Chemical Composition and Inhibitory Effects of Essential Oils on Germination and Seedling Growth of Barnyard Grass, *Echinochloa crusgalli* L.

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ABSTRACT

Hydrodistilled essential oils from twenty plant species grown in Egypt were analyzed by gas chromatography-mass spectrometry (GC-MS). The isolated oils were enriched with monoterpene hydrocarbons (i.e., limonene, sabinene, β-pinene, γ-terpinene, α-phellandrene, β-phellandrene, δ-3-carene, cis-Ocimene) and oxygenated monoterpenes (i.e., terpinen-4-ol, β–thujone, 4-terpineol, linalool, α-citral, β-citronellol, 1,8-cineole, camphor, pulegone, α-terpinolene) except the oil of *Schinus terebinthifolius* which was enriched with sesquiterpenes, and the oil of *Vitex agnus-castus* which contained similar amounts of monoterpenes and sesquiterpenes. The inhibitory effects of the essential oils on seed germination and seedling growth of barnyard grass, *Echinochloa crusgalli* were examined. The oil of *Myrtus communis* was the most potent seed germination inhibitor at the tested concentrations (625, 1250, 2500, and 5000 mg L^{-1}), followed by the oils of *Pelargonlum graveolens*, *V. agnus-castus*, *Cupressus macrocarpa* and *S. terebinthifolius*, while the oils of *Citrus lemon*, *Artemisla judaica* and *Cupressus sempervlrens* were the less effective. Furthermore, the oils of *M. communis*, *A. monosperma*, *V. agnus-castus* and *P. graveolens* showed the highest inhibition of root and shoot growth. However, the inhibition of root growth by all essential oils was greater than that of shoot growth. These results suggest that the essential oils may serve as natural herbicidal products.

Key words*: Essential oils, Egyptian plants, chemical composition, herbicidal activity, *Echlnochloa crusgalli

INTRODUCTION

The flora of Egypt includes about 2000 species of plants distributed in its different localities that vary in type of soil and prevailing climatic and other environmental conditions. In addition, many plants have been successfully introduced and acclimatized in Egypt (Khedr et al., 2002). Although chemical constituents and bioactivities of thousands of plants all over the world have been investigated against different pests and plant pathogens, many of Egyptian plants have not systemically been examined. Thus, it is very useful to study the chemical profiles and the biological activities of the Egyptian plants to explore their possible use in pest management programs.

Essential oils are a complex mixture of compounds, mainly monoterpenes, sesquiterpenes, and their oxygenated derivatives (alcohols, aldehydes, esters, ethers, ketones, phenols and oxides). Some volatile compounds present in essential oils include phenylpropenes and specific sulphur- or nitrogen-containing substances. Generally, essential oil composition is a balance of various compounds, although in many species one constituent may prevail over all others (Cowan, 1999). Plant essential oils, in general, have been recognized as an important natural resource of biopesticides (Gbolade et al., 2000). Their lipophilic nature facilitates their interference with basic metabolic, biochemical, physiological and behavioral functions of pests (Nishimura, 2001). Earlier studies have documented that essential oils and their constituents, mainly monoterpenoids, possess allelopathic and phytotoxic effects (Barney et al., 2005; Batish et al., 2006; Mutlu et al., 2010; Krifa et al., 2011).

Barnyard grass (*Echinochloa crusgalli* L.), an annual grass, is widely spread throughout the world. It has been reported to cause problems in at least 61 countries and in at least 36 different crops (Holm *et al.*, 1991). It is a major weed in paddy fields as it competes with rice (*Oryza sativa* L.) and causes reduction in rice yield. It reduces crop yields by removing up to 80% of the soil nitrogen. Competition from 25 barnyard grass plants/m^2 can cause 50% reduction in rice yield (Chin, 2001).

The aims of the present study were to investigate the chemical compositions of essential oils isolated from twenty plants growing in Northern Egypt, namely, *Artemisia judaica*, *A. monosperma*, *Astoma* seselifolium, *Callistemon viminals*, *Citrus aurantifolia*, *C. lemon*, *C. paradisi*, *C. sinensis*, *Cupressus macrocarpa*, *C. sempervirens*, *Myrtus communis*, *Origanum vulgare*, *Pelargonium graveolens*, *Pituranthos tortuosus*, *Rosmarinus officinalis*, *Syzygium cumini*, *Schinus molle*, *S. terebinthifolius*, *Thuja occidentalis* and *Vitex agnus-castus*, and evaluate the inhibitory effects of these essential oils on germination and seedling growth of barnyard grass, *E. crusgalli*, with a view to explore them as bioherbicides for management of this weed.

