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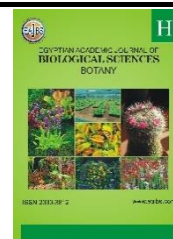
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Potency of *Alhagi maurorum* plant extracts as phytoacaricidal against *Panonychus citri* (Acari: Tetranychidae)

Reham M. Mostafa^{1*}, Heba S. Essawy¹, and Mohamed M. Baz²

1-Botany Department, Faculty of Science, Benha University, Benha, Qalyubiya 13518, Egypt.

2-Entomology Department, Faculty of Science, Benha University, Benha, Qalyubiya 13518, Egypt.

E-Mail : dr.rehammohamed74@gmail.com

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ABSTRACT

Recently, botanical insecticides have more alertness in pest control programs for its various advantages. *Alhagi maurorum* plant (camel thorn) one of the important medicinal plants in Fabaceae. The phytoacaricidal activity of *A. maurorum* plant extracts was evaluated against *Panonychus citri*. The aerial part of *A. maurorum* was extracted by methanol, petroleum ether, and water separately using the soaking and Soxhlet extraction. The rate of female daily deposited eggs varied considerably according to *A. maurorum* plant extracts and the sublethal concentrations. A few numbers of eggs laid were observed with the methanol extract (0.73 eggs), petroleum ether (2.16 eggs), and aqueous (4.31 eggs) at LC₇₅, while the high number observed in the untreated female groups (29.37 eggs) and Selecron insecticide (6.99 eggs). The same pattern was occurred in the hatchability with the tested bio-acaricides compared with Selecron insecticide and untreated ones. Based on sublethal dose LC₂₅, LC₅₀, and LC₇₅, the tested acaricides was significantly reduced the number of hatched eggs, where it reached (30.7, 13, 5.6%), (37.6, 21.6, 15%) and (44.3, 30.8, 23.8%) for methanol, petroleum ether, and aqueous plant extract, respectively compared with untreated groups (91.2%). Concurrently, data showed that methanol extract has a significantly impacted on the reduction of viability (58.16%) and reproductive process while the effect was less with the aqueous plant extracts (46.21%). Gas chromatography/mass spectrometry (GC-MS) analysis identified various bioactive complexes (phenols, tannins, and fatty acids) with insecticidal activity. The peak of compounds was higher in Benzene, (1-butylheptyl)- undecane, 5-phenyl (8.75 %), Maltol 4H-pyran-4-one,3-hydroxy-2-methyl(2.74%) 9,12,15-Octadecatrienoic acid, linolenic acid (2.45%) in petroleum ether extract and 4H-pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl (3.66%), 2-Furan-carboxaldehyde, 5-(hydroxymethyl) (3.33%), Bis(2-ethylhexyl) phthalatehalic acid, bis(2-ethylhexyl)ester (5.58%) in methanol extract. 2,3-Dimethylpenzene-1,4-dicarbonitrile (20.26%), 4-Fluoroveratrole, fluorobenzene,3,4-methoxy (19.52%) and Hexadecanoic acid (0.87 %). Finally, we concluded that methanol, petroleum ether, and aqueous extracts screened showed phytoacaricidal activity against mite *P. citri*.

INTRODUCTION

Alhagi belongs to the Fabaceae plants that produce several vital secondary metabolites. *Alhagi maurorum* is a legume species that are identified as Camel thorn (Duke 2007), where it distributes in different ecological areas, where it located in temperate areas like in Mediterranean region and mountains of Afghanistan and Pakistan. In Egypt, it spreads in various places especially in valleys and the Oasis and around the Nile Delta (Hassanein and Mazen 2010). *Alhagi* plant contains defensive compounds like phenolic and flavonoid compounds and many of different flavonoids were isolated (Sultan *et al.*, 2011). Mostafa and Essawy (2019) isolated some new anticancer bioactive compounds from *A. maurorum*.

