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Inhibitory allelopathic effects of *Moringa oleifera* Lamk plant extracts on wheat and *Sinapis arvensis* L.

N.A. Tahir[1]*, K.O. Qader[2], H.A. Azeez[2] and J.S. Rashid[2]
[1]Department of Horticulture, College of Agricultural Sciences,
Sulaimani University, Sulaimani, Iraq
[2]Department of Biology, College of Sciences,
Sulaimani University, Sulaimani, Iraq
E. Mail: nawroz.tahir@univsul.edu.iq , nawrozbiology@gmail.com

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ABSTRACT

We determined the chemical composition and the phytotoxicity of leaves, flowers and seeds of moringa (*Moringa oleifera*) plant, on the germination and seedling growth of wheat (*Triticum aestivum* L.) variety 'Aras' and *Sinapis arvensis* (wild mustard). The results showed that the leaves extracts were rich in the methyl 11,14,17-eicosatrienoate (13.69%) and octadec-9-enoic acid (27.78 %). The flower extracts were rich in hydrocarbon compounds (nonacosane with 18.28 %), unsaturated fatty acids derivatives (methyl 12,15-octadecadienoate with 17.88% , 9-octadecenoic acid, methyl ester, (E)- with 17.00%) and saturated fatty acids and derivatives (hexadecanoic acid, methyl ester with 12.51 %). While the seeds extracts were rich in unsaturated fatty acids derivatives (9-octadecenoic acid, methyl ester, (E)- with 36.94 % and octadec-9-enoic acid with 16.66 %). Principal component and hierarchical cluster analyses divided the shoot predominated components into three groups, and the results indicated inhibitory effects of leaves, flowers and seeds extracts on the seed germination, shoot and root growth of wild mustard plants but were stimulatory to seed germination and seedlings growth of wheat. According to PCA plot, 6- compounds (eicosane, gamma-sitosterol, l-(+)-ascorbic acid 2,6-dihexadecanoate, octadecanoic acid, methyl 11,14,17-eicosatrienoate, and octadec-9-enoic acid) were correlated positively with the inhibition of germination in wild mustard.

Keywords: Drumstick tree, chemical compounds, extracts, flowers, leaves, Moringa, *Moringa oleifera* phytotoxicity, *Sinapis arvensis*, *Triticum aestivum.*

INTRODUCTION

Moringa (*Moringa oleifera* Lamk. Drumstick, Moringaceae family), possess numerous biological activities and allelopathic potential. It has 13 species and among them, *M. oleifera* is cultivated worldwide (17). Moringa is domestic to sub-Himalayan lands of India, Pakistan, Bangladesh and Afghanistan but is presently found in all tropical and subtropical areas of the world (2,3). Its leaves, pods and seeds are used by humans to supply proteins and vitamins and also used for domestic, industrial, agricultural and medicinal uses [treatment of inflammation, cardiovascular, gastrointestinal and kidney problems (3,18,24)].

The functional components are in its leaves, seeds, flowers, bark, fruits and peel (25). Their extracts contain several compounds (terpenoids, lipids, vitamins and hydrocarbons). These secondary metabolites play great role in plant growth; plant's defense against microbial attacks, biotic and abiotic stresses (15). However, very little is known about the chemical composition of its aerial parts (leaves, flowers, seeds) and their

*Correspondence author, [1]Department of Horticulture

inhibitory and stimulatory potentials. Most of the previous researches on moringa (*M. oleifera*) focused on the phenolic compounds composition. Moringa (*M. oleifera*) is rich in minerals, vitamins, protein, fatty acids, antioxidants, allelochemicals and plant growth regulators [zeatin (cytokinins) and gibberellins (1,2,7)].

The powdered leaf of moringa (*Moringa oleifera*) increased the growth, yield and resistance to pests and diseases in wheat (13). Hence, this research aimed to determine (i). the chemical components in plant extracts from leaves, flowers and seeds of *M. oleifera* grown in Baranan mountain and (ii). the inhibitory or stimulatory activity of compounds present in different plant parts on the germination and seedling growth of wheat and wild mustard.

MATERIALS AND METHODS

The Baranan mountains, Kurdistan region, Iraq has rocky slopes and valleys. The moringa (*M. oleifera*) plantations are situated in Sulaimani, Kurdistan, Iraq [laltitude : 35.18279°N, longitude : 45.65111°E and altitude : 879.1 masl. Annual rainfall: 450-700 mm, temperatures ranged from -5 ° C to 45 °C]. The soils are rich in clay, silt, calcium, organic matter and bicarbonate and pH: 7.35 and also had Mg, Ca, Na, K, P and N was 3.50 meq/L, 1.51 meq/L, 0,082 meq/L, 0.13 meq/L, 9.89 ppm and 0.20 %, respectively.

