



Original article

Essential oil of *Bassia muricata*: Chemical characterization, antioxidant activity, and allelopathic effect on the weed *Chenopodium murale*

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ABSTRACT

The essential oil (EO) of *Bassia muricata* shoots was extracted via hydro-distillation and then investigated by gas chromatography-mass spectrometry. Thirty-four compounds were recognized for the first time from this plant, representing 100% of the total mass. Terpenoids represented the major components with 69.17% of the total mass, containing oxygenated sesquiterpenes (53.18%), oxygenated monoterpenes (9.77%), sesquiterpene hydrocarbons (5.03%), and diterpenes (1.19%). Additionally, 6-methoxy-1-acetonaphthone was the only aromatic compound represented in a high percentage of the total identified compounds with 22.35%. Additionally, a percent of 8.48% of the total mass was hydrocarbons. Only one oxygenated sesquiterpene namely hexahydrofarnesyl acetone representing 47.35% of the total mass was identified. It was followed by methoxy-1-acetonaphthone (19.92%), *n*-dotriacontane (3.58%), *endo*-borneol (3.24%), 6-methy- α -ionone (3.04%), and α -gurjunene (2.65%). The EO exhibited moderate antioxidant activity comparable with ascorbic acid as a standard, where it attained IC₅₀ value of 20.70 $\mu\text{L L}^{-1}$ and 16.32 $\mu\text{L L}^{-1}$, for DPPH and ABTS. The EO of *B. muricata* significantly reduces the germination and seedling development of the weed *Chenopodium murale*. The EO showed an IC₅₀ value of 175.60 $\mu\text{L L}^{-1}$, 246.65 $\mu\text{L L}^{-1}$, and 308.33 $\mu\text{L L}^{-1}$ for root growth, shoot growth, and germination, respectively. Therefore, this EO could be a good green resource for the control of weeds.

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1. Introduction

By the time the human population increases, and thereby, the human needs for food, feed and medicines become greater than before. In this context, using natural eco-friendly resources from plants attract the attention of researcher and scientists all over the world. Essential oils (EOs) are one of the important enriched

resources among different bioactive metabolites. They have been used in ancient Egypt for remediation of various diseases. The EOs have been reported to have several biological activities such as antifungal, antiviral, antibacterial (Perricone et al., 2015; Elshamy et al., 2019b), antioxidant, allelopathic, and insecticidal activities (Abd El-Gawad, 2016; Abd El-Gawad et al., 2016; Abd El-Gawad et al., 2018b; Abd El-Gawad et al., 2018a; Abd El-Gawad et al., 2019; Elshamy et al., 2019b). In addition, the EOs are intergraded in food preservation industries, aromatherapy, fragrance industries, pharmaceutical, cosmetic, and agricultural industries (Ali et al., 2015; Zeng et al., 2015).

EOs as natural antioxidants attract the attention of researchers and scientists worldwide, and many studies incorporated the EOs as an eco-friendly alternative for the synthetic antioxidants. Moreover, the EOs are considered as an important class of the allelopathy agents as they are very diverse, biodegradable and have low resistance from organisms (Dudai et al., 1999; Abd El-Gawad et al., 2018b; Abd El-Gawad et al., 2019). Allelopathy is a

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phenomenon where a plant releases chemical compounds; secondary metabolites called allelochemicals to its environment that possess stimulatory or inhibitory activity against other organisms (Rice, 1984). The EOs as allelopathy agents play different roles where they act as a chemical defense mechanism against pathogens and herbivorous organism as well as they play a specific role in plant signaling due to their dispersal and aroma characteristics (Kessler and Baldwin, 2001).