Some studies were investigated on *Alhagi* species and it indicated many secondary metabolism compounds like alkaloids, fatty acids, flavonoids, coumarins, and sterols (Behari and Gupta 1980, Kalhor *et al.*, 1997, Awaad *et al.*, 2011 and Verma *et al.*, 2013). Mena *et al.* (2016) revealed that *A. maurorum* and *Rosmarinus officinalis* have an insecticidal effect which may be the occurrence of effective compounds like alkaloids, glycosides, tannins, and phenols compounds in its extract.

The majority of secondary metabolic products from *A. maurorum* is using in the treatment of human disease like urinary system infections, liver, and as a purgative (Marashdah and Al-Hazimi 2010), furthermore, the plant has anti-microbial properties (Sulaiman 2013). *Panonychus citri* (Acari: Tetranychidae) and *Phyllocoptruta oleivora* (Acari: Eriophyidae) citrus mites are widely distributed in the world and they attack citrus plants and a variety of fruit crops and vegetables (Syahputraa and Endartob 2013, Abdallah 2016). *Panonychus citri*, considered a dangerous pest on citrus crops because all stages nymphs and adults are parasites on the plants and extract nutrients from the host tissue using their piercing mouthparts that lead to a change in plant leaves color and therefore the plant yield can be greatly reduced (Lee *et al.*, 2000).

Mite feeding leads to tissue damage and physiological problems in cellular sap, furthermore helping fungi enter to plant through the site of feeding, which leads to nutritional imbalance in the various plant parts. Also, besides damage to the leaves prevents photosynthesis, increases transpiration, and leads to necrosis (Jamieson & Stevens 2009).

Severe injuries can result in early leaf fall, and decreased activity (Kranz *et al.* 1977). The mite attack can cause damage to the outer layer of citrus as well as the presence of black holes (Yang *et al.*, 1994), which may reduce the quality of the fruits and lead to a lower price (Childers *et al.*, 1996).

The intensity of pest and transmitted diseases cause massive produce losses in crops production, and pesticides still play a crucial role in alleviating yield loss of agricultural produce, but synthetic pesticides were used since long for control, resulting in resistance, food contamination, mammalian toxicity, and environmental pollution (Beugnet *et al.*, 1997, Meng *et al.*, 2000, Damavandian 2007, Chen *et al.*, 2009, Shen *et al.*, 2016). Therefore, the insecticides which made from plant materials appear as a substitute for the synthetic insecticides since it has no toxic on the environment, organisms, and nature (Farhana *et al.*, 2006).

The aim of this study to evaluate the phytoacaricidal activity of *A. maurorum* extracts against *Panonychus citri* and determine some of the biological aspects with sub-lethal concentrations of the tested plant extracts.

MATERIALS AND METHODS

Plant Collection:

The plant was collected in a semi-desert area northeast of Benha Abu Zaabal city, Qalyubiya, Egypt. The plant was identified and authenticated through the Botany Department according to Tackholm (1974) keys. The plant was washed and air-dried before the extraction and crushed into semi-powder using magnetically mixed for 30 minutes at 35 °C and stored in brown glass jars.

Extraction:

The extraction of dried materials was done by petroleum ether (non-polar) and methanol (have a moderate polarity) using Soxhlet method (Nikhal *et al.*, 2010), and by soaking in water (high polar) at room temp. The extraction was done at laboratory conditions and filtered to 5 ml concentration through a rotary evaporator.

GC-Mass Analysis:

The analysis of *A. maurorum* plant extract was performed using a GC–MS instrument coupled with an Agilent mass spectrometric detector. The device was previously described as in Mostafa and Essawy (2019). These analyses were done at the laboratory of central pesticide, Cairo governorate, Egypt.

Chemical Acaricide:

Selecron 72% EC purchased from Kafr El-Zayat Pesticides and Chemicals Company, Egypt.

Citrus Red Mite Strain:

Panonychus citri attack the citrus plants were obtained from Laboratory of Nematode and Acaroses, Department of Plant Protection, Faculty of Agriculture, Ain Shams Univ. Egypt. The colony preserved under laboratory circumstances (28±2 °C, 65-85% RH, 12 L: 12 D).