Plant collection and sample preparation

The studies were done in 2017 in the Department of Biology, College of Sciences, University of Sulaimani, Iraq. The leaves, flowers and seeds of moringa (*Moringa oleifera*) for this study were collected from the Baranan mountain, Kurdistan region, Iraq. In 2008, moringa (*Moringa oleifera*) seeds were sown in orchard (distance 1 m plant to plant and 3 m row to row) and irrigated by drip system. Each plantation was irrigated once a week. No chemical fertilizer was added. The collected aerial parts were air-dried and ground into powder using a mechanical grinder and packed into ice-packed plastic container for transporting to GC-MS Laboratory, University of Basrah, College of Agriculture, Basrah, Iraq. For bioassay, we selected wheat: (*Triticum aestivum* L). 'Aras' variety and the weed (wild mustard: *Sinapis arvensis* L.) because, in Kurdistan the wild mustard is major weed in wheat crop.

Plant extracts preparation

Hexane was used as solvent to extract the chemical compounds from the moringa (*M. Oleifera*) leaves, flowers and seeds using the Soxhlet apparatus. Eighty g powder of dry leaf, flower and seed were kept in a thimble (made from thick filter paper), which was placed inside the main chamber of Soxhlet apparatus. The bottom flask containing the hexane was heated to reflux above 100°C for 8 h. Its vapours were cooled down in the extraction chamber, to get oil from the plant material. All extracts collected in the bottom flask were purified and kept in glass sample vial in the refrigerator at 4 °C for chemical analysis.

Qualitative and quantitative analyses of hexane extraction by GC-MS

Plant extracts analysis was done in the University of Basrah, College of Agriculture, Iraq. The GC-MS analysis was achieved by using Shimadzu GC-QP 2010 Ultra gas chromatograph. The GC oven temperature was programmed at 40°C and then progressively raised to 280 °C at a rate of 15 °C min^{-1}. Helium was utilized as a hauler gas;

inlet pressure was 96.1 kPa; linear velocity was 47.2 cm sec^{-1}. Column flux was 1.71 mL min^{-1}; injector temperature 280 °C; injection mode: split. MS scans conditions: source temperature 200 °C; interface temperature 280 °C; detector gain 0.69 kV +0.10 kV and mass range of m/z 50-800. The constituents of extracts from different parts were compared by the retention indices with those constituents stored in the NIST library (2005) or either those of the literature. Peak area concentrations of the components were calculated to depend on GC peak areas.

Figure 1. Moringa (*Moringa oleifera*) tree showing leaves, flowers, and seeds.

Bioassays

The bioactivity of the extracts from leaves, flowers and seeds of moringa (*M. oleifera*) was determined on the seed germination, shoot and root elongations of wheat (*Triticum aestivum*) and wild mustard (*Sinapis arvensis*). The wheat and wild mustard seeds were pre-sterilized with NaClO (1 %) for 8 min and then rinsed six times with autoclaved distilled water (10). The experimental treatments were: Control (Distilled water+Acetone), 0.45 and 0.9 mg/mL plant organ extracts. Fifteen seeds were sown per sterile Petri dish (90 mm diameter) lined with 3-sterile filter papers (Whatman). The plant organs extracts were prepared by hexane using Soxhlet apparatus, as mentioned in plant extracts preparation, were dissolved in a mixture of distilled water-acetone (98:2) (12) to

prepare desired concentrations (0.45 or 0.90 mg/mL). Seven ml of mixture [distilled water (98 %)+Acetone (2 %) (Control)] and plant extracts (0.45 and 0.9 mg/mL) were added to each Petri dish. The treatments were replicated five times by using Completely Randomized Design. The dishes were sealed with Parafilm to avoid the loss of moisture and to prevent microbial contaminations and kept in growth chamber in dark at 20 °C for 7 days. After seven days, the germination % and seedling growth were determined. A seed was considered germinated when the 2 mm radicle emerged from seed coat (7).

Statistical Analysis

Bioassays data were analysed by analysis of variance (One way-ANOVA) using XLSTAT 2016 software. Means were separated at 5 % significance level by Duncan's new multiple range test. We hypothesized that aerial part extracts would form relationships, according to their chemical components and that these extracts obtained would have stimulation or inhibition effects on the parameters related to the seed germination of two plant species. To check this hypothesis, the data were subjected to an analysis of PCA using XLSTAT 2016 software. For the grouping of different parts in terms of chemical composition, we performed an analysis of clustering using XLSTAT 2016 software.

RESULTS AND DISCUSSION

Chemical composition of moringa leaves, flower and seeds extracts.

The Gas chromatography-mass spectrometry (GC-MS) of leaves, flower and seeds extracts of moringa (*Moringa olifera*) identified 46 compounds from 4-classes: (i). hydrocarbons with 25 constituents, (ii). saturated fatty acids and their derivatives with 11 compounds, (iii). unsaturated fatty acids and their derivatives with 9 components and (iv). vitamins with one fraction (Table 1). The major class was unsaturated fatty acids and their derivatives followed by hydrocarbon compounds. The chemical compositions of moringa (*Moringa olifera*) organs and their retention indices are given in Table 1. The chemical structures of some major components are shown in Fig. 2. However, this chemical analysis of plant extracts demonstrated that the leaf, flower and seeds contained different compounds. Some of these compounds present in leaf, flower and seed have biological activity, industrial and medical applications.