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MATERIALIS AND METHODS

Plant materials

Twenty plant species were collected during the flowering stage from different locations of Alexandria, Behira and Matrouh Governorates, Egypt, in August, 2010 to April, 2011. The plant names and their used parts are shown in Table 1. The plant materials were identified by Prof. FathAllah Zaitoon of Plant Pathology Department, Faculty of Agriculture, Alexandria University. Voucher specimens have been deposited in Department of Pesticides Chemistry, Faculty of Agriculture, Alexandria University.

Isolation of essential oils

The aerial plant parts and leaves were partially dried at room temperature (26±1°C) for five days and the fruit peels were used fresh. The plant materials were subjected to 3h of hydrodistillation in a Clevenger-type apparatus. The resulting oils were dried over anhydrous sodium sulfate (Na_2SO_4). The oil yields and their colors are presented in Table 1. The oil samples were stored at 4 °C until used for GC-MS analysis and phytotoxic effects.

Analysis of essential oils

Analyses of essential oils were run on a gas chromatography (Hewlwett Packard 5890)/mass spectrometry (Hewlwett Packard 5989B) (GC-MS) apparatus. Essential oils were diluted in diethyl ether and the injection volume was 0.5 µl. The GC column was a 30 m (0.25 mm i.d., film thickness 0.25 µm) HP-5MS (5% diphenyl) dimethylpolysiloxane capillary column. The GC conditions were as follows: injector temperature, 240°C; column temperature, isothermal at 70°C and held for 2 min, then programmed to 280°C at 6°C/min and held at this temperature for 2 min; ion source temperature, 200°C; detector temperature, 300°C. Helium was used as the carrier gas at the rate of 1 mL min^{-1}. The effluent of the GC column was introduced directly into the ion source of the MS. Spectra were obtained in the EI mode with 70 eV ionization energy. The sector mass analyzer was set to scan from 40 to 400 amu for 5 s. The oil components were identified by comparison of their retention indices and mass spectra with the NIST Mass Spectral Library.

Test weed

Seeds of a field biotype barnyard grass, *Echinochloa crusgalli* L. (Poaceae) were obtained from Faculty of Agriculture Farm, Alexandria, Egypt. Uniform seeds were selected for the test while undersized and damaged seeds were discarded. Germination of the seeds was tested before use and was 55%.

Seed germination and seedling growth tests

Phytotoxic effects of the isolated essential oils were evaluated on barnyard grass (*Echinochloa crusgalli*) germination and subsequent seedling growth. The solutions of tested oils were first prepared in dimethyl sulfoxide (DMSO). Serial dilutions of these solutions were prepared with distilled water containing 0.02% of an emulsifying agent (Triton-X 100) to give the concentrations of 625, 1250, 2500, and 5000 mg L^{-1}. An aqueous solution of DMSO (0.5% v/v) and Triton-X 100 (0.02%) was used as control treatment. Twenty seeds were placed in each Petri dishes (9 cm) lined with Whatman No. 2 filter paper. Three replicates were prepared for each treatment . Six milliliters of each test solution were added to the Petri dish. Afterward, Petri dishes were placed in the bottom of 0.1 mm thick polyethylene bags (15 × 30 cm) that were expanded to contain air and then closed at the top with rubber bands to prevent the loss of moisture. The Petri dishes were kept on a germination cabinet at 26±2 C with a 12-h photoperiod. After 6 days of sowing, the percentages of seed germination and the lengths of root and shoot were determined. The growth inhibition percentages of root and shoot lengths were calculated from the following equation: I (%) = [1 - T/C] × 100; T is the root or shoot length of treatment (cm) and C is the root or shoot length of control (cm).

Statistical analysis

Germination percentages, root lengths and shoot lengths were subjected to one-way analysis of variance followed by Student–Newman–Keuls test (Cohort software Inc. 1985) to determine significant differences among mean values at the probability level of 0.05.

RESULTS

Yields and chemical compositions of the isolated essential oils

The essential oil yields of the selected plant species obtained by hydrodistillation, on a partially dry and/or fresh weight basis, are shown in Table 1. The oil yields ranged between 0.08% and 0.88% (v/w). The plants of *S. molle*, *A. monosperma*, *C. aurantifolia* and *C. sinensis* contained high concentrations of oils, while the plants of *S. cumini*, *P. graveolens*, *A. seselifolium* and *C. paradisi* contained low concentrations of oils. The major components of the essential oils are presented in Table 1. It can be noticed that, some major components were found in more than one plant, such as limonene, α-pinene, β-pinene, 1,8-cineole, β-citronellol, sabinene and γ-terpinene but others were specific to the plant species. The major constituents of the essential oils mainly belonged to four chemical groups: oxygenated monoterpenes (e.i., α-thujone, β-

thujone, chrysanthenone, terpinen-4-ol, linalool, pulegone, α-citral, β-citronellol camphor and linalool oxide), monoterpene hydrocarbons (e.i., limonene, sabinene, γ-terpinene, β-pinene, δ-3-carene, phellandrene and α-pinene), sesquiterpene hydrocarbons (e.i., bicyclogermacrene, α-elemene, β-elemene and *trans*-caryophyllene) and oxygenated sesquiterpenes (e.i., cedrol and elemol).