Bioassays Procedure:

Acaricidal activity of *A. maurorum* extracts was assayed on newly emerged (< 48 hrs) females using a residual contact bioassay. The plant, *A. maurorum* was extracted using soaking in water and Soxhlet method. The required concentration to produce mortality against newly adult females with plant extracts was determined and applied during 24 and 48 hrs, respectively. Fifteen females were placed on the lower surface of the castor bean disc (1.5 cm) using a binocular microscope. Each treatment repeated 5 times (75 individuals/concentration). After 24 hrs, the survived adult females transferred to clean discs with castor bean leaves, each petri dish having a wet cotton wick, and covered with a muslin cloth. The number of eggs was daily counted during the oviposition period, concurrently; the hatchability of daily deposition eggs was also recorded. The tests were performed at laboratory temperature (26 ± 2 °C, 65 ± 10% RH, and 14 L: 10 D h photoperiod). Data analyzed using SPSS for windows, release 17.0 (SPSS Inc, Chicago, IL. USA). Kruskal Wallis test was performed to find out the significant difference. Statistical data analysis regarding LC₅₀, LC₉₀, and slope were calculated using Finney (1971) Probit analysis software. Significant levels were located at a probability level of ≤ 0.05. The percent control of viability was estimated as follows (modified Mulla *et al.*, 1971): -

Percent reduction of viability = [(C-T)/C] x 100

Where: C= % hatched eggs/female in the check. T= % hatched eggs/female in the treatment.

RESULTS

The obtained results showed that *A. maurorum* plant extracts have prominent acaricidal activity against *Panonychus citri*.

Petroleum Ether Extract

Table (1) showed that the three major compounds among 16 phenolic compounds were Benzene, (1-butylheptyl)- undecane, 5-phenyl; Benzen, (1-methyldecyl) -2-phenylundecane, undecane, 2-phenyl, and Benzen, (1-propyloctyl) – undecane, 4-phenyl- (1-Propyloctyl) benzene with peak area 8.75, 4.45, and 4.36 respectively. Maltol 4H-pyran-4-one, 3-hydroxy-2-methyl, and 2H-1-Benzopyran-7-ol, 3-(2,4-dimethoxyphenyl) -3,4-dihydro have the highest peak areas (2.74, 0.23) respectively among three tannin compounds. While the 9, 12, 15-Octadecatrienoic acid, linolenic acid has the highest peak area (2.45) among five fatty acid compounds.

Table 1: Compounds detected in petroleum ether extract

RT	Chemical name	Peak area	Nature of compound
10.60	Benzeneethanol	(+) 0.67	Phenol
10.77	Maltol 4H-pyran-4-one,3-hydroxy-2-methyl	(+) 2.74	Tannin
21.88	Benzene, (1-butylhexyl)decane, 5-phenyl-(5-decyl) benzene	(+) 2.32	Phenol
22.40	Dodecanoic acid	-	SFA*
22.90	4-Fluoroveratrole, fluorobenzene,3,4-methoxy	-	Tannin
24.14	Benzene, (1-butylheptyl)- undecane, 5-phenyl	(+) 8.75	Phenol
24.36	Benzen, (1-propyloctyl) - undecane, 4-phenyl- (1-Propyloctyl)benzene	(+) 4.36	Phenol
24.49	2-Furanethanol,-.beta.-ethoxy	-	Phenol
24.81	Benzene, (1-ethylnonyl) Undecane, 3-phenyl-3-phenylundecane	(+) 3.87	Phenol
25.62	Benzen, (1-methyldecyl) -2-phenylundecane , undecane,2-phenyl	(+) 4.45	Phenol
26.22	Benzene, (1-pentylheptyl)-dodecane, 6-phenyl-6-phenyldodecan	(+) 2.82	Phenol
26.33	Benzene, (1-butylloctyl)-dodecane,5-phenyl-5-phenyldodecane	(+) 3.68	Phenol
26.56	Benzene, (1-propylnonyl)-4-phenyldodecane	(+) 3.81	Phenol
27.01	Benzene, (1-ethyldecyl)-3-phenyldodecane	(+) 3.26	Phenol
27.82	Benzene, (1-methylundecyl)-dodecane, 2-phenyl-	(+) 3.50	Phenol
28.27	Benzene, (1-pentylloctyl)- tridecane, 6-phenyl-	(+) 4.28	Phenol
29.5	9,12,15-Octadecatrienoic acid,	(+) 0.12	USFA**
30.09	Farnesol	(+) 0.08	Phenol
30.88	Hexadecanoic acid	(+) 0.82	USFA
34.27	9,12,15-Octadecatrienoic acid,linolenic acid	(+) 2.45	USFA
34.73	Ethyl 9, 12, 15-octadecatrienoate	(+) 0.60	USFA
42.67	2H-1-Benzopyran-7-ol,3-(2,4-dimethoxyphenyl) -3,4-dihydro	(+) 0.23	Tannin

