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Original Research Article

Effect of soil type on chemical composition and antioxidant properties of *Solanum nigrum* (L.) shoot oil extracts

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Abstract

Purpose: *To investigate the effect of different soil textures on chemical composition and antioxidant properties of essential oils from Solanum nigrum.*
Methods: *Four soils of differing texture were formulated from soil under fallow to cultivate S. nigrum in a glasshouse. Essential Oil was extracted from fresh shoots by solvent-free microwave extraction (SFME) and analysed using gas chromatography-mass spectrometry (GC-MS). Antioxidant properties were assayed (DPPH) and ABTS*
Results: *GC-MS profiling revealed variations in the quality index (QI), number of chemical constituents and antioxidant results of S. nigrum oil. Geraniol and citronellol were the two principal components. The highest activity of the antioxidant was found in plants cultivated on clay loam soil. Fifty percent (50%) Inhibitory Concentration (IC_{50}) ranged from 1.196 to 1.594 µg/mL and 0.067 to 3.59 µg /mL in DPPH and ABTS assays, respectively.*
Conclusions: *This research work indicates that soil texture influences the oil quality, quantity and chemical composition of oil extracted from S. nigrum shoots. Essential oil extracts from S. nigrum grown on clay loam soils recorded the highest antioxidant properties.*

Keywords: *Soil types, Essential oil, Solanum nigrum, Antioxidant properties*

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INTRODUCTION

The folkloric use of nutraceutical medicinal plants has put further declaration on the importance of plants in human health. The report that diseases such as cancer, hepatotoxicity and others can be controlled if or when antioxidants, normally from natural plant foods or products are assimilated is highly encouraging [1]. Other reports have also confirmed the ability of rich antioxidant containing food of plant origin in the prevention of cancer. The bioactive compounds in the plants have been confirmed better and with fewer side effects when compared to the chemically synthesised compounds [2]. So therefore, the effectiveness of these compounds may be considered for use in both chemoprevention and chemotherapy of cancer [3]. All encouraging pieces of information on biomedical activities of plants gave the insight

that the essential oil could be another means of exploring the plants.

The use of essential oils in food and cosmetic products is widespread and on demand. However, the biological functions of essential oils depend on the chemical composition of the oil and these vary with part of plant, method of extraction, age and environmental conditions [4]. Therefore, there is still need for further search for more important plants especially those with nutraceutical values to exploit them for essential oil with different bioactive compounds.

Solanum nigrum (Black nightshade); is an aromatic plant with an unsatisfactory odour, however with successful reports as a medicinal plant [5]. Medicinal aromatic plants have been reported in the treatment of HIV / AIDS, malaria, diabetes, sickle-cell anaemia and microbial infections [6]. So also, many studies have reported cancer preventive potentials of oil extracted from aromatic plants with their efficacies tied on their antioxidant properties [7]. The plant has been extensively used in the folkloric treatment of chronic diseases and ailments. Crowning the information about the plant is the notable report of its anticancer properties documented by [8].

Variations in the quality and chemical composition of essential oils extracted from the same plant have been reported and these may result from factors such as geo-climatic location, growing season, and growing conditions [9]. However, soil types on which the plant is grown is another environmental factor that has not been reported, the gap considered to be filled by this study. The focus of this study is therefore, to investigate the effect of soil texture types on the chemical composition and antioxidant properties of essential oils from the shoot parts of cultivated *S. nigrum*.

EXPERIMENTAL

Soil collection and treatments

The soil was collected from a fallow land at a depth of 30 cm from the University of Fort Hare farm, Alice campus in South Africa located at $32^0$46'47''S and $26^0$50' 5''E and 524 m a.s.l. Soil treatments were relative combinations of sand, silt and clay in different proportions according to the classification system by [10], using soil texture triangle rules.

The physical composition of the relative combined soil types on which *S. nigrum* was cultivated is presented as follows on Table 1.

Table 1: Textural composition of experimental soils

Soil type	Sand particle (%)	Silt particles (%)	Clay particles (%)
Control ST_0	60	30	10
Sandy clay loam ST_1	66	13	21
Silty clay loam ST_2	10	60	30
Clay loam ST_3	36	30	34
Loam ST_4	40	40	20

The content of Ca, K, Mg, Na and P was determined using the Inductively Coupled Plasma – Optical Emission Spectrometer [11]. The soil results were garnished on Tables 2.

