C_{11}H_{16}N_4O_2$	236
Cubenol	0.09	14.19	55	$C_{15}H_{26}O$	222
7,7-Dimethyl-2,3-dioxobicyclo [2.2.1] heptane-1-	0.09	19.741	51	$C_{11}H_{14}O_4$	210
1H-Cyclopenta [1,3] cyclopropa[1,2]benzene, oc	0.08	11.959	89	$C_{15}H_{24}$	204
Longifolenaldehyde	0.03	19.820	53	$C_{15}H_{24}O$	220
2-Cyclohexen-1-one, 3-(3-hydroxybutyl)-2,4,4-trimethyl	0.06	22.330	49	$C_{13}H_{22}O_2$	210
2(1H)-Naphthalenone, octahydro-1,1,4a-trimethyl	0.06	22.365	56	$C_{13}H_{22}O$	194
Methoxyacetic acid, 4-tridecyl ester	0.07	22.200	57	$C_{16}H_{32}O_3$	272

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https://doi.org/10.51168/sjhrafrica.v5i6.1215
Original Article

Table 6: The chemical composition of essential oils from greenhouse - grown *Leonotis leonurus* seedlings treated with 10g of *Moringa oleifera* leaf powder biweekly for eight weeks.

Chemical Name	Area %	Retention Time	Similarity %	Molecular Formulae	Molecular Weight
1,6-Cyclodecadiene	40.44	12.57	88	$C_{15}H_{24}$	204
Caryophyllene	15.13	11.88	97	$C_{15}H_{24}$	204
Phytol	9.37	22.09	97	$C_{20}H_{40}O$	296
Gamma. -Muurolene	6.77	12.69	88	$C_{15}H_{24}$	204
Humulene	5.45	12.27	95	$C_{15}H_{24}$	204
Beta. -copaene	1.96	11.451	84	$C_{15}H_{24}$	204
1-Hydroxy-1,7-dimethyl-4-isopropyl-2,7-cyclodecadiene	1.89	13.56	84	$C_{15}H_{26}O$	222
Naphthalene	1.55	12.05	79	$C_{20}H_{32}$	272
1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-,	1.18	13.26	87	$C_{15}H_{26}O$	222
Naphthalene, 1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1	1.14	12.87	90	$C_{15}H_{24}$	204
alpha. -Cubebene	1.03	10.97	89	$C_{15}H_{24}$	204
Cubedol	0.88	12.9	82	$C_{15}H_{26}O$	222
6,11-Undecadiene, 1-acetoxy-3,7-dimethyl-	0.84	29.67	78	$C_{16}H_{28}O_2$	252
alfa. -Copaene	0.69	11.33	93	$C_{15}H_{24}$	204
5-(7a-Isopropenyl-4,5-dimethyl-octahydroinden-4	0.63	25.11	76	$C_{20}H_{34}O$	290
1,2,5,5,8a-Pentamethyl-1,2,3,5,6,7,8,8a-octahydrona	0.62	26.96	85	$C_{15}H_{26}O$	222
Pentadecanal-	0.61	14.78	82	$C_{15}H_{30}O$	226
alpha. -Cadinol	0.56	14.12	91	$C_{15}H_{26}O$	222
Megastigmatrienone	0.52	25.2	57	$C_{13}H_{18}O$	190
1H-Cycloprop[e]azulene, 1a,2,3,4,4a,5,6,7b-octahydro-	0.23	11.96	89	$C_{15}H_{24}$	204
Caryophyllene oxide	0.59	13.62	93	$C_{15}H_{24}O$	208
4-(2,2,6-Trimethyl-bicyclo[4.1.0]hept-1-yl)-butan-2	0.56	14.76	78	$C_{15}H_{24}O$	208
alpha. -Farnesene	0.41	12.63	90	$C_{15}H_{24}$	204
trans-calamenene	0.41	12.935	91	$C_{15}H_{22}$	202

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Table 6: Continued (the chemical composition of essential oils from greenhouse - grown *Leonotis leonurus* seedlings treated with 10g of *Moringa oleifera* leaf powder biweekly for eight weeks).