*SFA: Saturated fatty acids, **USFA: Unsaturated Fatty acids

Methanolic Extract

Table (2) presented that the two major compounds among five phenolic compounds were 4H-pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl and (E) -1-(2,3,6-trimethylphenyl) buta-1,3-diene with peak area (3.66, 3.59), respectively. 2-Furan-carboxaldehyde, 5-(hydroxymethyl), and Mome inositol have the highest peak area (3.33, 2.36) among four tannin compounds. While Bis(2-ethylhexyl) phthalatehalic acid, bis(2-ethylhexyl) ester, Hexadecanoic acid; 9,12,15-Octadecatrienoic acid, linolenic acid and Octadecanoic acid (Stearic acid) have the highest peak area (5.58, 4.46, 3.43, 1.53), respectively among nine fatty acid compounds.

Table 2: Fatty acids and tannin compounds in Methanolic extract

RT	Chemical name	Peak area	Nature of compound
5.95	Propanedioic acid,dimethyl ester	(+) 0.78	USFAs*
7.16	2,3-Dihydro-3,5-dihydroxy-6-methyl-4h-pyran-4-one	(+) 1.06	Tannin
11.78	4H-pyran-4-one ,2,3-dihydro-3,5-dihydroxy-6-methyl	(+) 3.66	Phenol
14.28	2-Furan- carboxaldehyde,5-(hydroxymethyl)	(+) 3.33	Tannin
15.30	2-Ethoxyethyl-.beta.-phenylpropionate ,2-ethoxyethyl,3-phenylpropanoate	(+) 1.19	Phenol
18.30	(E) -1-(2,3,6-trimethylphenyl)buta-1,3-diene	(+) 3.59	Phenol
19.08	Acetic acid , (1,2,3,4,5,6,7,8-octahydro -3,8,8-trimethylnaphth-2-yl)methyl ester	(+) 0.96	USFAs*
19.19	Ethanone, 1-(2,3-dihydro-1,1-dimethyl-1 h -inden-4-yl)	(+) 0.60	Phenol
22.40	Dodecanoic acid	(+) 0.19	SFA*
26.83	Tetradecanoic acid	(+) 0.93	SFA*
30.18	9,11-Octadecadiynoic acid, 8-hydroxy-methyl ester	(+) 1.24	USFAs*
30.83	Hexadecanoic acid	(+) 4.46	SFA*
30.84	Mome inositol	(+) 2.36	Tannin
34.13	9,12-Octadecadienoic acid	(+) 0.88	USFA*
34.27	9,12,15-Octadecatrienoic acid,linolenic acid	(+) 3.43	USFA*
40.32	Hexadecanoic acid , 2-hydroxy-1-(hydroxymethyl)ethyl ester	(+) 1.20	SFAs**
40.96	Bis(2-ethylhexyl) phthalatehalic acid , bis(2-ethylhexyl)ester	(+) 5.58	SFAs**
42.67	2H-1-Benzopyran-7-ol,3-(2,4-dimethoxyphenyl) -3,4-dihydro	(+) 1.31	Tannin
43.14	Linolenic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester	(+) 2.23	SFAs**
50.26	(E) -5,10-secocholest-1(10) - en-3,5-dione	(+) 1.17	Phenol