Bassia muricata (L.) Asch. is an annual plant of Chenopodiaceae family, Syns. *Salsola muricata* L. or *Kochia muricata* (L.) Schrad. It is growing in sandy habitats in North Africa, East Mediterranean region, Sinai, Saudi Arabia, and Iran (Boulos, 1999). It is one of the important plants that used in traditional medicine where it used as analgesic, antipyretic, and nephritic as well as it has several biological activities such as antioxidant, antibacterial (Chemsa et al., 2016) molluscicidal, (El-Sayed, 1993) and insecticidal activities (El-Sayed et al., 1998). The extract of *B. muricata* has been reported to reduce the white blood cells counts, increase the prothrombin time as well as to have hypotension effect and antimicrobial activities (Al-Yahya et al., 1990; Chemsa et al., 2016). Some phytochemical constituents were isolated and identified from *B. muricata* such as flavonoid glycosides, (El-Sayed et al., 1998; El Hossary et al., 2000; Kamel et al., 2001; Shaker et al., 2013) saponins, (El-Sayed, 1993) and phenolic compounds (Shaker et al., 2013). Up to our knowledge, there is not any report concerning the EO of *B. muricata* or their bioactivity. Therefore, the present study aimed to (i) determine of the chemical composition of the EO from *B. muricata* shoots (ii) evaluate the antioxidant activity of its EO, and (iii) determine its allelopathic effect against the weed, *Chenopodium murale*.

2. Materials and methods

2.1. Plant material

Healthy shoots of *B. muricata* were collected throughout the flowering stage in March 2017 from sandy habitat in Gamsa City, northern Egypt (31°30'14.1"N 31°21'43.9"E). The plant was identified according to Boulos (1999) by Dr. Ahmed Abd-ElGawad, Associate Professor of Plant Ecology, Botany Dept, Mansoura University, Egypt. A voucher specimen with code Mans.030213002 was dropped in the Faculty of Science herbarium, Mansoura University, Egypt.

2.2. Extraction, GC–MS analysis, and identification of the EO

The EO (0.01% w/w) was extracted from 300 g of air-dried shoots of *B. muricata* through hydrodistillation for three hours via a Clevenger-type apparatus. The oil layer was separated and dried with 0.5 g of anhydrous sodium sulfate. This extraction was repeated two times using two samples and collected oils were stored in sealed air-tight glass vials at 4 °C until further GC–MS analysis.

The samples of EOs were analysed by GC–MS analysis using gas chromatography-mass spectrometry instrument at the Medicinal and Aromatic Plants Research Department, National Research Center of Egypt. The details of the GC–MS analysis and identification of chemical compounds were mentioned in detail in our previously work (Abd El-Gawad et al., 2019).

2.3. Antioxidant activity of the EO

2.3.1. DPPH radical scavenging activity

The reduction in the color of stable radical, 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Sigma-Aldrich, Germany) by the EO was

determined as scavenging activity following the methods of Miguel (2010) and as described in (Abd El-Gawad et al., 2019).

2.3.2. ABTS-free radical scavenging activity

To confirm the antioxidant activity of the *B. muricata* EO, the ability of the EO to scavenge the 2,2'-azino-bis(3-ethylbenzothiazole-6-sulphonic acid) (ABTS) radical (Sigma-Aldrich, Germany) was determined according to Re et al. (1999) and as described in our reported work (Abd El-Gawad et al., 2019).

2.4. Allelopathic activity of the EO

The allelopathic activity of the extracted EO from *B. muricata* was tested against the germination and seedling growth of the weed *C. murale*. The seeds of this weed were harvested from the garden of Agriculture College, Mansoura University, Egypt (31°02'35.4"N 31°21'01.5"E). Homogenous seeds with uniform color and size were selected and sterilized using 0.3% sodium hypochlorite.