Effect of essential oils on *E. crusgalli* seed germination

The inhibitory effect of isolated oils on seed germination of *E. crusgalli* after 6 days of treatment is shown in Table 2. The results indicated that seed germination responses of *E. crusgalli* to essential oils differed significantly depending on the plant species and oil concentration. All of the tested oils caused significant reduction of seed germination particularly at the higher concentrations of 2500 and 5000 mg L^{-1}.

Table 1. Major constituents and yields of essential oils isolated from twenty Egyptian plant species

Plant name	Family	Plant part	Oil yield (%) (v/w) (color)	Major components (%)
Artemisia judaica	Asteraceae	Aerial parts	0.2 (Pale yellow)	β –Thujone (49.83), Chrysanthenone (10.88), α-Thujone (8.21), 1,8-Cineole (4.91)
Artemisia monosperma	Asteraceae	Leaves	0.8 (Pale yellow)	Capillene (36.86), capillin (14.68), γ-Terpinene (12.46), β-Pinene (7.85)
Astoma seselifolium	Apiaceae	Leaves	0.1 (Pale yellow)	Sabinene (23.02), 4-Terpineol (17.83), γ-Terpinene (8.97), Germacrene D (8.27)
Citrus aurantifolia	Rutaceae	Fruit peels	0.75 (Colorless)	Limonene (40.19), β-Pinene (19.65), α-Citral (8.14), γ-Terpinene (6.34)
Citrus limon	Rutaceae	Fruit peels	0.2 (Colorless)	Limonene (56.30), β-Pinene (8.81), γ-Terpinene (6.42), α-Citral (4.96)
Cupressus macrocarpa	Cupressaceae	Leaves	0.45 (Colorless)	Terpinen-4-ol (20.29), Sabinene (18.67), β-Citronellol (13.01), γ-Terpinene (7.59)
Citrus paradisi	Rutaceae	Fruit peels	0.12 (Colorless)	Limonene (74.29), Linalool (4.61), Linalool oxide (4.18), β-Citral (2.66)
Cupressus sempervirens	Cupressaceae	Leaves	0.14 (Colorless)	α-Pinene (37.88), δ-Carene (20.05), α-Terpinolene (6.91), β-Myrcene (5.47)
Citrus sinensis	Rutaceae	Fruit peels	0.7 (Colorless)	Limonene (89.23), Linalool (2.98), β-Myrcene (1.77), Octanal (1.28)
Callistemon viminals	Myrtaceae	Leaves	0.5 (Colorless)	1,8-Cineole (71.77), α-Pinene (11.47), Terpinen-4-ol (3.18), Octadecanoic acid (3.08)
Myrtus communis	Myrtaceae	Leaves	0.2 (Pale yellow)	α-Pinene (26.16), 1,8-Cineole (16.45), Linalool (11.23), β-Fenchyl alcohol (8.34)
Origanum vulgare	Lamiaceae	Aerial parts	0.5 (Pale yellow)	Pulegone (77.45), Menthone (4.86), *cis*-Isopulegone (2.22), Piperitenone (2.13)
Pelargonium graveolens	Geraniaceae	Leaves	0.09 (Pale yellow)	β-Citronellol (35.92), Geraniol (11.66), Citronellylformate(11.40), Linalool (9.63)
Pituranthos tortuosus	Apiaceae	Aerial parts	0.22 (Pale yellow)	Sabinene (32.09), Terpinen-4-ol (20.31), Myristicine (6.84), Dillapiole (5.72)
Rosmarinus officinalis	Lamiaceae	Leaves	0.33 (Colorless)	1,8-Cineole (19.60), Camphor (17.01), α-Pinene (15.12), Verbenone (9.55)
Syzygium cumini	Myrtaceae	Leaves	0.08 (Pale yellow)	α-Pinene (17.26), α-Terpineol (13.88), β-Pinene (11.28), cis-Ocimene (11.27)
Schinus molle	Anacardiaceae	Leaves	0.88 (Colorless)	α-Phellandrene (29.87), β-Phellandrene (21.08), Elemol (13.00), τ-Muurolol (5.35)
Schinus terebinthifolius	Anacardiaceae	Leaves	0.25 (Colorless)	Sabinene (14.93), γ-Elemene (13.18), β-Elemene (6.63), α-Candiol (6.61)
Thuja occidentalis	Cupressaceae	Leaves	0.25 (Pale yellow)	α-Pinene (35.49), δ-3-Carene (25.42), α-Cedrol (9.05), α-Terpinolene (6.76)
Vitex agnus-castus	Lamiaceae	Leaves	0.16 (Yellow)	*trans*-Caryophyllene (15.19), 1,8-Cineole (13.04), *trans*-β-Farnesene (8.35), 4-Terpineol (7.45)