Leaves extract

Twenty-five constitutions were identified in the leaf extract (Table 1). The major components were: octadec-9-enoic acid (27.78 %), methyl 11,14,17-eicosatrienoate (13.69 %), l-(+)-ascorbic acid 2,6-dihexadecanoate (8.74 %), octadecanoic acid (6.77 %), gamma-sitosterol (5.31 %), hexadecanoic acid, methyl ester (5.16 %), eicosane (4.94 %) and hexatriacontane (4.73 %). All other components were < 3.0 %. The data show that during the fermentation, some esters in moringa (*M. Oleifera*) leaf may be transformed to fatty acids. The compounds contents differed within the plant parts. The identified fractions in leaf extract were divided into 4-classes: (i). Hydrocarbons (12 compounds), (ii). Saturated fatty acids and their derivatives (8 compounds), four compounds of (iii). Unsaturated fatty acid and their derivatives (4 compounds) and (iv). Vitamin (one compound). The unsaturated fatty acids and derivatives were highest (45.15 %), > hydrocarbon components (27.58 %) > saturated fatty acids and derivatives (26.71 %). Vitamins were the least (0.56 %).

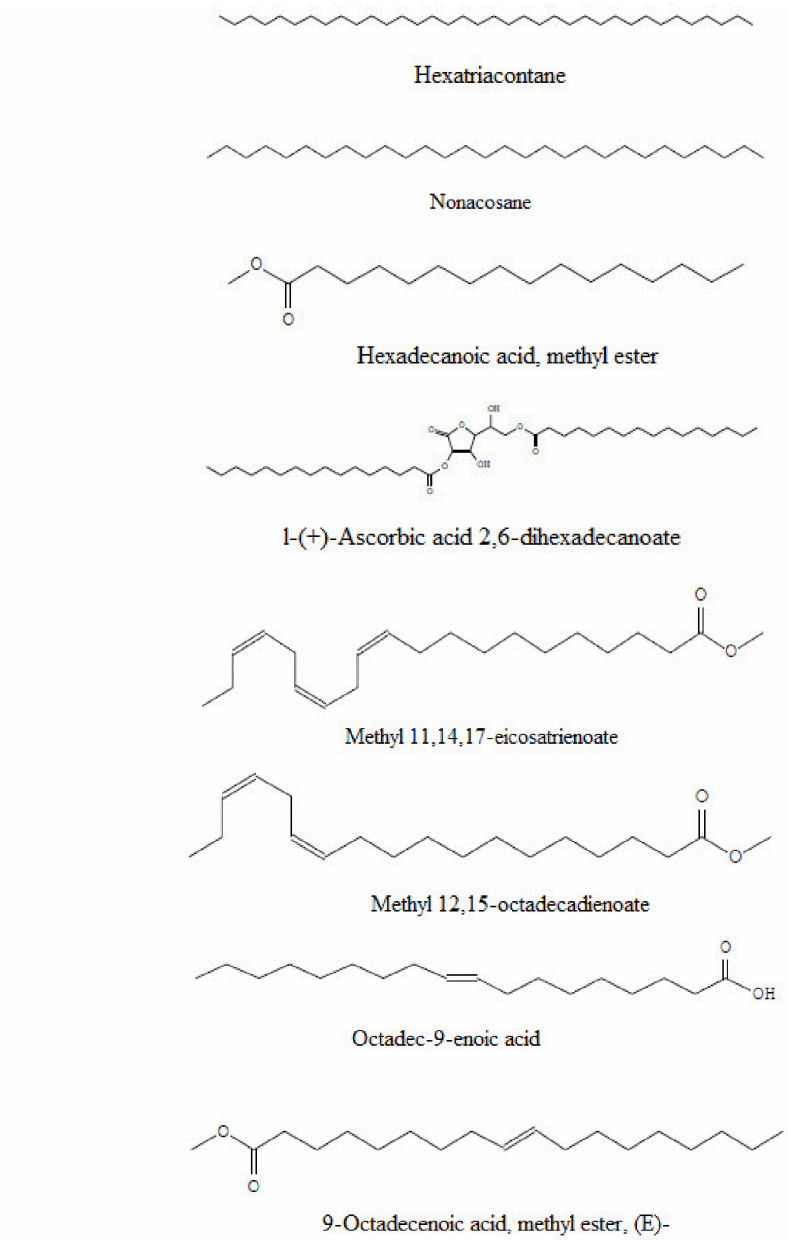

Figure 2. Some predominated components identified in aerial parts extracts of moringa (*M. oleifera*).

Table 1. Chemical components of leaf, flower, and seed extracts in moringa (*Moringa olifera)*.