Concentrations of 25, 50, 100, 150, 200, and 250 $\mu\text{L L}^{-1}$ of the EO were prepared using 1% (v/v) Tween[®]80 (Sigma-Aldrich, Germany), as an emulsifying agent. To test the allelopathic activity, 20 seeds were moved to a sterilized Petri plate (90 mm) lined with filter papers (Whatman No. 1). Subsequently, 4 mL of each concentration of the EO was poured to the plates, and sealed by a Parafilm[®] tape (Sigma, USA) and kept at 25 °C in a growth chamber. (Abd El-Gawad et al., 2016) Control plates were prepared as previously mentioned but using Tween 1% alone instead of EO. After eight days of incubation, the germinated seeds were counted and the lengths of the root and shoot were measured. The inhibition of seed germination or seedling growth was calculated as follows:

Inhibition (%) = 100

$$\times \frac{(\text{No/Length of control} - \text{No/Length of treatment})}{\text{No/Length of control}}$$

2.5. Statistical analysis

Bioassay of the allelopathic activity of EO of *B. muricata* was conducted in a completely randomized design, and the experiment was repeated two times with five replicates per each treatment. The data were subjected to one-way ANOVA, followed by Duncan's test at the probability level of 0.05. The data from the antioxidant experiment in triplicates was also subjected to one-way ANOVA using CoStat software program (CoHort Software, Monterey, CA, USA).

3. Results and discussion

3.1. Chemical composition of the EO

The study of EO from *Bassia* plant species around overall the world is rare. For the first time, the EO of the aerial parts of *B. muricata* collected from Egypt was isolated by hydro-distillation using a Clevenger-type apparatus for three hours. The EO was analyzed by GC–MS (Fig. 1). Thirty-four compounds were identified representing 100% of the total mass. The identified compounds based on GC–MS analysis showed that the EO of this plant is very rich in terpenoid compounds, which attained 69.17% of the total identified compounds (Table 1).

The aerial parts EO of *B. muricata* was characterized by its richness in terpenoids including sesquiterpenes (58.21%), monoterpenes (9.77%), and diterpenes (1.19%) as well as considerable concentrations of aromatic compounds (21.92%) and hydrocarbons (8.91) (Fig. 2). Terpenoids, especially mono and sesquiterpenes as

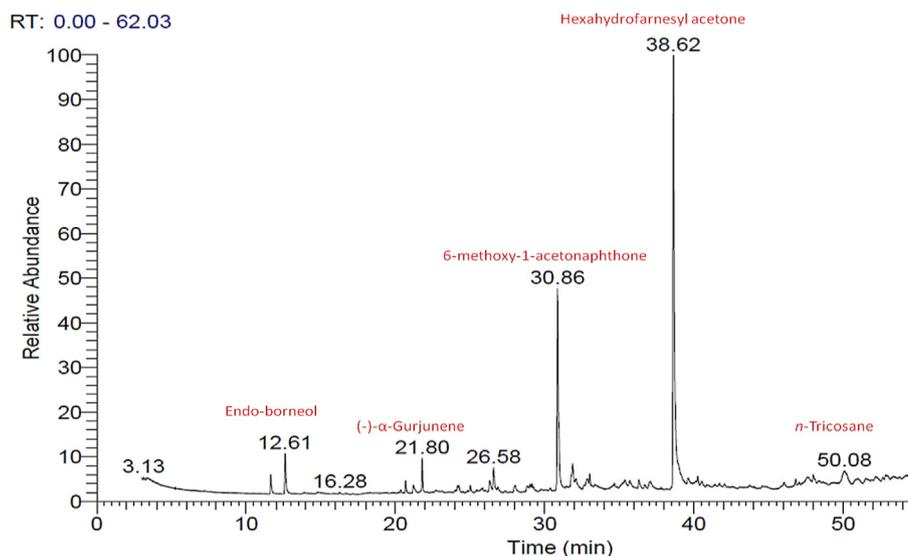


Fig. 1. GC-MS chromatogram of the essential oil of *Bassia muricata* aerial parts.

Table 1

Essential oil constituents extracted from the aerial parts of *Bassia muricata*.