Plant collection and identification

Seeds were obtained from mature berries of plants by hand squeezing, washing in distilled water and air-dried for 3 days and planted in nursery trays in the green house. Seedlings of *S. nigrum* were transplanted at 4 leaf stage into experimental pots containing different soil texture nutrient compositions Table 1. The trial was conducted between February and March, 2016 at the University of Fort Hare, Alice campus, Eastern Cape, South Africa, located at $32^0$46'47''S and 2650' 5''E and 524m a.s.l. The plant had earlier been identified (BVE11/017) and deposited at the Giffen herbarium of the same University. For this study, *S. nigrum* cultivated on different soil types, were harvested at the early flowering stage (4^{th} week) from each of the soil types in the green house, at the Faculty of Agriculture, University of Fort Hare. The freshly collected samples were separated into shoot and root parts, air dried and weighed.

Solvent-free microwave extraction (SFME)

About 315 g fresh shoot samples of *S. nigrum* were differently placed into the reactor without addition of water or solvent. Oils were obtained by Solvent Free Microwave Extraction (SFME) using Milestone Dry DIST (2004) apparatus. Incorporated in multimode reactor is a twin magnetron (2 x 800 W, 2450 MHz) having maximum delivered power of 500 W in 5 W increments. Homogeneous microwave distribution was achieved by a rotating microwave diffuser throughout the plasma coated PTFE cavity. An external infrared sensor monitored the temperature and the temperature constant conditions and water were guaranteed by the reflux of the condensed water which was achieved at 5^0 C by a circulating cooling system.

The extraction got complete in 40 minutes. Essential oil was collected in air tight bottles and stored in the refrigerator at 4 ^{0}C before analysis [12]. The oils were qualitatively and quantitatively analysed with Gas Chromatography-Mass Spectrometry.

Gas chromatography-mass spectrometry (GC-MS)

Oil samples were analysed using coupled Agilent 5975 and Agilent 6890 MSD with a Zebron- 5MS column (ZB-5MS 30 m x 0.25 µm) 5%-phenyl methyl polysiloxane). A carrier gas of GC grade helium at a flow rate of 2 ml/ min was used. Split less 1 µl injections for analysis. Injector temp was 280 ^{0}C; source temp was 280 ^{0}C. Oven temp 70^0 C, ramp at 15 ^{0}C/ min to 120 ^{0}C, ramp at 10 ^{0}C/ min to 180 ^{0}C then ramp at 20 ^{0}C/ min to 270 ^{0}C hold for 3 mins. Data were gathered with Chem station.

Determination of effect of soil type on antioxidant properties of essential oil

Antioxidant radical screening of *S. nigrum* shoot oil from different soil types were investigated using the 1, 1-diphenyl-2-picryl-hydrazyl (DPPH) and 2, 2'-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid (ABTS).

DPPH assay

Free radical scavenging activity measured in DPPH assay was achieved by adopting the method of Odeyemi *et al* [13]. It followed a concentration dependent pattern (0.025, 0.5, 0.1, 0.2, 0.4) µg/ml. 1.0 ml was prepared in a solution of 0.135 mM DPPH radical methanol. 1 ml of this solution was mixed with β-carotene and vitamin C separately. The reaction mixture was vortexed thoroughly and left in the dark at room temperature for 30 min. Absorbance was measured spectrophotometrically at 517 nm. The actual decrease in absorbance was measured against β-carotene and ascorbic acid (AA) as standards. DPPH scavenging ability (D) was then calculated using Eq 1.

D (%) = {Ac – As)/Ac}100 …… (1)

where Ac and As are the absorbance of control and test samples, respectively.

ABTS assay

ABTS radical scavenging activity was achieved using the method described by Kibiti and Afolayan [14 Stock solutions of essential oils of *S. nigrum* were prepared following a concentration dependent pattern (0.025, 0.5, 0.1, 0.2, 0.4) µg/ml. Briefly, the stock solutions of 7 mM ABTS solution and 2.4 mM potassium persulfate solution were prepared separately. Mixture of equal ratios 1:1 v/v of the two solutions was prepared and allowed to react for 12h in the dark at room temperature. The solution was then diluted by mixing 1mL ABTS + solution with 60 mL of methanol to obtain an absorbance of 0.708 ± 0.001 units at 734 nm using the spectrophotometer. The oil extracts (1 mL) and their controls were allowed to react with 1mL of the ABTS + solution for 7 min. The decrease of absorption was measured at 734 nm in a cuvette with the spectrophotometer. The ABTS + scavenging capacity of the oil extract was then compared with those of the standards. Inhibition (H) of ABTS was calculated as in Eq 2.

$$H\ (\%) = \left[1 - \frac{Abs\ sample}{Abs\ control}\right] \times 100 \quad \ldots\ldots\ldots (2)$$

where Abs sample and Abs control are the absorbance of test and control samples, respectively.