No.	Compound name and class	RI	Leaf	Flower	Seed
	A. Hydrocarbon class				
1	Decane, 1,9-bis[(trimethylsilyl)oxy]-	1519	0.56	-	-
2	Eicosane	2009	4.94	0.6	1.92
3	Gamma.-Sitosterol	2731	5.31	-	-
4	Heneicosyl trifluoroacetate	2309	0.62	-	-
5	Hexatriacontane	3600	4.73	8.52	-
6	Nonane, 3-methyl-5-propyl-	1185	2.24	-	4.72
7	Octane, 3,5-dimethyl-	887	1.60	-	5.67
8	Phytol	2045	2.23	-	
9	Stigmast-5-en-3-ol, oleate	4469	0.71	-	0.33
10	Tetradecane	1413	2.92	-	3
11	Tetratriacontane	3401	0.65	1.88	-
12	Urea, octadecyl-	2518	1.07	-	0.34
13	2,6-Dimethyldecane	1086	-	-	0.20
14	Cyclooctane, 1,2-diethyl-	1280	-	-	0.43
15	Cyclopentane, 1-hexyl-3-methyl-	1219	-	-	0.39
16	Nonane, 2,3-dimethyl-	986	-	-	0.29
17	Undecane, 2,3-dimethyl-	1185	-	-	0.22
18	11,15-Dimethylpentatriacontane	3571	-	0.55	-
19	13,17,21-Trimethylheptatriacontane	3805	-	0.49	-
20	Dotriacontane	3202	-	1.20	-
21	Eicos-9-ene-1,20-diacetate	2749	-	1.34	-
22	Hentriacontane	3103	-	3.20	-
23	Heptacosane	2705	-	0.73	-
24	Hexacosane,9-octyl-	3337	-	0.50	-
25	Nonacosane	2904	-	18.28	-
	Total		27.58	37.29	17.51
	B. Saturated fatty acid and their derivatives class				
26	Hexadecanoic acid, methyl ester	1878	5.16	12.51	4.93
27	l-(+)-Ascorbic acid 2,6-dihexadecanoate	4765	8.74	-	1.86
28	Methyl 18-methylnonadecanoate	2212	0.86	1.36	2.65
29	Methyl 20-methyl-heneicosanoate	2411	1.39	2.42	4.17
30	Methyl tetradecanoate	1680	1.38	0.67	-
31	Octadecanoic acid	2167	6.77	-	3.46
32	Octadecanoic acid, methyl ester	2077	1.12	3.33	4.88
33	Tetracosanoic acid, methyl ester	2674	1.29	2.45	1.02
34	Methyl hexadec-9-enoate	1886	-	-	1.14
35	Hexacosanoic acid, methyl ester	2872	-	1.76	-
36	Octacosanoic acid, methyl ester	3071	-	1.56	-
	Total		26.71	26.06	24.11
	C. Unsaturated fatty acid and their derivatives class				
37	9,12-Octadecadienoic acid (Z,Z)-	2183	1.81	-	0.52
38	Methyl 11,14,17-eicosatrienoate	2300	13.69	-	-
39	Methyl 12,15-octadecadienoate	2093	1.87	17.88	-
40	Octadec-9-enoic acid	2175	27.78	1.13	16.66
41	9,12-Octadecadienoic acid (Z,Z)-, 2,3-dihydroxypropylester	2697	-	-	0.55
42	9-Octadecenoic acid, methyl ester, (E)-	2085	-	17.00	36.94
43	Ethanol,2-(9,12-octadecadienyloxy)-, (Z,Z)-	2344	-	-	0.40
44	Methyl 11-eicosenoate	2284	-	-	2.35
45	Methyl 9-cis,11-trans-octadecadienoate	2093	-	-	0.96
	Total		45.15	36.01	58.38
	D. Vitamins class				
46	Alpha.-tocopherol-.beta.-D-mannoside	4489	0.56	-	-
	Total		0.56		

Comparing the previous works with our results, we found some variations. Because the sample analyzed by us were different from the others viz., Rawandan and China. Mukunzi *et al*. (20) compared the profile of volatile oil in moringa (*M. oleifera*) leaves from Rwanda and China. The Rwandan leaf contained 59 compounds, with hexanoic acid (19.8 % of total volatiles) as the major compound, while the Chinese leaf has 61 components and mainly component was acetic acid (12.5 %). In the moringa (*M. oleifera*) extract from Mozambique, the major compound was hexacosane (13.9 %), pentacosane (13.3 %) and heptacosane (11.4 %) (17). The major constituents in our leaf samaples were similar to leaves of moringa (*M. oleifera*) grown in Taiwan, which conained Pentacosane (17.4 %), hexacosane (11.2 %) and (*E*)-phytol (7.7 %) (5) and in Ceará which contained 21.6 % phytol and 9.6 % thymol in the leaves extract of moringa (*M. oleifera*) (3). The variation in our results from the finding of other researchers might be due to extraction method, location, collection period, seasonal and environmental factors.