Table 2. Effect of essential oils on *Echinochloa crusgalli* seed germination 6 d after sowing[a]

Conc mg L^{-1}	Germination % ± SE				
	Plant oil				
	A. Judaica	*A. monosperma*	*A. seselifolium*	*C. aurantifolia*	*C. limon*
0	55.0±2.89a[b]	55.0±2.89a	55.0±2.89a	55.0±2.89a	55.0±2.89a
625	55.0±2.89a[b]	45.0±2.89ab	45.0±2.89b	50.0±2.89b	50.0±2.89ab
1250	48.3±1.66ab	43.3±1.66ab	41.7±3.33b	48.3±3.31b	45.0±0.0ab
2500	43.3±1.66b	33.3±3.31b	38.3±3.33b	48.3±3.31b	45.0±0.0ab
5000	43.3±1.66b	33.3±4.41b	36.7±1.66b	31.7±1.66b	43.3±5.77b
Conc mg L^{-1}	Germination % ± SE				
	Plant oil				
	C. macrocarpa	*C. paradisi*	*C. sempervirens*	*C. sinensis*	*C. viminals*
0	55.0±2.89a	55.0±2.89a	55.0±2.89a	55.0±2.89a	55.0±2.89a
625	38.3±4.41b	38.3±1.66b	43.3±3.33b	40.0±2.89b	40.0±5.78b
1250	38.3±1.66b	38.3±1.66b	41.7±1.66b	40.0±5.0b	40.0±2.89b
2500	38.3±3.33b	35.0±5.01b	40.0±2.89b	36.7±3.33b	38.3±3.31b
5000	26.7±4.41b	35.0±2.89b	40.0±0.0b	36.7±3.33b	38.3±6.01b
Conc mg L^{-1}	Germination % ± SE				
	Plant oil				
	M. communis	*O. vulgare*	*P. graveolens*	*P. tortuosus*	*R. officinals*
0	55.0±2.89a	55.0±2.89a	55.0±2.89a	55.0±2.89a	55.0±2.89a
625	33.3±1.66b	53.3±4.41a	55.0±2.89a	38.3±1.66b	40.0±0.0b
1250	30.0±2.89b	31.7±1.66b	33.3±1.66b	36.7±4.41b	38.3±3.31b
2500	25.0±2.89b	30.0±2.89b	28.3±3.31b	35.0±0.0b	36.7±3.31b
5000	11.7±1.66c	30.0±2.89b	16.7±3.31c	35.0±2.89b	31.7±3.31b
Conc mg L^{-1}	Germination % ± SE				
	Plant oil				
	S. cumini	*S. molle*	*S. terebinthifolius*	*T. occidentalis*	*V. agnus-castus*
0	55.0±2.89a	55.0±2.89a	55.0±2.89a	55.0±2.89a	55.0±2.89a
625	41.7±4.41b	43.3±1.66b	38.3±4.41b	43.33±3.33b	33.3±1.66b
1250	35.0±2.89b	43.3±1.66b	38.3±1.66b	43.3±1.66b	31.7±1.66b
2500	31.7±1.66b	33.3±4.41b	36.7±3.33b	38.3±3.33b	31.7±4.41b
5000	31.7±1.66b	31.7±1.66b	28.3±3.33b	38.3±3.33b	31.7±1.66b

[a] Data are expressed as means ± SE from experiments with three replicates of 20 seeds each.
[b] Means within a column sharing the same letter are not significantly different at the 0.05 probability level.

The oil of *M. communis* revealed the highest reduction of seed germination at the tested concentrations. In addition, the oils of *P. graveolens*, *V. agnus-castus*, *C. macrocarpa* and *S. terebinthifolius* showed remarkable inhibition of seed germination. In contrast, the oils of *C. lemon*, *A. judaica* and *C. sempervirens* displayed the lowest inhibition of seed germination at the tested concentrations.

Effect of essential oils on *E. crusgalli* seedling growth

The mean of root lengths and the percents of root growth inhibition of *E. crusgalli* treated with different concentrations of isolated oils are presented in Table 3. The results revealed that the tested oils caused reduction of root growth based on the concentration and the plant species. In the most cases, the reduction of root growth was in concentration-dependent manner. At the concentration of 625 mg L^{-1}, the oils of *R. officinalis*, *C. lemon* and *A. monosperma* caused the highest reduction in root growth with inhibition percents of 54.5%, 45.5% and 40.9%, respectively. In contrary, the oils of *O. vulgare* and *V. agnus-castus* stimulated the root growth compared with control, while the oils of *C. macrocarpa*, *S. cumini* and *S. molle* showed no root inhibition at this concentration. At the concentration of 1250 mg L^{-1}, all of the tested oils inhibited root growth except the oil of *S. molle*.