*USFAs: Fatty acid methyl ester, ** SFAs: Fatty acids ethyl ester

Aqueous Extract

Table (3) showed that the two major compounds among seven phenolic compounds were 2,3-Dimethylpenzene-1,4-dicarbonitrile and 1,3-Butanediol,1,3-butylene glycol with peak area (20.26,17.40), respectively. 4-Fluoroveratrole, fluorobenzene,3,4-methoxy has the highest peak area (19.52) among five tannin compounds. While Hexadecanoic acid has the highest peak area (0.87) among 2 fatty acid compounds.

Table 3: Compounds detected in water extract

RT	Chemical name	Peak area	Nature of compound
4.00	2,3-Butanediol,2,3-butanediol	(+) 3.14	Phenol
4.13	1,3-Butanediol,1,3-butylene glycol	(+) 17.40	Phenol
5.65	Oxime-,methoxy-phenyl,methyl N-hydroxy benzenecarboximidoate	(+) 1.05	Phenol
14.85	1,2-Benzenediol, 3-methoxy-pyrocatechol, 3-methoxy	(+) 1.36	Tannin
16.05	1,2-Ethanediol,1-phenyl- styrene glycol	(+) 1.25	Tannin
18.30	(E) -1-(2,3,6-trimethylphenyl)buta-1,3-diene	(+) 0.70	Phenol
19.25	Phenol, 4-(methoxymethyl)	(+) 1.23	Tannin
20.82	2,3-Dimethylpenzene-1,4-dicarbonitrile	(+) 20.26	Phenol
22.90	4-Fluoroveratrole,fluorobenzene,3,4-methoxy	(+) 19.52	Tannin
24.49	2-Furanethanol,-beta-ethoxy	(+) 2.08	Tannin
25.61	Tetradecanoic acid, methyl ester	(+) 0.51	SFAs*
30.83	Hexadecanoic acid	(+) 0.87	SFA**
50.99	2-p-Nitrophenyl-1,3,4-oxadiazol-5-one	(+) 2.29	Phenol

*USFAs: Fatty acids ethyl ester, **SFA: Saturated Fatty acids

Sublethal concentration was calculated and presented in table (4), where the Methanolic extracts were found to be the best extracts on citrus red mite after 24 and 48 hrs at followed by Petroleum ether and Aqueous extracts. Data concerning the effect of *Alhagi* extracts (aqueous, methanol, and petroleum ether) on the reproductive potential of adult female mites are presented in tables (5-7). The results showed that egg-laying, rate of hatchability, and reproductive potential of female citrus red mite are decreasing by increasing concentration and the type of plant extract solvent.

Table 4: Toxicity effect of *Alhagi* extracts (ppm) on citrus red mite, *Panonychus citri* at 24 hrs

Alhagi extracts	LC ₂₅	LC ₅₀	LC ₇₅	LC ₉₀	Slope	P-value	X ²
Aqueous	2981.5	6158.6	12988	25284	2.0922±0.1935	0.8870	0.637
Methanolic	1248.7	2375.2	4536.0	8120.2	2.4006±0.1705	0.0673	0.717
Petroleum ether	1417.6	3078.7	6686.0	13437.6	2.0026±0.1662	0.004	0.681