Flowers extract

The GC-MS output of hexane moringa (*M. oleifera*) flower recognized a total of 22 constituents, corresponding to 99.36 % of the total extracts, while, 0.64 % of the extract were not recognized (Table 1). The major constituents of the extract were nonacosane (18.28.44 %), methyl 12,15-octadecadienoate (17.88 %), 9-octadecenoic acid, methyl ester (17.00 %), hexadecanoic acid, methyl ester (12.51 %), hexatriacontane (8.52 %), octadecanoic acid, methyl ester (3.33 %) and hentriacontane (3.2 %). A classification of the constituents of the moringa (*M. oleifera*) flower is given in Table 1. The extracts included 11-hydrocarbon compounds (37.29 %), 8-saturated fatty acids and their derivative compounds (26.06 %) and 3-saturated fatty acids and their derivative compounds (36.01 %).

Comparing the current results with the previous findings from India (16), there were qualitative and quantitative variations. Among the 26 compounds determined, only 4- were detected in our flower extract: hexadecanoic acid, methyl ester (palmitic acid, methyl ester), octadecanoic acid, methyl ester, tetratriacontane and hexatriacontane. They found that ethyl oleate (19.94 %), quinic acid (13.43 %) and cis-9-hexadecenal (11.80 %) were main compounds. The nonacosane (18.28 %), 9-octadecenoic acid, methyl ester (eliadic acid, methyl ester) (17.88 %) and 9-octadecenoic acid, methyl ester, (E) (eliadic acid, methyl ester) (17.00 %) are not found in the flower extract of moringa (*M. oleifera*) (16). Nepolean *et al.* (21) reported that the ethanoic extracts of moringa (*Moringa oleifera*) flowers, contained 9-octadecen-1-ol, cis-9-octadecen-1-ol, oleol, satol, ocenol, sipo, decanoic acid, dodecanal as the major contents in flower essential oil. The extraction profile of flower of moringa (*M. oleifera*) extracted and analyzed using the distillation-extraction differed from the extracted profile explained here (23). They reported that (*E*)-nerolidol (13.3 %), α-terpineol (7.8 %) and benzyl isothiocyanate (6.4 %) were the main factions in flower essential oil. This variability between our results and previous study may be attributed to different genetic background, environmental factors, plant-developmental stage and the sample preparation.

Seeds extract

Twenty-six constitutions were detected in seed extract (Table 1). The major compounds were : 9-octadecenoic acid, methyl ester, (E)- (36.94 %), octadec-9-enoic acid (16.66 %), octane, 3,5-dimethyl- (5.67 %), hexadecanoic acid, methyl ester (4.93 %),

octadecanoic acid, methyl ester (4.88 %), nonane, 3-methyl-5-propyl- (4.72 %), methyl 20-methyl-heneicosanoate (4.17 %), octadecanoic acid (3.46 %) and tetradecane (3.00 %) (Table 1). The other compounds were < 3 %. The identified fractions in seeds extract were: seven unsaturated fatty acids and derivatives (58.38 %), 11 hydrocarbon compounds (17.51 %) and eight saturated fatty acids and esters (24.11 %).

Compared to our results, the compounds in oils from South Africa (19) were extracted by hydrodistillation, hence, contained the major compounds: tetracosane (34.259 %), heptadecane (22.202 %), eicosane (19.583 %), *n*-hexadecanoic acid (8.454 %) and phenanthrenecarboxylic acid (3.784 %). These data are similar to our results. The amount of *n*-hexadecanoic acid (4.93 %) in our work is less than that obtained by Monday *et al*. (19).

Moringa extracts Bioassay

The stimulatory and inhibitory influence of moringa (*Moringa oleifera*) extracts from leaves, flower, and seeds on *Triticum aestivum* and *Sinapis arvensis* seeds germination and seedling early growth differed with the organ and the extract concentration (Fig. 3, Fig. 4, Fig. 5 and Table 2). There was significant variability in the influence of moringa aerial parts extracts on the root and shoot length of *Triticum aestivum*, while the effects on the germination were non-significant (P = 0.224). The germination (%), root length, and shoot length ranged from 90.67 to 100 %, 0.56 to 1.21 cm and 2.30 to 4.67 cm, respectively. The root and shoot elongation of *Triticum aestivum* were stimulated by the extracts of leaf -0.45 mg/mL, flower -0.45 mg/mL, and seed -0.45 mg/mL extracts. There were significant effects of plant extracts from different parts on the germination (%) (P=0.00), root length (P=0.00) and shoot length (P=0.001) of *Sinapis arvensis*. The mean germination, root length, and shoot length in wild mustard varied from 2.34 to 54.33 %, 0.07 to 0.53 cm and 0.13 to 2.01 cm, respectively. Seeds germination and seedling growth of *Sinapis arvensis* tested at 0.45 and 0.90 mg/mL concentration. Moringa extracts of different organs significantly inhibited the germination (29.67 to 52.00 %),

Table 2. Mean effect of extracts of different organs of moringa (*M. oleifera*) on *Triticum aestivum,* and *Sinapis arvensis.*