No	RT ^[a]	KI _{Lit} ^[b]	KI _{Exp} ^[c]	Compound Name	Conc. (%) ^[d]	Identification ^[e]
Oxygenated monoterpenes						
1	11.66	1146	1148	2-Bornanone	1.60 ± 0.02	KI, MS
2	12.61	1139	1140	endo-Borneol	3.24 ± 0.02	KI, MS
3	21.22	1351	1354	α-Damascenone	1.08 ± 0.01	KI, MS
4	31.87	1480	1477	Methy-α-Ionone	3.04 ± 0.03	KI, MS
5	28.00	1142	1146	P-Menth-3-en-8-ol	0.81 ± 0.01	KI, MS
Sesquiterpene hydrocarbons						
6	20.36	1363	1359	Cyclosativene	0.16 ± 0.02	KI, MS
7	20.68	1377	1372	α-Copaene	1.19 ± 0.02	KI, MS
8	21.80	1408	1411	α-Gurjunene	2.65 ± 0.04	KI, MS
9	24.25	1460	1457	Rotundene	0.43 ± 0.01	KI, MS
10	26.88	1517	1495	trans-calamenene	0.34 ± 0.01	KI, MS
11	25.84	1467	1474	α-Muurolene	0.26 ± 0.02	KI, MS
Oxygenated sesquiterpenes						
12	26.32	1687	1683	Nerolidyl acetate	1.36 ± 0.04	KI, MS
13	32.11	1645	1646	Torreyol	0.41 ± 0.01	KI, MS
14	32.85	1876	1879	Longifolenaldehyde	0.57 ± 0.03	KI, MS
15	29.15	1580	1544	Caryophyllene oxide	0.30 ± 0.02	KI, MS
16	29.03	1608	1591	Spathulenol	0.21 ± 0.01	KI, MS
17	35.36	1631	1602	Alloaromadendrene oxide-2	0.35 ± 0.03	KI, MS
18	35.70	1675	1681	Z-α-Bisabolene epoxide	0.52 ± 0.02	KI, MS
19	36.30	1749	1753	Driminol	1.11 ± 0.02	KI, MS
20	36.71	1603	1608	Longiborneol	0.26 ± 0.03	KI, MS
21	38.62	1845	1846	Hexahydrofarnesyl acetone	47.35 ± 0.05	KI, MS
22	39.61	2005	2045.9	Isochiapin B	0.74 ± 0.03	KI, MS
Diterpenes						
23	40.26	1811	1810	Phytan	1.19 ± 0.02	KI, MS
Aromatics						
24	30.86	1621	1618	6-methoxy-1-acetonaphthone	19.92 ± 0.06	KI, MS
25	26.58	-	1669	4-(2',3',4'-Trimethylphenyl)-but-3(E)-en-2-one	2.00 ± 0.02	KI, MS
26	28.81	1237	1241	Chavicol	0.43 ± 0.03	KI, MS
Non-terpene compounds						
27	24.16	1555	1550	2,6,10-Trimethyltetradecane	0.64 ± 0.02	KI, MS
28	25.02	1993	1995	10-Octadecenal	0.92 ± 0.03	KI, MS
29	33.02	2100	2098	n-Heneicosane	0.89 ± 0.02	KI, MS
30	37.08	2200	2198	n-Docosane	0.35 ± 0.05	KI, MS
31	42.03	2300	2300	n-Tricosane	0.33 ± 0.01	KI, MS
32	46.81	2700	2703	n-Heptacosane	0.67 ± 0.04	KI, MS
33	48.00	-	2872	13-Heptadecyn-1-ol	1.10 ± 0.02	KI, MS
34	50.08	3200	3203	n-Dotriacontane	3.58 ± 0.03	KI, MS

[a] retention time, [b] Kovats retention index from literature reviews, [c] Experimental Kovates retention index, [d] Values are mean ± SD, and [e] The identification of essential oil components was established depending upon the mass spectral data of compounds (MS) and Kovats indices (RI) with those of Wiley spectral library collection and NIST (the National Institute of Standards and Technology) library databases.