9,12,15-Octadecatrien-1-ol, (Z, Z,Z)-	0.39	17.10	93	$C_{18}H_{32}O$	264
alpha. -Cadinol	0.38	14.2	91	$C_{15}H_{26}O$	222
17.alfa.,21. beta. -28,30-Bisnorhopane	0.32	24.33	76	$C_{28}H_{48}$	384
11-Oxa-dispiro [4.0.4.1] undecan-1-ol	0.29	23.075	74	$C_{10}H_{16}O_2$	168
8a(2H)-Phenanthrenol, 7-ethenyldodecahydro-1,1,4a,7-tetramethyl	0.28	18.74	79	$C_{22}H_{36}O_2$	332
1H-Cyclopenta[1,3]cyclopropa[1,2]benzene, oc	0.23	11.96	84	$C_{15}H_{24}$	204
Ledene oxide-(II)	0.22	14.65	81	$C_{15}H_{24}O$	220
Alloaromadendrene	0.21	13.31	80	$C_{15}H_{24}O$	220
2-Pentadecanone, 6,10,14-trimethyl-	0.21	16.26	93	$C_{18}H_{36}O$	268
4,8,13-Cyclotetradecatriene-1,3-diol, 1,5,9-trimethyl	0.22	14.52	81	$C_{20}H_{34}O_2$	306
Aromadendrene oxide-(1)	0.21	14.4	78	$C_{15}H_{24}O$	220
beta.-copaene	0.20	12.4	90	$C_{15}H_{24}$	204
4-(2,2,6-Trimethyl-bicyclo [4.1.0]hept-1-yl)-buta	0.20	24.9	78	$C_{14}H_{24}O$	208
cis, cis-7,10,-Hexadecadienal	0.19	17.0	93	$C_{16}H_{28}O$	236
3,11-Dioxa-2,12-disilatridecane, 2,2,12,12-tetramethyl	0.19	25.40	49	$C_{13}H_{32}O_2Si_2$	276
Cyclononasiloxane, octadecamethyl-	0.17	20.45	75	$C_{18}H_{54}O_9Si_9$	666
Globulol	0.16	13.86	90	$C_{15}H_{26}O$	222
cis-1-Chloro-9-octadecene	0.16	17.5	80	$C_{18}H_{35}Cl$	286
1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23	0.15	19.66	89	$C_{30}H_{50}O$	426
Methoxyacetic acid, 4-tetradecyl ester	0.14	30.85	76	$C_{17}H_{34}O_3$	286
Alpha - ylangene	0.13	12.7	76	$C_{17}H_{34}O_3$	286
Cubedol	0.13	14.04	81	$C_{15}H_{26}O$	222
Naphthalene, decahydro-1,4-dimethoxy-, (1.alp)	0.13	25.38	79	$C_{20}H_{32}$	272
Pentadecanal-	0.13	13.76	92	$C_{15}H_{30}O$	226
Cyclopropanemethanol, 2,2-dimethyl-3-(2	0.12	15.3	65	$C_{10}H_{18}O$	154
9,10-Secocholesta-5,7,10(19)-triene-3,25,26-triol	0.09	25.16	52	$C_{27}H_{44}O_3$	416
Phytol, acetate	0.09	26.04	69	$C_{22}H_{42}O_2$	338
trans-Chrysanthemal	0.08	13.72	67	$C_{10}H_{16}O$	152

Student's Journal of Health Research Africa
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Original Article

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Chlorpyrifos	0.08	18.66	74	$C_9H_{11}Cl_3NO_3PS$	349
(-)-Aristolene	0.07	12.06	80	$C_{15}H_{24}$	204
Isoaromadendrene epoxide	0.07	14.12	75	$C_{15}H_{24}O$	220
6-Isopropenyl-4,8a-dimethyl-1,2,3,5,6,7,8,8a-oct	0.07	14.72	75	$C_{15}H_{24}O$	220
Naphthalene	0.07	12.21	79	$C_{20}H_{32}$	272
Bicyclo[2.2.1]heptane-2,3-diol, 1,7,7-trimethyl	0.05	13.72	56	$C_{10}H_{18}O_2$	170
Cyclohexane, 1-ethenyl-1-methyl-2-(1-methylethenyl	0.05	10.79	91	$C_{15}H_{24}$	204
cis-5,8,11-Eicosatrienoic acid, trimethylsilyl ester	0.04	23.33	54	$C_{23}H_{42}O_2Si$	378