Egg-Laying Behavior

Data in table (5) clearly indicate that the rate of daily deposited eggs varied considerably according to *Alhagi* extracts and the level of sub-lethal concentration was more effective compared with chemical acaricides and untreated ones. The methanol extract was more effective in reducing the daily number of eggs laid (2nd day) followed petroleum ether (3rd day), aqueous (4th day), and selecron (5th day) compared with untreated groups over than 6th day at LC₇₅. Furthermore, the lowest total number of eggs was observed in the methanol extract (0.73), petroleum ether (2.16), and aqueous (4.31), while the highest total number of eggs laid was observed in the untreated groups (29.37) followed by selecron (6.99) eggs. It is clear to notice the inverse correlation between acaricide concentration and the maximum number of deposits eggs. Considering, the total number of deposited eggs during the whole oviposition period. Static analysis of data using a Kruskal-Wallis test revealed that the *Alhagi* extracts had a significant influence on the reduction of female eggs ($X^2 = 18.78$, $df = 4$, $P = 0.001$). Data in the table (5) showed that methanol extract proved to be the most efficient phytoacaricidal activity in reducing the total number of eggs laid, compared to selecron a chemical acaricide.

Table 5: Potential effects of sub-lethal concentrations of certain *Alhagi* plant extracts (phytoacaricides) on the daily number of eggs laid / female of *P. citri*, citrus red mite

Alhagi Extracts	Lethal conc.	Average No. of deposited eggs on successive day						Total No. of deposited eggs/day	Average No. of eggs laid
		1 ^a	2 nd	3 rd	4 th	5 th	6 th		
Aqueous	LC ₂₅	2.40	2.10	1.50	1.20	0.70	0.00	7.90	1.82±0.88
	LC ₅₀	2.01	1.60	1.11	0.66	0.00	0.00	5.38	0.90±0.83
	LC ₇₅	1.70	1.22	0.96	0.43	0.00	0.00	4.31	0.72±0.68
Methanolic	LC ₂₅	1.20	0.80	0.50	0.28	0.00	0.00	2.78	0.46±0.47
	LC ₅₀	0.90	0.60	0.20	0.00	0.00	0.00	1.70	0.28±0.38
	LC ₇₅	0.60	0.13	0.00	0.00	0.00	0.00	0.73	0.12±0.24
Petroleum ether	LC ₂₅	1.60	1.26	0.92	0.50	0.26	0.00	4.54	0.76±0.61
	LC ₅₀	1.30	0.94	0.60	0.20	0.00	0.00	3.04	0.51±0.53
	LC ₇₅	0.96	0.72	0.48	0.00	0.00	0.00	2.16	0.36±0.42
Selecron	LC ₇₅	2.40	1.90	1.11	0.96	0.62	0.00	6.99	1.17±0.86
Untreated	-----	6.75	6.10	5.50	4.00	3.90	3.12	29.37	4.90±1.42

* Recommendation dose

Rate of Hatchability

Data in the table (6) clearly indicate that the rate of daily hatched eggs differed considerably according to the type of the tested plant extracts (acaricide) as well as the applied concentration. The highest number of hatched eggs occurred at untreated groups through the whole successive days (6 days) and followed by chemical acaricidal, selecron within 5 days, aqueous extract within 4 days, petroleum ether within 3 days at LC₇₅ dose respectively, while the lowest number of hatched eggs occurred at methanol extract within 1 day only.

Table 6: Potential effects of sub-lethal concentrations of *Alhagi* plant extracts (phyto-acaricides) on the daily number of hatched eggs/ females of *P. citri*, citrus red mite