Statistical analysis

All data were subjected to statistical analysis using Minitab, version 17. One-way analysis of variance (ANOVA) was used to compare the mean values among soil treatments. Means were separated using Fisher's least significant difference (LSD) paired wise comparison and taken as significantly different at $p < 0.05$.

RESULTS

Effect of soil type on chemical composition of essential oil

Microwave extraction of fresh shoot part of *S. nigrum* yielded 0.2, 0.3, 0.4, 0.4, 0.3 % (v/w) essential oils from the control, sandy clay loam, silty clay loam, clay loam and loam soil respectively. The chemical compounds from GC-MS analysis of the volatile oil from *S. nigrum* samples were identified from different soil types. The components were characterized by a mass spectral survey using the NIST mass spectral search program and GC-MS Library. Comparison was made on calculated Kovat retention indices (RI) of oils from different soil types with those already cited in literature [15]. The various constituent percentage compositions, molecular formulae, molecular weight and retention time are shown on Table 3. Compounds found in oils extracted from *S. nigrum* shoot samples from different soil types are presented in Table 3. The GC-MS analysis resulted in identification of 13 to 16 compounds in *S. nigrum*. These compounds

were representing 87.9, 93.8, 96, 99.1 and 78 % of the total oil composition of *S. nigrum* shoot samples from the control, sandy clay loam, silty clay loam, clay loam and loam soil types respectively. The general chemical profile of fractions, the percentage contents and the retention indices of the constituents are summarized in Table 3. Principal constituents of *S. nigrum* shoot oil samples from different studied soil types were: citronellol, geraniol, citronellyl tiglate and geraniol tiglate, which were of high-quality index (83 - 99 %). The compounds reported in the different soil types decreased in the order: ST_3>ST_2 >ST_1 >ST_0 >ST_4 as shown in Table 3.

Generally, in this study, regardless of the soil types, the major compounds found in the essential oils could be classified as terpenoids, esters and hydrocarbons [16]. Highest geraniol and citronellol levels were recorded forclay loam soil (Table 3).

Citronellol was the second principal compound after geraniol in the essential oil of *S. nigrum* cultivated in different soil types and they are both known for defence mechanisms [17].

Effect of soil type on DPPH radical scavenging activity of essential oil

The free radical scavenging activity increased with increase in oil concentration ranging from 61.16 to 79.70 % (Table 4). In all the working concentrations, all the treatments competed favourably with the two standards, β-carotene and vitamin C. However, the highest radical scavenging value was reached by plants cultivated on clay loam soil which also compared favourably well with β-carotene and vitamin C as shown in Table 4. Moreover, the IC_{50} value of 1.196 - 1.594 µg/ml is an indication that *S. nigrum* had high antioxidant activity. However, the positive controls, vitamin C and β-carotene, showed an IC_{50} value of 0.7224 and 0.8430 µg /ml, respectively. From the current study, clay loam soil (ST_3) recorded the highest IC_{50} value (1.9594 µg /ml) while loam soil recorded the lowest value (1.252 µg /ml); the lowest value indicates the best treatment (Table 4).

Effect of soil type on ABTS radical scavenging activity of essential oil

ABTS radical scavenging activity increased from 41.86 to 67.23 % as the concentrations increased as shown in Table 5. At all working concentrations, all treatments appeared to have competed favourably with the two standards used (BHT and vitamin C). At lower concentrations (0.025 - 0.100 mg/mL), oil extract treatments compared favourably and better than the two standards BHT and vit C. At higher concentrations (0.2 and 0.4 mg/mL), the two standards exhibited higher radical scavenging power but oil extracts from clay loam (ST_3) showed higher radical scavenging power than BHT but still compared well with vitamin C at 0.2 mg/mL. However, vitamin C exhibited higher radical scavenging power than BHT. Clay loam soil has the highest significant (p > 0.05) radical scavenging activity when compared with the control soil and the two standards. The two standards showed higher radical scavenging power than all the oil treatments. However, from 0.1 to 0.4 mg/mL concentrations, oil extracts from silty clay loam and loam soil showed higher radical scavenging power than 50 % of the ABTS standard and the highest value (67.23 %) was reached by the extract cultivated on clay loam soil as shown in Table 6. The IC_{50} range from 0.067 to 3.59 µg/mL is a good indicator of good scavenging power of *S. nigrum* (Table 6).