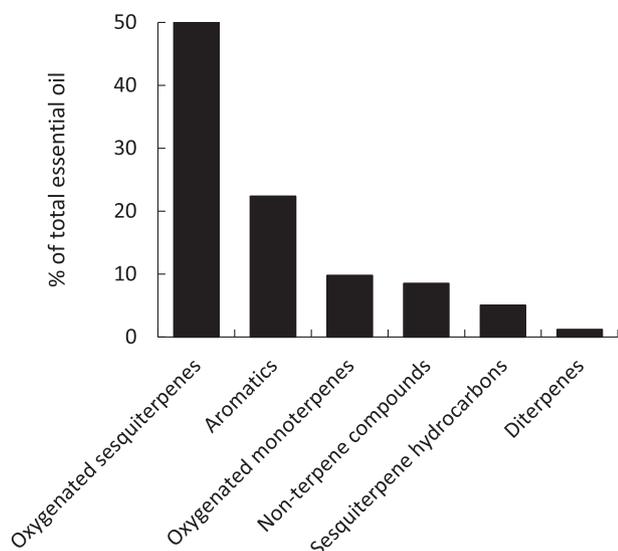


Fig. 2. Essential oil classes from *Bassia muricata* aerial parts.

well as rarely diterpenoids, were reported as the major constituents of EOs of most of the plants. (Abd El-Gawad et al., 2019; Elshamy et al., 2019b)

The sesquiterpenoids were the major components of *B. muricata* EO of which the oxygenated sesquiterpenes constituted 53.18%, and sesquiterpene hydrocarbons were 5.03%. Hexahydrofarnesyl acetone was the main oxygenated sesquiterpenes (47.34%) followed by nerolidyl acetate (1.36%) and driminol (1.11%), while longiborneol represented the minor compound (0.26%). Hexahydrofarnesyl acetone was documented and deduced as widely distributed and preponderance compound in EOs of several plants such as several plants belonging to, *Launaea*, (Elshamy et al., 2019a) *Phlomis*, (Liolios et al., 2007) *Cyperus*, (Nassar et al., 2015) and other genera. The EO composition of the present study is more or less similar to that for *Bassia indica* EO, where the later is also rich in the terpenoids. (El-Shamy et al., 2012) However, the major compound in the EO of *B. indica* was α -thujaplicin.

Monoterpenes were the second major terpenoid components with a concentration of 9.77% from the total. All the identified monoterpenes were characterized as oxygenated type. *Endo*-borneol (3.24%) and 6-methyl- α -ionone (3.04%) represented the main oxygenated monoterpene by around 64.27% from overall identified monoterpenes. Otherwise, *p*-menth-3-en-8-ol was characterized as the minor one. The diterpenes are considered as rare compounds in the EOs of most plants, while few plants have high content of diterpenes such as *Lactuca serriola*, (Abd-ElGawad et al., 2019b) *Araucaria cunninghamii*, and *Araucaria heterophylla*. (Verma et al., 2014) In our study, diterpenes were represented as a minor

class of compounds (1.19%). Only one very common diterpene hydrocarbon, phytan, was characterized. (Liolios et al., 2007; Abd El-Gawad et al., 2019; Elshamy et al., 2019a) In this context, El-Shamy et al. (2012) reported the presence of phytan with comparable content (1.22%) in the EO of *B. indica*.

The aromatic compounds were also characterized in the EO of *B. muricata* with fairly concentration (22.35%) and they are represented by two compounds; 6-methoxy-1-acetonaphthone (19.92%) and 4-(2',3',4'-Trimethylphenyl)-but-3(*E*)-en-2-one (2.0%). Additionally, nine compounds were identified as hydrocarbons with a percentage of 8.48% from the total mass in which *n*-dotriacontane (3.58%), and 13-heptadecyn-1-ol (1.10%) were the majors, while *n*-tricosane was a minor (Table 1).