Alhagi extracts	Lethal conc.	Average No. of hatched eggs on successive day (%)						Total No. of hatched eggs (%)	Average No. of hatched eggs/day
		1 ^a	2 ^a	3 ^a	4 ^a	5 ^a	6 ^a		
Aqueous	LC ₂₅	1.50 (62.5)	1.20 (57.1)	0.80 (53.3)	0.60 (50.0)	0.30 (42.9)	0.0 (0.0)	4.40 (44.3±22.6)	0.73
	LC ₅₀	1.20 (59.7)	0.80 (50.0)	0.50 (45.0)	0.20 (30.3)	0.0 (0.0)	0.0 (0.0)	2.70 (30.8±25.7)	0.45
	LC ₇₅	0.80 (47.1)	0.50 (41.0)	0.30 (31.3)	0.10 (23.3)	0.0 (0.0)	0.0 (0.0)	1.70 (23.8±20.1)	0.28
Methanolic	LC ₂₅	0.70 (58.3)	0.4 (50.0)	0.2 (40.0)	0.10 (35.7)	0.0 (0.0)	0.0 (0.0)	1.40 (30.7±25.0)	0.23
	LC ₅₀	0.40 (44.4)	0.20 (33.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.60 (13.0±20.3)	0.10
	LC ₇₅	0.20 (33.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.20 (5.6±13.6)	0.03
Petroleum ether	LC ₂₅	0.90 (56.3)	0.60 (47.6)	0.40 (43.5)	0.20 (40.0)	0.10 (38.5)	0.0 (0.0)	2.20 (37.6±19.5)	0.37
	LC ₅₀	0.70 (53.8)	0.40 (42.6)	0.20 (33.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.30 (21.6±24.5)	0.22
	LC ₇₅	0.40 (41.7)	0.20 (27.8)	0.10 (20.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.70 (15.0±17.7)	0.12
Selecron	LC ₇₅	1.4 (58.3)	1.1 (57.9)	0.60 (54.1)	0.20 (2.8)	0.1 (16.1)	0.0 (0.0)	3.40 (28.4±19.4)	0.57
Untreated	-----	5.8 (85.2)	5.7 (93.4)	4.50 (81.8)	3.8 (95.0)	3.6 (92.3)	3.1 (99.4)	26.45 (91.2±6.5)	4.41

Examination of data in table (7) showed that the tested plant extracts (acaricide) significantly reduced the number of hatched eggs. Where, the total number of hatched eggs (%) was low at methanol extract 1.4 (30.7), 0.6 (13), 0.2 (5.6%), petroleum ether 2.2 (37.6), 1.3 (21.6), 0.7 (15%) and aqueous 4.4 (44.3%), 2.7 (30.8), 1.7 (23.8) at LC₂₅, LC₅₀ and LC₇₅ doses, respectively, while the highest total number of hatched eggs was observed in the untreated groups, 26.5 (91.2%). Static analysis of data using a Kruskal-Wallis test revealed that the *Alhagi* extracts had significant on hatching rate of female citrus red mite. ($X^2 = 17.81$, $df = 4$, $P = 0.001$). It is evident that the type of plant extracts solvent and increasing concentration associated with a decrease in the rate of hatchability.

Control of Reproductive Potential

About the remarkable importance of reducing egg production (fecundity) as a criterion for blocking the reproductive potential. *Panonychus citri* mortality induced by plant extracts showed differs from the control treatment. It could be noticed that methanol extract was the most effective material, followed by petroleum ether and aqueous extracts that produced the greatest reduction in *P. citri* fecundity and therefore fertility (Table 7). Regarding sublethal effects of *A. maurorum* plant extract, it caused the greatest reduction in

P. citri viability, where the data showed that methanol extract has a significant impact on the viability reduction (58.16%) while it was low in aqueous plant extract (46.21%) followed by selecron (45.9%) (Table 7).

Table 7: Effect of sub-lethal concentrations of certain *Alhagi* plant extracts (phyto-acaricides) on mortality and reproductive potential of *P. citri*, citrus red mite