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Original Article

DISCUSSION

Generally, findings from the present study suggested that MLP modified the quantitative and qualitative properties of essential oils from L. leonotis. Comparative differences between the control and treatments could, to some extent, be attributed to the presence of varying quantities of ABA, IAA, Gibberellins, and micro- and macronutrients in MLP (Abd El-Mageed et al., 2017, Rady and Mohamed, 2015, Saini et al., 2016), which most likely altered the physio-biochemical properties of the study plant. Although the control (S1) contained 45 -71 more compounds than the treatments, some MLP constituents stimulated marked increases in the concentration of several major compounds (area % > 1) in the plant. Some components of the leaf powder also caused considerable changes in the chemical composition of the plant essential oils. As shown in Tables 1-6, each treatment and the control had distinctive chemical profiles, which were also quite different from those previously reported for the same plant (Nsuala et al., 2015, Nsuala et al., 2017). Differences in the chemical profiles particularly of the control used in the present study and samples used in previous studies could be attributed to several factors including the oil extraction processes used, storage, geographical location, climatic conditions, harvest season, and age of the study plant (Nsuala et al., 2017, Tock et al., 2020, Asekun et al., 2007).

Caryophyllene and humulene were among the well-known bioactive compounds whose concentration increased considerably in treatments (S2-S6). Increased concentration of these and other pharmacologically important compounds in the plant could probably improve the yield of bioactive compounds in ethnopharmacological assays, and herbal preparations resulting in enhanced potency. Increased concentration of biologically active compounds in the plant could also give the plant improved resistance against pathogenic infections, and perhaps other biotic stresses as well. However, these beneficial effects depend on intricate interactions (synergistic / additive) between bioactive, and possibly other compounds in the plant.

CONCLUSIONS

It was interesting to note that the MLP applications significantly altered the composition and concentration of volatile compounds in *L. Leonotis*. However, more studies are still needed to ascertain the importance of MLP as a potential biofertilizer for the plant.

STUDY LIMITATIONS

Although MLP demonstrated noteworthy biostimulating properties in the current study, the experiment was conducted under strictly controlled (greenhouse) conditions which do not depict actual field conditions. The present study did, therefore, not factor in the manifold effects of plant genotypic differences, soil types, weather patterns, and other agroecological factors on the quantity and quality of EOs produced by *L. Leonotis*. Furthermore, we did not know the precise agroecological conditions prevailing before and during the time the Moringa leaves used in the study were harvested and processed. Given these limitations, it may be difficult for one to reproduce the results reported in the present study.

RECOMMENDATIONS FOR FUTURE STUDIES

Future studies could perhaps explore the effects of the powder on the plant when used in combination with other biostimulants, bio-fertilizers, or organic fertilizers. It is also imperative that the optimum amount of powder needed to obtain the highest plant biomass and the best quality oils be established. Future studies should also investigate the effects of MLP on plant morpho-physiological parameters such as size, number, length, and weight of test plant organs; photosynthetic pigments, nutrients, phenolics, tannins, alkaloids, and phytohormone content, etc. Furthermore, the effects of Moringa leaf extracts (soil drench or foliar application) on the plant's morpho-physiological properties should also be assessed. It could also be interesting to know the effects of applying MLP at different stages of the *L. leonotis* life cycle.

AUTHOR CONTRIBUTION

MV conceived the original idea and wrote the first draft, SA extracted the essential oils, GDA, KN, KS, SA, and RMC edited the manuscript, provided resources, and supervised the project.

SOURCE OF FUNDING

Mangosuthu University Research Directorate is thanked for its financial support.

COMPETING INTEREST

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing the article.

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Mangosuthu University of Technology or those who funded the study.

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