3.2. Antioxidant activity of *B. muricata* EO

The EO of the aerial parts of *B. muricata* exhibited considerable antioxidant activity comparable with ascorbic acid as a standard reference, where it attained an IC₅₀ value of 20.70 $\mu\text{L L}^{-1}$ and 16.32 $\mu\text{L L}^{-1}$ for DPPH and ABTS, respectively (Table 2). The antioxidant activity of the present EO was higher than those reported for the EOs of other plants such as *Xanthium strumarium*, (Abd El-Gawad et al., 2019) *Cleome droserifolia*, (Abd El-Gawad et al., 2018b) *Cullen plicata*, (Abd El-Gawad, 2016) and *Euphorbia heterophylla*. (Elshamy et al., 2019b)

The antioxidant activity may be correlated to the high percentage of sesquiterpenoids, especially oxygenated ones (53.18%). The oxygenated sesquiterpenoids were reported to have radical scavenging activity. (Barbieri et al., 2016; Abd El-Gawad et al., 2019) The free hydroxy groups in the oxygenated sesquiterpenoids were documented to play a significant role to increase antioxidant abilities due to the highly donating of hydrogen atoms. (Ruberto and Baratta, 2000). Hexahydrofarnesyl acetone, with around 50% from the total mass in our study, might act a leading antioxidant agent as described in previous studies. As example, EOs derived from *Heliotropium curassavicum* (Abd-ElGawad et al., 2019a), *Launaea mucronata*, and *Launaea nudicaulis* (Elshamy et al., 2019a) were described to have significant antioxidant activities due to the abundance of hexahydrofarnesyl acetone. Also, the EO of *B. muricata* consisted of a high percentage of aromatics especially phenolics. The phenolic compounds were deduced to be promising antioxidant agents especially with the presence of free hydroxyl groups that have highly donating of hydrogen atoms. (El-Kashak et al., 2017) Many reports described the high impact of the phenolic compounds as antioxidant agents (Hammad et al., 2013). However, no data for the antioxidant activity of 6-methoxy-1-acetonaphthone are reported till now, thus further study is recommended to evaluate the biological activity of this aromatic compound. Furthermore, the synergetic effect of the interaction of these significant factors that increased by increasing the concentrations of these oxygenated sesquiterpenes and phenolic

Table 2

Scavenging activity of 2,2-Diphenyl-1-picrylhydrazyl (DPPH) and 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) as well as the IC₅₀ values by *Bassia muricata* essential oil.

Treatment	Concentration ($\mu\text{L L}^{-1}$)	DPPH		ABTS	
		Scavenging (%) ^a	IC ₅₀ ($\mu\text{L L}^{-1}$)	Scavenging (%)	IC ₅₀ ($\mu\text{L L}^{-1}$)
<i>Bassia muricata</i> (Essential oil)	5	2.89 ± 0.11 ^E	20.70	4.95 ± 0.19 ^E	16.32
	10	24.62 ± 1.57 ^D		30.46 ± 1.22 ^D	
	15	31.09 ± 1.84 ^C		48.65 ± 1.53 ^C	
	20	50.34 ± 2.00 ^B		65.04 ± 1.05 ^B	
	25	63.53 ± 2.01 ^A		74.11 ± 1.98 ^A	
Ascorbic acid			0.40		0.33

^a Values are means of triplicate ± SE, IC₅₀: the concentration of the sample that required to reduce the DPPH or ABTS absorbance by 50%. Different superscript letters within the column means values significant variation at $p \leq 0.05$.

compounds could briefly play an important role as antioxidant agents.