Table 3. Effect of essential oils on *Echinochloa crusgalli* root growth 6 d after sowing[a]

Conc mg L^{-1}	*A. Judaica*		*A. monosperma*		*A. seselifolium*		*C. aurantifolia*	
	Root length (cm)	I (%)[b]	Root length (cm)	I (%)	Root length (cm)	I (%)	Root length (cm)	I (%)
0	2.2±0.11a[c]	0.0	2.2±0.11a	0.0	2.2±0.11a	0.0	2.2±0.11a	0.0
625	2.1±0.29a	4.5	1.3±0.15b	40.9	1.9±0.19a	13.6	1.8±0.28ab	18.2
1250	1.5±0.12b	31.8	1.2±0.15b	45.5	1.9±0.24a	13.6	1.5±0.07b	31.8
2500	1.2±0.15c	45.5	1.1±0.21b	50.0	0.9±0.15b	59.1	1.4±0.03b	36.4
5000	0.5±0.07d	77.3	0.1±0.03c	95.5	0.7±0.23b	68.2	0.3±0.07c	86.4
Conc mg L^{-1}	*C. limon*		*C. macrocarpa*		*C. paradisi*		*C. sempervirens*	
	Root length (cm)	I (%)	Root length (cm)	I (%)	Root length (cm)	I (%)	Root length (cm)	I (%)
0	2.2±0.11a	0.0	2.2±0.11a	0.0	2.2±0.11a	0.0	2.2±0.11a	0.0
625	1.2±0.22b	45.5	2.2±0.20a	0.0	2.0±0.03a	9.1	2.1±0.17a	4.5
1250	1.2±0.25b	45.5	1.5±0.09b	31.8	1.4±0.15b	36.4	1.8±0.21a	18.2
2500	0.5±0.07b	77.3	1.4±0.12b	36.4	1.3±0.12b	40.9	0.9±0.22b	59.1
5000	0.5±0.09b	77.3	0.6±0.12c	72.7	0.9±0.09c	59.1	0.6±0.19b	72.7
Conc mg L^{-1}	*C. sinensis*		*C. viminals*		*M. communis*		*O. vulgare*	
	Root length (cm)	I (%)	Root length (cm)	I (%)	Root length (cm)	I (%)	Root length (cm)	I (%)
0	2.2±0.11a	0.0	2.2±0.11a	0.0	2.2±0.11a	0.0	2.2±0.11a	0.0
625	1.9±0.12ab	13.6	1.6±0.20b	27.3	1.8±0.12ab	18.2	2.3±0.26a	–4.5
1250	1.9±0.18ab	13.6	1.4±0.19b	36.4	1.6±0.20b	27.3	1.5±0.26b	31.8
2500	1.4±0.19bc	36.4	1.3±0.17b	40.9	0.5±0.07c	77.3	1.1±0.19b	50.0
5000	1.3±0.12c	40.9	0.6±0.07c	72.7	0.1±0.02d	95.5	0.7±0.35b	68.2
Conc mg L^{-1}	*P. graveolens*		*P. tortuosus*		*R. officinals*		*S. cumini*	
	Root length (cm)	I (%)	Root length (cm)	I (%)	Root length (cm)	I (%)	Root length (cm)	I (%)
0	2.2±0.11a	0.0	2.2±0.11a	0.0	2.2±0.11a	0.0	2.2±0.11a	0.0
625	2.1±0.22a	4.5	1.9±0.23a	13.6	1.0±0.09b	54.5	2.2±0.20a	0.0
1250	1.2±0.42b	45.5	1.8±0.15a	18.2	0.9±0.10bc	59.1	1.5±0.15b	31.8
2500	0.6±0.10c	72.7	1.7±0.12a	22.7	0.9±0.15bc	59.1	1.3±0.22b	40.9
5000	0.2±0.06c	90.9	0.9±0.13b	59.1	0.5±0.12c	77.3	0.4±0.10c	81.8
Conc mg L^{-1}	*S. molle*		*S. terebinthifolius*		*T. occidentalis*		*V. agnus-castus*	
	Root length (cm)	I (%)	Root length (cm)	I (%)	Root length (cm)	I (%)	Root length (cm)	I (%)
0	2.2±0.11a	0.0	2.2±0.11a	0.0	2.2±0.11a	0.0	2.2±0.11a	0.0
625	2.2±0.13a	0.0	2.1±0.31a	4.5	2.1±0.23b	4.5	2.4±0.09a	–9.1
1250	2.2±0.17a	0.0	1.9±0.06a	13.6	2.1±0.12b	4.5	1.6±0.23b	27.3
2500	0.9±0.18b	59.1	1.6±0.18a	27.3	1.6±0.15b	27.3	1.1±0.12c	50.0
5000	0.3±0.12c	86.4	1.0±0.15b	54.5	1.0±0.12b	54.5	0.2±0.06d	90.9