DISCUSSION

Disparity in the number, types and quality of chemical components in essential oils from shoot extracts of *S. nigrum* established that soil texture has an influence on the volatile oil synthesised. The presence of geraniol and citronellol (monoterpenes) in *S. nigrum* as an aromatic plant agree with the report of Singh *et al* [18]. High contents of geraniol and citronellol as the principal constituents in the oils may be responsible for the antioxidant properties of *S. nigrum.* The potency of this plant in folkloric treatment of chronic ailments and the antioxidant results of the essential oils in this study agree with the report that geraniol as an acyclic monoterpene alcohol, exerts a broad spectrum of pharmacological activities like anti-inflammatory, antioxidant, anti-ulcers and neuroprotective activities [19].

Carnesecchi *et al* [20] demonstrated that geraniol (monoterpene) sensitized human colonic cancer cells to 5-fluorouracil treatment in vitro, a mechanism related to its antioxidant properties. The results from some previous authors confirmed the presence of geraniol in *S. nigrum* which has been known for its potential role in the treatment of different types of cancers such as breast, colon, lung, prostate, pancreatic and hepatic toxicity [16].

In the present study, higher radical scavenging activity and lower IC_{50} values recorded in DPPH and ABTS scavenging activity could be due to the presence of geraniol and citronellol in the

Table 2: Chemical composition of the soils before the trial

Soil types	Content (mg/kg) P	K	N	Ca	Mg	Zn	Mn	Cu	Org. cont %	pH	Clay %	Sand %	Silt %
ST_0	68^{b}±1	524^{a}±0	3.4^{c}±1	1389^{a}±0.5	332^{b}±0.1	6.0^{b}±0.3	29^{d}±1	10.5^{c}±0	4^{c}±0.5	6.22^{a}±0	10^{c}±1	60^{a}±1	30^{c}±1
ST_1	84^{a}±0	467^{d}±1	3.6^{c}±0	1357^{b}±0.5	347^{a}±0.5	8.1^{a}±0.5	66^{a}±0	15.6^{a}±0	3.9^{c}±0	5.7^{b}±1	21^{b}±1	66^{a}±0.5	13^{d} ±0
ST_2	62^{c}±1	524^{a}±0	5^{a}±0.5	1278^{e}±0.5	316^{d}±0.0	5.9^{bc}±0.1	45^{b}±0	10.6^{c}±1	5^{a}±1	5.7^{b}±0	30^{a}±0	10^{c} ±1	60^{a}±0
ST_3	60^{cd}±0	519^{b}±1	4.8^{b}±0	1318^{c}±1.0	321^{c}±0.0	5.3^{c} ±0.1	38^{c}±0	10.3^{c}±0	4.5^{b}±0	5.63^{b}±1	34^{a}±0	10^{c}±1	30^{c}±0.1
ST_4	63^{c}±1	482^{c}±0	4.6^{b}±0	1290^{d}±0.5	330^{b}±0.5	6.2^{b}±0	45^{b}±0	11.4^{b}±0	4.8^{a}±1	5.63^{b}±0	20^{b}±1	40^{b}±1	40^{b}±0

Values shown are mean ± standard deviation (SD); Different letters down a column represent significant differences at $p < 0.05$; different letters denote significant differences among the soil types ST_0, ST_1, ST_2, ST_3 and ST_4; letters that represents significant differences are from up ST0 column down the ST4 column for each of the measured parameters

Table 3: Effect of soil types on chemical composition of essential oils from *S. nigrum* shoots