Treatment	*Triticum aestivum*			*Sinapis arvensis*		
	Germination (%)	Root length (cm)	Shoot length (cm)	Germination (%)	Root length (cm)	Shoot length (cm)
Control	93.00 ab	0.69 bc	2.87 b	54.33 a	0.30 c	1.08 bc
Leaf-E0.45 mg/mL	93.35 ab	1.20 a	4.67 a	2.34 c	0.07 c	0.27 cd
Leaf-E0.90 mg/mL	91.35 ab	0.71 bc	2.66 b	2.34 c	0.07 c	0.13 d
Flower-E0.45 mg/mL	95.34 ab	1.33 a	3.81 ab	22.67 b	0.38 b	1.07 bc
Flower-E0.90 mg/mL	100.00 a	0.56 c	2.30 b	2.34 c	0.20 c	0.60 cd
Seed-E0.45 mg/mL	90.67 b	1.21 a	3.32 ab	24.67 b	0.51 a	2.01 a
Seed-E0.90 mg/mL	91.00 b	0.82 bc	2.39 b	2.34 c	0.53 a	1.66 ab
Pr > F	0.22	0.02	0.03	0.00	0.00	0.001
Significant	No	*	*	**	**	**

Dissimilar letters within a column designated significant variation according to Duncan's new multiple range test at the 0.05 level.
*: Significant
**: High significant

root length (32.58 to 77.53 %) and shoot elongation (3.54 to 5.70 %). At the higher dose (0.90 mg/mL) of the extracts of leaves, flowers, and seeds were more inhibitory to the germination, root and shoot elongation. Our study showed that the allelopathic effects of leaf, flower, and seed extracts reduced the shoot and root length of *Sinapis arvensis.*

Figure 3. Wheat and wild mustard treated with leaf extract. A and D: plant treated with water: acetone, B and E: plant treated with 0.45 mg/ml of extract, C and F: plant treated with 0.90 mg/ml of extract.

We hypothesized that the chemical fractions in the leaf, flower, and seed extracts were related to the inhibition of seed germination. To prove this hypothesis, we did a principal component analysis (PCA). Fifteen fractions owning at minimum 4.00 % or more of the total extract composition in at least one plant organ were selected for the principal component analysis (Fig. 6). The PCA horizontal axis (PC1) and vertical axis (PC2)

accounted for 59.04 % and 40.96 % of the entire variance. The PCA study has mentioned the prevailing compounds that characterized each extract. The dendrogram constructed by cluster analysis using Euclidean distances revealed three main classes, including the class of leaf, class of flower and class of seed. The dendrogram displayed that seed extract composition differed from other extracts (Fig. 7).

Table 3. Percentage of contribution and coefficient of correlation (r) of the PC1 and PC2. The analyzed variables were 15 chemical constituents identified by GC-MS in the leaf, flower, and seed and the inhibition of seed germination of wild mustard.

Code	Compound name	PC1		PC2	
		Contribution (%)	r	Contribution (%)	r
C1	**Eicosane**	**10.57**	**1.00**	0.02	-0.03
C2	**Gamma.-Sitosterol**	**9.44**	**0.94**	1.65	-0.33
C3	Hexatriacontane	0.76	-0.27	14.17	-0.96
C4	Nonane, 3-methyl-5-propyl-	0.96	0.30	13.88	0.95
C5	Octane, 3,5-dimethyl-	0.08	0.09	15.14	1.00
C6	Nonacosane	6.06	-0.76	6.52	-0.65
C7	Hexadecanoic acid, methyl ester	5.78	-0.74	6.93	-0.67
C8	**l-(+)-Ascorbic acid 2,6-dihexadecanoate**	**10.40**	**0.99**	0.26	-0.13
C9	Methyl 20-methyl-heneicosanoate	3.03	-0.53	10.90	0.85
C10	**Octadecanoic acid**	**10.16**	**0.98**	0.61	0.20
C11	Octadecanoic acid, methyl ester	5.59	-0.73	7.20	0.69
C12	Methyl 12,15-octadecadienoate	5.06	-0.69	7.97	-0.72
C13	**Methyl 11,14,17-eicosatrienoate**	**9.44**	**0.94**	1.65	-0.33
C14	**Octadec-9-enoic acid**	**9.75**	**0.96**	1.20	0.28
C15	9-Octadecenoic acid, methyl ester, (E)-	4.05	-0.62	9.43	0.79
IG	Mean inhibition of germination (0.45+0.90 mg/mL)	**8.86**	**0.91**	2.48	-0.40

The bolded compounds inhibited the seeds germination in wild mustard.