[a] Data are expressed as means ±SE from experiments with three replicates of 20 seeds each.
[b] I = inhibition.
[c] Means within a column sharing the same letter are not significantly different at the 0.05 probability level.

The oil of *R. officinalis* revealed the highest root growth inhibition (59.1%), followed by the oils of *A. monosperma*, *C. lemon* and *P. graveolens*. The oils displayed strong root growth inhibition at concentrations of 2500 and 5000 mg L^{-1}. The inhibition percents of *E. crusgalli* root growth ranged between 22.7% and 77.7% at concentration of 2500 mg L^{-1}, and ranged between 40.9% and 95.9% at concentration of 5000 mg L^{-1}.

The essential oils of *M. communis*, *A. monosperma* and *V. agnus-castus* showed pronounced shoot growth inhibition of *E. crusgalli* at the tested concentrations (Table 4). In contrary, the oils of *A. seselifolium*, *C. sempervirens* and *T. occidentalis* displayed weak shoot growth inhibition without significant differences between the treatments and control. The other oils showed moderate shoot growth inhibition.

Table 4. Effect of essential oils on *Echinochloa crusgalli* shoot growth 6 d after sowing[a]

Conc mg L^{-1}	*A. Judaica*		*A. monosperma*		*A. seselifolium*		*C. aurantifolia*	
	Shoot length (cm)	I (%)[b]	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)
0	4.6±0.12a[c]	0.0	4.6±0.12a	0.0	4.6±0.12a	0.0	4.6±0.12a	.0.0
625	3.8±0.10b	17.9	3.3±0.0b	28.3	4.6±0.10a	0.0	3.6±0.22b	21.7
1250	3.6±0.10b	21.7	3.3±0.03b	28.3	4.5±0.19a	2.2	3.5±0.35b	23.9
2500	3.4±0.18b	26.1	3.2±0.06b	30.4	4.3±0.13a	6.5	3.4±0.24b	26.1
5000	2.5±0.24c	45.7	1.6±0.17c	65.2	4.1±0.09a	10.9	2.3±0.20c	50.0
Conc mg L^{-1}	*C. limon*		*C. macrocarpa*		*C. paradisi*		*C. sempervirens*	
	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)
0	4.6±0.12a	0.0	4.6±0.12a	0.0	4.6±0.12a	0.0	4.6±0.12a	0.0
625	4.0±0.30ab	13.0	4.0±0.22b	13.0	3.9±0.33ab	15.2	4.3±0.10a	6.5
1250	3.5±0.26bc	23.9	4.0±0.22b	13.0	3.8±0.22ab	17.9	4.2±0.09a	8.7
2500	3.2±0.21cd	30.4	3.6±0.09b	21.7	3.6±0.15b	21.7	3.8±0.29a	17.9
5000	2.7±0.06c	41.3	2.7±0.09c	41.3	3.3±0.20b	28.7	3.8±0.26a	17.9
Conc mg L^{-1}	*C. sinensis*		*C. viminals*		*M. communis*		*O. vulgare*	
	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)
0	4.6±0.12a	0.0	4.6±0.12a	0.0	4.6±0.12a	0.0	4.6±0.12a	0.0
625	3.8±0.1b	17.9	3.9±0.27b	15.2	3.7±0.01b	19.6	4.1±0.07b	10.9
1250	3.7±0.06b	19.6	3.4±0.22b	26.1	2.8±0.17c	39.1	3.9±0.19bc	15.2
2500	3.4±0.03bc	26.1	3.3±0.25b	28.3	1.9±0.15d	58.7	3.4±0.25c	26.1
5000	3.2±0.15c	30.4	3.3±0.27b	28.3	0.7±0.10c	84.8	3.4±0.10c	26.1
Conc mg L^{-1}	*P. graveolens*		*P. tortuosus*		*R. officinals*		*S. cumini*	
	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)
0	4.6±0.12a	0.0	4.6±0.12a	0.0	4.6±0.12a	0.0	4.6±0.12a	0.0
625	4.3±0.12a	6.5	3.9±0.27b	15.2	3.7±0.19b	19.6	3.6±0.27b	21.7
1250	3.6±0.19b	21.7	3.8±0.19b	17.9	2.8±0.07c	39.1	3.3±0.12b	28.3
2500	3.5±0.10b	23.9	3.6±0.27b	21.7	2.8±0.07c	39.1	3.1±0.09b	32.6
5000	2.2±0.23c	52.2	2.9±0.28b	37.0	2.6±.23c	43.5	2.5±0.12c	45.7
Conc mg L^{-1}	*S. molle*		*S. tereblnthifolius*		*T. occidentalis*		*V. agnus-castus*	
	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)	Shoot length (cm)	I (%)
0	4.6±0.12a	0.0	4.6±0.12a	0.0	4.6±0.12a	0.0	4.6±0.12a	0.0
625	3.9±0.21b	15.2	4.4±0.10a	4.3	4.2±0.26a	8.7	2.9±0.25b	37.0
1250	3.8±0.17b	17.9	3.7±0.15b	19.6	4.1±0.09a	10.9	2.9±0.25b	37.0
2500	3.4±0.07bc	26.1	3.7±0.15b	19.6	3.7±0.28a	19.6	2.7±0.06b	41.3
5000	3.0±0.20c	34.8	3.3±0.27b	28.3	3.7±0.22a	19.6	2.1±0.06b	54.3