Compound	Soil type		**ST_0**			**ST_1**			**ST_2**			**ST_3**			**ST_4**		
	M F	***MM***	***KI***	***RT***	***%A***	***KI***	***RT***	***%A***	***KI***	***RT***	***%A***	***KI***	***RT***	***%A***	***KI***	***RT***	***%A***
Geraniol	$C_{10}H_{18}O$	154	1061	6.4	26.3	1057	6.3	31.3	1051	6.2	31.5	1061	6.4	22.4	1051	6.2	31.7
Citronellol	$C_{10}H_{20}O$	156	1051	6.2	13.0	1062	6.4	19.1	1061	6.4	15.1	1051	6.2	39.5	1061	6.4	17.9
Citral	$C_{10}H_{16}O$	152	847.7	2.1	2.1	-	-	-	-	-	-	1061	6.4	0.9	1061	6.4	0.9
Geraniol butyrate	$C_{14}H_{24}O$	208.3	-	-	-	-	-	-	-	-	-	1166	8.5	2.9	-	-	-
Phytol	$C_{20}H_{40}O$	296.5	1233	11.4	3.3	-	-	-	-	-	-	-	-	-	-	-	-
Phenyl ester	$C_{10}H_{12}O_2$	164.2	1176	8.7	6.7	1176	8.7	6.3	-	-	-	-	-	-	-	-	-
Neryl acetate	$C_{12}H_{20}O$	196.3	1299	7.9	2.0	-	-	-	1299	7.9	2.9	-	-	-	1138	8.0	2.3
Trans citral	$C_{10}H_{16}O$	152.2	1071	6.6	2.1	1071	6.6	3.0	-	-	-	-	-	-	-	-	-
Fumaric acid	$C_4H_4O_4$	116.1	-	10.2	1.5	-	-	-	-	-	-	-	-	-	-	-	-
Geranyl tiglate	$C_{15}H_{24}O_2$	236.3	1172	9.3	9.3	1171	9.3	7.2	1172	9.3	6.7	1172	9.3	4.8	1172	9.3	4.9
Citronellyl tiglate	$C_{15}H_{26}O_2$	238.4	1163	9.1	3.8	1163	9.1	3.1	1163	9.1	2.9	1163	9.1	2.3	1163	9.1	2.1
Phenylethyl tiglate	$C_{13}H_{16}O_2$	204.3	-	-	-	-	-	-	64	8.7	5.7	866.9	8.7	4.0	-	-	-
Caryophylene oxide	$C_{15}H_{24}O$	220.4	650.4	8.8	6.3	1150	8.8	5.8	650.4	8.8	6.3	650.4	8.8	5.4	-	-	-
Methyl naphthalene	$C_{15}H_{24}$	204.4	1159	9.0	2.9	-	-	-	1159	9.0	2.4	-	-	-	-	-	-
Cyclohexene	C_6H_{10}	82.1	-	-	-	-	9.0	2.4	-	-	-	-	-	-	-	-	-
Tetracosane	$C_{24}H_{50}$	338.7	97	12.2	1.0	-	-	-	-	-	-	-	-	-	-	-	-
Eicosane	$C_{20}H_{42}$	282.6	1227	11.3	1.4	1227	11.3	1.1	-	-	-	-	-	-	-	-	-
Geranyl acetate	$C_2H_3O_2$	59.0	-	-	-	-	7.3	0.9	-	6.8	4.6	-	7.3	0.1	-	7.3	1.6
Geranyl vinyl ether	$C_{12}H_{20}O$	180.3	-	-	-	-	-	-	-	-	-	1090	6.8	2.9	-	-	-
Heptachlor	$C_{10}H_5C_{17}$	373.3	-	-	-	-	-	-	-	-	-	1251	10.2	0.7	-	-	-
Propanoic acid	$C_3H_6O_2$	74.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Butanoic acid	$C_4H_8O_2$	96.2	-	8.5	4.5	-	12.1	5.6	-	8.5	4.3	-	8.5	2.8	-	-	-
Ethyl carbonate	$C_5H_{10}O_3$	118.1	-	8.3	1.7	-	8.3	1.7	-	7.9	1.4	-	-	-	-	8.0	0.8
Trans-sequisabenene hydrate	$C_{15}H_{26}O$	222.4	-	-	-	-	-	-	-	-	-	-	-	-	659.1	9.0	0.8
Geranyl formate	$C_{11}H_{18}O$	182.3	-	-	-	975.7	6.6	6.3	1080	6.7	5.5	1075	6.6	9.2	957.7	6.6	9.2
Citronellyl formate	$C_{11}H_{20}O_2$	184.3	-	-	-	-	-	-	975.7	6.6	6.3	-	-	-	984.2	6.8	5.0
3-octadecene	$C_{18}H_{36}$	252.5	-	-	-	-	-	-	338.6	10.2	0.8	-	-	-	-	-	-
Citronellyl cinnamate	$C_{19}H_{28}O_2$	286.4	-	-	-	-	-	-	-	-	-	1021	8.0	1.8	-	-	-
Isobutyl carbonate	$C_9H_{18}O_3$	174.2	-	-	-	-	-	-	-	-	-	-	-	-	-	9.4	0.9
Carboxyethane/ Luprisol	$C_3H_6O_2$	74.1	-	-	-	-	-	-	-	-	-	-	-	-	-	10	0.8
Total % oil content					87.9			93.8			96.4			99.1			78.9