According to PCA plot, six constituents [eicosane, gamma-sitosterol, l-(+)-ascorbic acid 2,6-dihexadecanoate, octadecanoic acid, methyl 11,14,17-eicosatrienoate, and octadec-9-enoic acid]. matched positively (Table 3) with the inhibition of seed germination of wild mustard. In addition, the accumulation of these allelopathic compounds decreases the hydrolytic enzymes (amylases, lipase, and isocitrate lyase) during the seed germination (10). Further, the decreased growth of wild mustard might be result of the oxidative damage from the polyunsaturated fatty acids viz., methyl 12,15-octadecadienoate as evident from the latge amount of malondialdehyde in the plant (26). In this study, we observed that the germination (%) of large seeds such as *Triticum aestivum* (plant rich in carbohydrate) was not affected significantly by different concentrations of extracts of aerial parts. Wanner and co-workers (28) observed that the germination (%) of large seeds was not influenced by fatty acids, while the germination (%) was decreased in small seeds. In addition, high accumulation of fatty acids in plants rich in oil could infiltrate membrane lipids and changed their physical properties. Thus the physiological features of the seeds would also change and the membrane lipids lose their ordinary arrangement, the power of germination was missing (14).

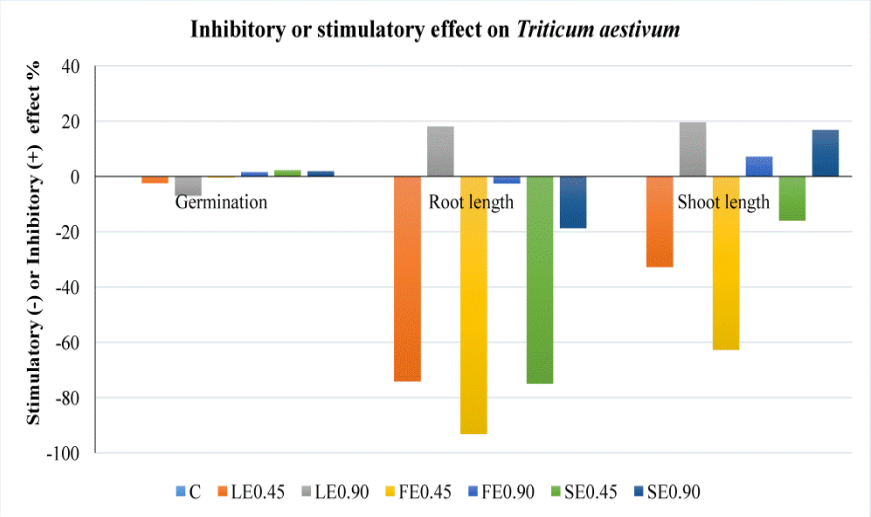

Figure 4. Inhibitory/stimulatory effect of moringa on the germination parameters of bread wheat (Aras variety). C: Control, LE0.45: Leaf extract-0.45 mg/mL, LE0.90: Leaf extract-0.90 mg/mL, FE0.45: Flower extract-0.45 mg/mL, FE0.90: Flower extract-0.90 mg/mL, SE0.45: Seed extract-0.45 mg/mL SE0.90: Seed extract-0.90 mg/mL.

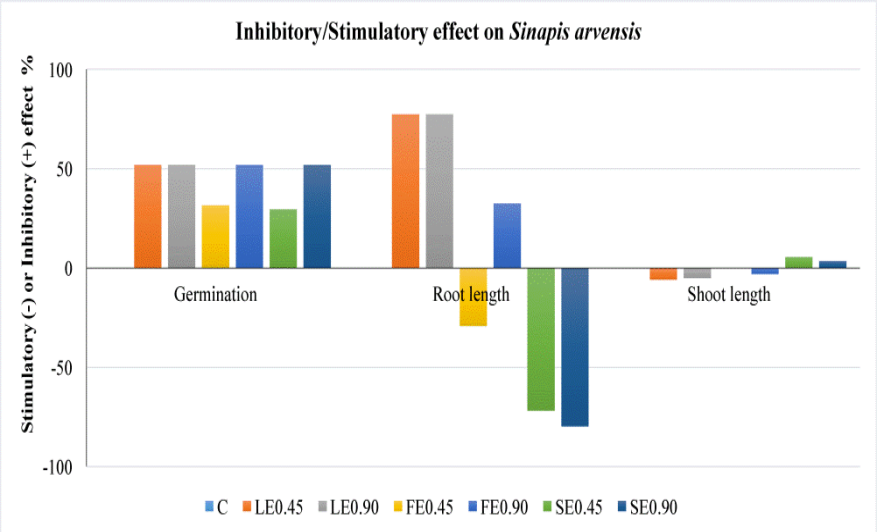

Figure 5. Inhibitory/stimulatory effect of moringa on the germination parameters of wild mustard. C: Control, LE0.45: Leaf extract-0.45 mg/mL, LE0.90: Leaf extract-0.90 mg/mL, FE0.45: Flower extract-0.45 mg/mL, FE0.90: Flower extract-0.90 mg/mL, SE0.45: Seed extract-0.45 mg/mL SE0.90: Seed extract-0.90 mg/mL.