3.3. Allelopathic activity of *B. muricata* EO

The EO from the aerial parts of *B. muricata* exhibited significant phytotoxic effect ($P \leq 0.05$) on both seed germination and seedling growth of *Chenopodium murale* in a dose-dependent manner (Fig. 3). However, the seedling growth was more affected than the seed germination. At high concentration of the EO ($250 \mu\text{L L}^{-1}$), the germination of seeds was inhibited by 41.51% compared to control, while the shoots and roots were reduced by 52.89% and 65.98%, respectively (Fig. 3). The EO attained IC_{50} value of $175.60 \mu\text{L L}^{-1}$, $246.65 \mu\text{L L}^{-1}$, and $308.33 \mu\text{L L}^{-1}$ for root growth, shoot growth, and germination, respectively. By comparison of the inhibitory activity of the EO with common herbicides, the 2,4-dichlorophenoxyacetic acid (2, 4-D), 2,4,5-trichlorophenoxyacetic acid (2, 4, 5-T), and 2-methyl-4-chlorophenoxyacetic acid (MCPA) were reported to inhibited the seed germination of *C. murale* by 78.82%, 44.71% and 35.29%, respectively at concentration of 250 ppm. (Agarwal, 2009). This means that the activity of the EO from *B. muricata* showed a comparable effect to that for the synthetic herbicide 2, 4, 5-T and higher activity than MCPA. It is worth mentioning herer that *C. murale* is considered as winner weed in the cultivated crops as well as the roadsides habitat. It is imported to the cultivated land as contaminants with the seeds and it has cabability to compete with the crops via allelopathy (Al-Johani et al., 2012).

The roots of *C. murale* were more sensitive to the phytotoxic effect of the EO than shoots. This sensitivity could be correlated to the direct contact with the allelochemicals (EO) as well as the membrane permeability of the root cells. (Abd El-Gawad, 2014; El-Shora and Abd El-Gawad, 2015b,a; Abd El-Gawad, 2016; Abd El-Gawad et al., 2019)

The EOs from various plants were tested against the weed *C. murale* such as *Tagetes minuta* (Arora et al., 2017) and *Cleome droserifolia*. (Abd El-Gawad et al., 2018b) The EO from *C. droserifolia* attained the IC_{50} value of 157.5, 147.1, and $169.4 \mu\text{L L}^{-1}$, for the germination, root growth, shoot growth of *C. murale*, respectively. (Abd El-Gawad et al., 2018b) However, the EO from *T. minuta*

showed less effective germination inhibition on the *C. murale*, where it attained an IC_{50} value of $490 \mu\text{L L}^{-1}$

The oxygenated terpenes are considered to be more biologically active than non-oxygenated ones. (Dambolena et al., 2016) In the present study, the majority of compounds are oxygenated, so this could explain the activity of our EO. The hexahydrofarnesyl acetone was reported as predominant compounds of the EOs from *Hildegardia barteri*, (Balogun et al., 2017) *Equisetum arvense*, (Radulović et al., 2006) *Geranium columbinum*, (Radulović et al., 2011) *Tilia tomentosa*, (Fitsiou et al., 2007) *Ecballium elaterium*, (Razavi and Nejad-Ebrahimi, 2010) *Sagittaria trifolia*, (Xiangwei et al., 2006) *Leontopodium longifolium*, (Qian et al., 2018) *Phlomis bucharica*, *P. salicifolia* and *P. sewerzowii*. (Mamadaliyeva et al., 2019) In addition, the EOs from these plants exhibited antimicrobial, (Xiangwei et al., 2006; Radulović et al., 2011; Balogun et al., 2017; Mamadaliyeva et al., 2019) antioxidant, (Qian et al., 2018) and allelopathic activities. (Razavi and Nejad-Ebrahimi, 2010)

The amount of hexahydrofarnesyl acetone our EO was higher (47.35%) than all these plants (11.0–19.1%), except for *S. trifolia*, which comprises 62.3%. Thereby, the allelopathic activity of *B. muricata* EO could be ascribed to this major compound. However, the allelopathic activity of the other major compound 6-methoxy-1-acetonaphthone still is not known.

Hexahydrofarnesyl acetone is a very common identified sesquiterpene in EOs derived from numerous plant species. This compound was reported as major compound in EOs of several plants such as *Atriplex cana*, (Wei et al., 2019), *Launaea lanifera*, (Abd El-Gawad and El-Shora, 2017), *Cyperus leavigatus*, (Nassar et al., 2015) *Trianthema portulacastrum*, (Abd El-Gawad et al., 2016) *Launaea mucronata* and *Launaea nudicaulis*, (Verma et al., 2014). Elshamy et al. (2019a) ascribed the phytotoxic activity of the EO from *Launaea* species to hexahydrofarnesyl acetone as major compound. In addition, Wei et al. (2019) deduced that the significant phytotoxic activity of *Atriplex cana* EO was correlated with the major compounds especially hexahydrofarnesyl acetone.