Table 4: Effect of soil type on DPPH radical scavenging activity on *S. nigrum* shoot oil extract

Oil conc µg/ml	ST_0	ST_1	ST_2	ST_3	ST_4	B Caro	Vit. C
0.025	62±0.03	64.2±0.13	65.1±0.19	66.2±0.27	64.3±0.14	33.6±0.21	23.8±2.7
0.05	65.8±0.24	66.1±0.26	66.6±0.3	72.1±0.68	65.8±0.24	51.8±0.74	26.3±2.52
0.1	66.9±0.32	67.4±0.35	68.2±0.41	74±0.81	66.1±0.26	52.9±0.66	28.8±2.35
0.2	66.5±0.29	69±0.46	69.5±0.5	76.3±0.97	68.4±0.42	69.4±0.49	46.8±1.09
0.4	68.8±0.45	72.1±0.68	75.9±0.95	78.1±1.1	72.4±0.7	77.5±1.06	54.2±0.57

Table 5: Effect of soil types on ABTS radical scavenging activity on *S. nigrum* oil extract

Oil conc µg/ml	ST_0	ST_1	ST_2	ST_3	ST_4	BHT	Vit. C
0.025±	42.5±0.03	41.8±0.04	43±0.03	44±0.02	42±0.04	22.5±0.01	26±0.01
0.05±	43.2±0.03	43.5±0.02	44±0.02	50.4±0.02	39±0.06	34.8±0.09	37.5±0.07
0.1±	46±0.01	47.6±0.0	53.7±0.04	56±0.06	43.4±0.03	36.9±0.07	42.3±0.03
0.2±	43±0.03	49.2±0.01	56.8±0.06	58.9±0.08	48±0.003	37.5±0.07	45.5±0.01
0.4±	41±0.04	50.5±0.02	57.8±0.07	68.6±0.14	48±0.003	82±0.2	99.5±0.3

Table 6: Effect of soil type on IC_{50} of oil extract

1	Soil types / standard	2	DPPH IC_{50}	3	ABTS IC_{50}
4	ST_0	5	1.196	6	3.590
7	ST_1	8	1.422	9	0.328
10	ST_2	11	1.534	12	0.147
13	ST_3	14	1.594	15	0.067
16	ST_4	17	1.252	18	0.595
19	β- carotene	20	0.722	21	-
22	Vitamin C	23	0.843	24	0.843
25	BHT	26	-	27	0.945

Note: ST_0- Control, ST_1-Sandy clay loam, ST_2- Silty clay loam, ST_3- clay loam, ST_4- Loam

essential oils. Citronellol and geraniol are well known for defence mechanisms in human physiology [16]. Citronellol has been found to possess herbicidal activities as well [21]. The possession of novel modes of action in Citronellol (responsible for herbicidal activities) differs from that of synthetic herbicides. These synthetic herbicides persist in the environment long after their application, however, the non-persistence of Citronellol has led to its adoption in the Generally Regarded as Safe (GRAS) category by the United States Environmental Protection Agency [22]. Furthermore, this compound has been confirmed as a flavouring compound that can be used to synthesise other aroma compounds such as oxides [23]. Its biotransformation can produce large metabolites [24].

CONCLUSION

The findings of this study indicate that the essential oil of *S. nigrum* shoots is of high quality but slightly differ regarding the different soil textures on which the plant was cultivated. The oil displayed good antioxidant properties which may be due to the presence of geraniol and citronellol (monoterpene alcohols) which are the major compounds present in the oil. Therefore, *S. nigrum* shoots could serve as a possible source of geraniol and citronellol which are basic ingredients in some pharmaceutical formulations.

DECLARATIONS

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Conflict of interest

No conflict of interest is associated with this work

Contribution of authors

We declare that this work was done by the author(s) named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by the authors. Adijat Funke Ogundola is the PhD student that carried out the experiment, collected and analysed the data and wrote the manuscript. Dr Callistus Bvenura is the co-supervisor that supervised the practical aspect and guided on the writing up of the manuscript. Prof Anthony Jide Afolayan is the major supervisor that conceived and designs the study. He also sourced for fund to carry out the Research and read the manuscript. In addition, a declaration of the role of each author mentioned

in the manuscript should be provided. The author who conceived and designed the study, the person(s) who collected and analysed the data, and the person who wrote the manuscript as well as an indication that all authors read and approved the manuscript for publication must be specified

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