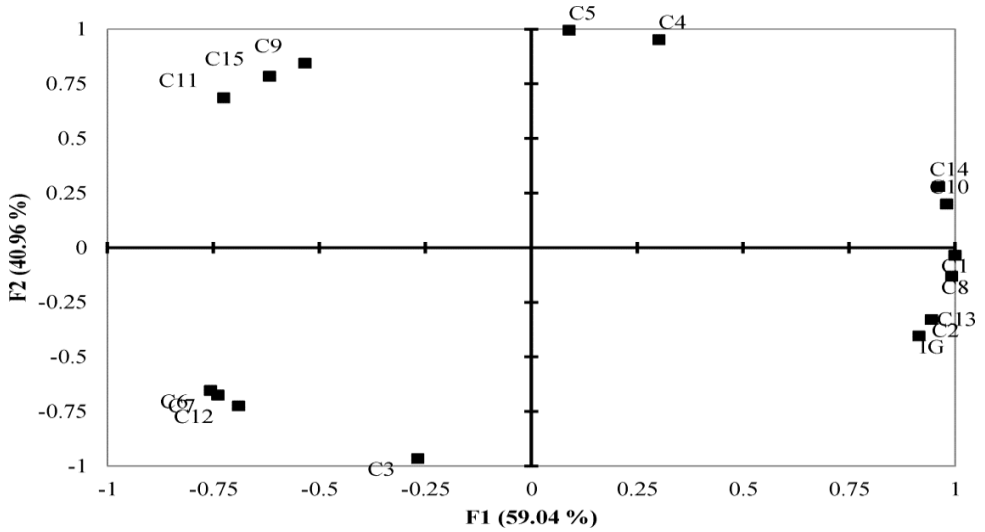

Figure 6. PCA plot of the inhibition of seed germination of wild mustard and 15 foremost compounds of the three plant organs extracts of moringa (*M. oleifera*) cultivated in Baranan mountain, Iraqi Kurdistan. The selected components have at least 4.0 % or more of the total extracts composition in at least one plant organ. IG: Mean inhibition at 0.45 and 0.90 mg/mL concentrations

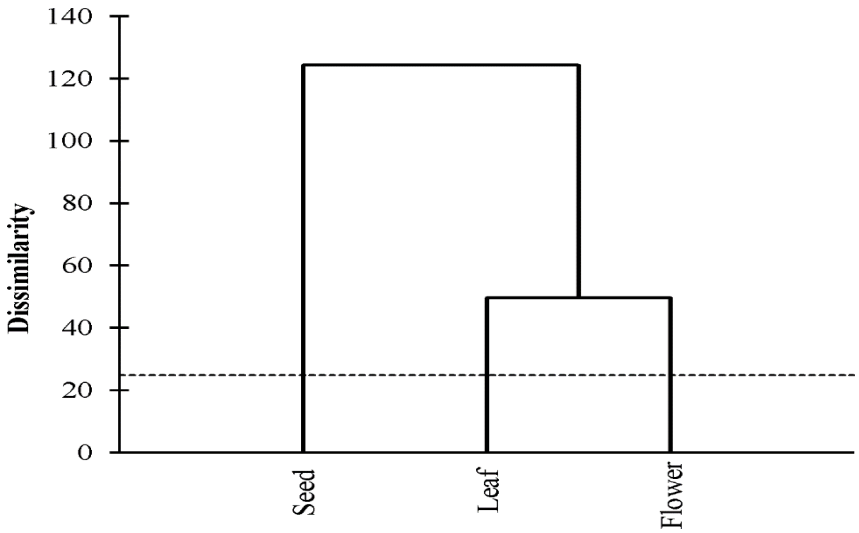

Figure 7. Dendrogram created by cluster analysis depending on the Euclidean distances between the classes of the extracts from three parts of moringa (*M. oleifera*) implanted in Baranan mountain in Iraqi Kurdistan. The selected components have at least 4.0 % or more of the total extracts composition in at least one plant organ.

The lower doses (0.45 mg/mL) of seeds, flowers and leaves moringa (*Moringa oleifera*) extracts demonstrated a stimulatory activity compared to control. At base doses, the extracts contain small amounts of allelochemical compounds. It is well known that low concentration of extracts oil compounds can promote the plant growth (27). The low concentration of extracts may be having no negative effect on the mobilization of carbohydrates and lipid and also created more energy during seed germination. Moringa (*Moringa oleifera*) is excellent source of plant growth-promoting substances, however, some resecherss reported its phytotoxicity (4,8,9,11,22,29).

CONCLUSIONS

The moringa extracts were rich in the octadec-9-enoic acid (27.78%), nonacosane with 18.28%, methyl 12,15-octadecadienoate with 17.88%, and 9-octadecenoic acid, methyl ester, (E)- with 36.94%. These extracts inhibited and stimulated the germination and seedling growth of wheat and *Sinapus arvensis*. The leaf extract at 0.90 mg/mL inhibited the germination and seedlings growth of wild mustard, while the 0.45 mg/mL concentration proved stimulatory to wheat. The leaf is a perfect raw material for inhibitory and stimulatory components that could be developed as herbicides or plant growth regulator.

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