On the other hand, *C. murale* has been reported to have various allelochemicals such as benzoic acid, *p*-coumaric acid, ferulic acid, and vanillic acid. (Batish et al., 2007b) *C. murale* is a noxious weed as it interferes negatively with wheat, (Batish et al., 2007a; Majeed et al., 2012) barley, (Al-Johani et al., 2012) rice, (Alam and Shaikh, 2007) pea, and chickpea (Batish et al., 2007b) through its allelopathic activity.

Summing up, our results revealed promising allelopathic activity against weeds, at least the noxious weed *C. murale* compared to other EOs reported from other wild plants. Therefore, the EO from *B. muricata* aerial parts could be integrated into the control tools of the *C. murale* as green, biodegradable, and eco-friendly resource.

4. Conclusions

The very rich EO with terpenoids from the aerial parts of *B. muricata* was found to have 34 compounds. Sesquiterpenes represented the major class (58.21%) with abundance of hexahydrofarnesyl acetone, 6-methoxy-1-acetonaphthone, *n*-tricosane, *endo*-borneol, and methyl- α -ionone. The EO of *B. muricata* exhibited considerable antioxidant activity; thus, it could be used as a green antioxidant. The present study revealed that EO from *B. muricata* has potential allelopathic activity against the weed *C. murale*. Therefore, this EO could be a promising food supplement and natural, green, eco-friendly resource to control this noxious weed. However, further studies are required to separate the chemical compounds from the EO of *B. muricata*, and evaluate their allelopathic activities individually or in combination against *C. murale* or maybe other weeds, and evaluate its valuable economic use on a large scale.

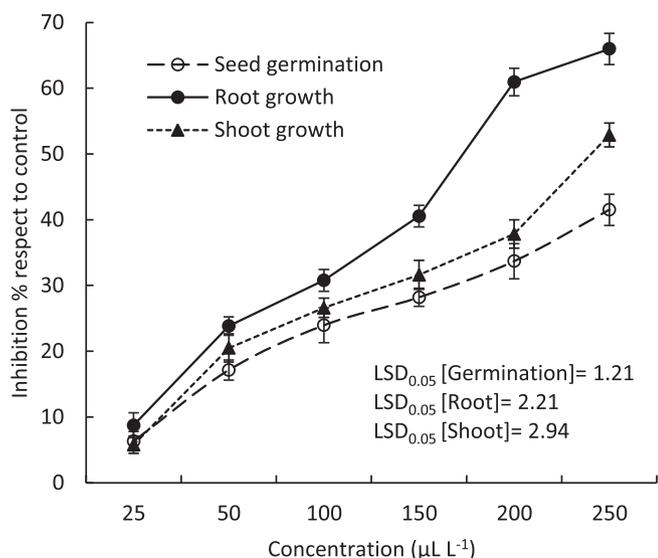


Fig. 3. Inhibitory effect of different concentrations of the essential oil from the aerial parts of *Bassia muricata* on the germination, root, and shoot growth of *Chenopodium murale*.

Author contributions

Conceptualization, A.A-E. and A.E.; Data curation, A.A-E. and A. E.; Formal analysis, A.A-E., A.E-G., A.G. and A.E.; Investigation, A. A-E., Y.E., A.G. and A.E.; Methodology, A.A-E., A.E-G. and Y.E.; Resources, A.A-E. and A.E.; Writing – original draft, A.A-E., Y.E. and A.E.; Writing – review & editing, A.A-E., S.O., S.A-R., A.A., Y.D., and A.E.

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Declaration of Competing Interest

The authors declare that there is no conflict of interest.

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