[a] Data are expressed as means ±SE from experiments with three replicates of 20 seeds each.
[b] I = inhibition.
[c] Means within a column sharing the same letter are not significantly different at the 0.05 probability level.

DISCUSSION

The chemical compositions of the isolated essential oils from *C. aurantifolia*, *C. paradise*, *C. limon*, *C. sinensis*, *C. viminals*, *C. sempervirens*, *S. molle*, *C. macrocarpa*, *P. graveolens*, *R. officinals* and *M. communis* are in accordance with those previously reported in literature (Lota et al., 2001; Srivastava et al., 2003; Tuberoso et al., 2006; Viuda-Martos et al., 2009; Bendaoud et al., 2010). The oil of *A. seselifolium* was analysed for the first time in this study. On the other hand, the major constituents of the essential oils isolated from *A. monosperma*, *O. vulgare*, *T. occidentalis* and *A. judaica* were completely differed with those previously reported on the chemistry of these oils (Şahin et al., 2004; Mohamed and Abdelgaleil, 2008; Tsiri et al., 2009; Khan et al., 2012). Some of the major constituents of the essential oils of *P. tortuosus*, *V. agnus-castus*, *S.*

terebinthifolius and *S. cumini* were similar to those previously reported for the oils isolated from plants growing in Egypt and other countries around the world (Singab et al., 2003; Gundidza et al., 2009; Stojković et al., 2011). However, the percentages of the major constituents are differed. The chemical composition of essential oils of the same plants may vary widely depending on geographical location, season, environmental conditions and nutritional status of the plants (Perry et al., 1999).

All of the tested oils showed seed germination inhibition against *E. crusgalli*. In general, our results agree with those reported in the literature on inhibitory activity exerted by some of tested essential oils on seed germination of other plant and weed species. For example, the oils of *S. molle*, *A. judaica*, *R. officinals*, *O. vulgare* and *P. graveolens* were described to possess seed germination inhibition of wheat, *Triticum aestivum* L. (Dudai et al., 1999; Zahed et al., 2010). The oil of *R. officinals* showed inhibitory effect on seed germination of *Cynodon dactylon* L., *Festuca arundinacea* L. and *Lolium peranne* L. (Saharkhiz et al., 2009). In addition, the oil of *O. vulgare* was reported to inhibit seed germination of *Raphanus sativus* L., *Lactuca sativa* L. and *Lepidium sativum* (Arminante et al., 2006). Similarly, Amri et al. (2013) demonstrated that the oil of *C. sempervirens* reduced the seed germination of *Sinapis arvensis* L., *Phalaris paradoxa* L. and *Raphanus raphanistrum* L. Also, the inhibitory effect of essential oils from other plants on seed germination was previously reported (Barbosa et al., 2007; Paudel and Gupta, 2008; Kordali et al., 2009).

The results of the inhibitory effects of the isolated oils on the seedling growth showed that the oils caused higher inhibitory effect on root growth than shoot growth. These results are consistent with those reported elsewhere for plant metabolites and extracts (Abdelgaleil et al., 2009; Saad et al., 2012). This finding might be expected, because it is likely that roots are the first to absorb the allelochemical compounds from the environment (Turk and Tawaha, 2002).

To the best of our knowledge, this is the first report on the herbicidal activity of the twenty isolated oils against *E. crusgalli*. However, some of essential oils isolated from the tested plants were documented to possess allelopathic and herbicidal activities. Zahed et al. (2010) stated that the oil of *S. molle* had inhibitory effect on the seedling growth of wheat. Similarly, the oil of *R. officinalis* reduced the seedling growth of of *Cynodon dactylon* L., *Festuca arundinacea* L. and *Lolium peranne* L. (Saharkhiz et al., 2009). Moreover, the oil of *O. vulgare* inhibited the radicle growth of *Raphanus sativus* L., *Lactuca sativa* L. and *Lepidium sativum* L. (Almeida et al., 2010). The inhibitory effect of the essential oils of *C. sempervirens* and *C. sinensis* on the seedling growth of common crop weeds was described (Amri et al., 2013; Ribeiro and Lima, 2012). In addition, the herbicidal and phytotoxic activities of other essential oils were described (Scrivanti et al., 2003; Singh et al., 2009; Mutlu et al., 2010).

The results of the present study indicated that there is a correlation between the chemical compositions of the essential oils and their bioactivities. Thus, the essential oils with high content of oxygenated monoterpenes showed stronger phytotoxic effects than the essential oils with low content of oxygenated monoterpenes and high content of monoterpene hydrocarbons. This finding is in congruent with earlier studies on the bioactivity of essential oils and monoterpenes in which the potent inhibition of seed germination and seedling growth was linked to the present of high percentage of oxygenated monoterpenes (Scrivanti et al., 2003; Almeida et al., 2010).

It is clear that the allelopathic activity of the essential oils resulted from the combined effects of several allelochemicals, mainly monoterpenoids and sesquiterpenoids, including addition, synergism and antagonism (Kordali et al., 2009). The modes of action of the allelopathic activity of the essential oils remain unclear. However, several studies were described the possible mechanisms of action of essential oils and monoterpenes. These mechanisms include, DNA synthesis inhibition, disruption of membranes surrounding mitochondria and nuclei, uncoupling oxidative phosphorylation, inhibition of electron transfer, inhibition of mitochondrial ATP production, inhibition of mitochondrial reparation, reduction of chlorophyll contents; inhibition of cell proliferation and disruption of the activity of metabolic enzymes involved in glycolysis (Nishida et al., 2005; Singh et al., 2006; Macias et al., 2007; Kaur et al., 2010).

Based on the results of the present study, it can be concluded that the essential oils of *M. communis*, *A. monosperma*, *V. agnus-castus* and *P. graveolens* had remarkable herbicidal activity against *E. crusgalli*. Such results provide evidences for the possible utilization of these oils as bioherbicides in future.

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الملخص العربي

التركيب الكيميائى والتأثير التثبيطى للزيوت الطيارة على إنبات ونمو بادرات حشيشة الدينبة

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تم تحليل الزيوت الطيارة لـــ ٢٠ من النباتات النامية فى مصر والمتحصل عليها بالتقطير المائى بواسطة جهاز كروماتوجرافى الغاز المتصل بمطياف الكتلة (GC-MS). أوضحت النتائج أن الزيوت المعزولة كانت غنية بمركبات التربينات الهيدروكربونية الأحادية (مثل مركبات limonene و sabinene و β-pinene و γ-terpinene و α-phellandrene و β-phellandrene و δ-3-carene و cis-Ocimene) والتربينات الأحاية المحتوية على الأوكسجين (مثل مركبات terpinen-4-ol و β–thujone و 4-terpineol و linalool و α-citral و β-citronellol و 1,8-cineole و camphor و pulegone و α-terpinolene)، عدا زيت الفلفل عريض الأوراق حيث كان غنياً بمركبات السسكيوتربينات ونبات كف مريم الذى كان يحتوى على كميات متقاربة من المونوتربينات والسسكيوتربينات. تم تقييم التأثير التثبيطى للزيوت المعزولة على إنبات بذور ونمو بادرات حشيشة الدنيبة. أظهرت النتائج أن زيت نبات الميرسين كان أكثر الزيوت تثبيطاً لإنبات البذور على كل التركيزات المختبرة، يليه زيوت كل من العتر البلدى وكف مريم والسرو الليمونى وفلفل عريض الأوراق، فى حين زيوت كل من الليمون الأضاليا وشيح الجبل والسرو كانت أقل الزيوت فاعلية فى تثبيط إنبات البذور. بالإضافة إلى ذلك كانت زيوت الميرسين واللال وكف مريم والعتر البلدى أعلى الزيوت تثبيطاً لنمو المجموع الخضرى والمجموع الجذرى للحشيشة. على الرغم من أن تثبيط الزيوت للمجموع الجذرى كان أعلى من تثبيطها للمجموع الخضرى. من خلال هذه الدراسة يمكن أن نقترح أن للزيوت الطيارة فاعلية فى مكافحة بعض الحشائش رفيعة الأوراق خاصة الدنيبة ويمكن أن تستخدم كمركبات طبيعية فى مكافحة الحشائش.