Alhagi extracts	Lethal conc.	Mortality (%)		Fecundity (no. of eggs/female)	Fertility {Hatching rate (%)}	Viability (reduction%) ^a
		24	48			
Aqueous	LC ₂₅	1.6±1.1 (11)	3.2±1.1 (21)	7.90±0.88	55.70±15.9	38.16
	LC ₅₀	4.6±1.5 (31)	7.6±2.3 (51)	5.38±0.68	50.19±18.6	44.27
	LC ₇₅	8.6±1.6 (57)	12.2±2.6 (81)	4.31±0.67	39.44±13.9	56.20
	Mean	4.9±1.4 (33)	7.7±2.0 (51)	5.86±0.7	48.44±15.8	46.21
Methanolic	LC ₂₅	3.0±1.6 (20)	5.6±1.8 (37)	2.78±0.47	50.36±16.6	44.08
	LC ₅₀	7.4±1.3 (49)	10.8±3.4 (72)	1.70±0.36	35.29±13.8	60.81
	LC ₇₅	10.4±1.8 (69)	14.4±1.6 (96)	0.73±0.24	27.40±6.9	69.58
	Mean	6.9±1.6 (69)	10.3±2.3 (96)	1.74±0.4	37.68±12.2	58.16
Petroleum ether	LC ₂₅	2.8±1.3 (19)	5.0±1.2 (33)	4.54±0.63	48.46±12.9	46.16
	LC ₅₀	6.6±1.8 (44)	10.2±2.6 (68)	3.04±0.53	42.76±17.6	52.52
	LC ₇₅	9.6±3.1 (64)	14.0±2.3 (93)	2.16±0.42	32.41±10.9	64.01
	Mean	6.0±2.0 (42)	9.7±2.0 (65)	3.25±0.5	41.21±13.6	54.24
Selecron	LC ₇₅	9.0±2.6 (60)	12.0±3.2 (81)	6.99±0.68	48.64±12.6	45.90
Untreated	----	0.0±0.0	0.3±0.1	29.37±1.2	90.06±0.2	----

a: Percent reduction of viability = [(C-T)/C] x 100, Where: C= % hatched eggs/female in the check. T= % hatched eggs/female in the treatment.

DISCUSSION

Today, many countries of the world use pesticides in various fields and in our daily lives, which has led to extensive use to stimulate insect resistance for many pesticide compounds. Therefore, many studies are carried out on eco-friendly products to reduce unwanted effects and solving this problem gradually. Plant insecticides consider the most effective alternative solutions in the biological control program, where plant products contain sources of bioactive compounds including phytochemicals possessing pesticide, that is based on a single active natural component to enhance the environmentally safe and pest control agents (Abay *et al.*, 2013).

The obtained results showed that *A. maurorum* plant extracts have insecticidal activities that maybe the existence of secondary metabolic compounds like terpenes, fatty acid, and phenolic in the extracts and this agrees with Salih *et al.* (2015) and Mena *et al.* (2016) who stated the *R. officinalis* and *A. maurorum* have toxic effects which resulted to secondary metabolites like phenols alkaloids, glycosides and tannins compounds in its

extract. Different plant extracts proved to be toxic to insects, had an insecticidal effect, or show antifeedant activity (Ismail *et al.*, 2016).

Insecticidal activity of *Alhagi* extracts showed the rate of daily deposited and hatched eggs varied considerably according to the type of solvents and concentration, where the highest effect was obtained from plant methanol extract. The second highest activity was gained from the petroleum ether extract. The lowest activity was acquired from the aqueous extract. So, the methanol extract has proved to be the most efficient phytoacaricide in reducing the total number of eggs laid and hatchability compared to selecron, chemical acaricide, especially at high concentrations. This confirms the results of some studies that indicated the extremely lethal effect of plant against insects, for example, Nikkon *et al.* (2009) who showed that the crude extracts of *Duranta repens* were very effective larvicidal agents against 1st, 2nd, 3rd and 4th mosquito larvae of *Culex quinquefasciatus*. Hatem *et al.* (2009) reported that *Brassica niger*, *Sonchus olearcues*, and *Raphanus sativa* extracts were highly toxic ($LC_{50} = 218.36, 96.11, \text{ and } 5574.66 \text{ ppm}$), respectively against 4th instar larvae of Egyptian cotton worm, *Spodoptera littoralis*. Badr El- Sabah *et al.* (2011) revealed that the *Cumin*, *Duranta*, and *Demsisa* plants have the potential to be used as an insecticide on *Oligonychus afrasiaticus* in the form of ethanolic extracts.

In the present study, a high quantity of phytochemicals such as phenolic, fatty acids, and tannin was resulted from *A. maurorum* plant extracts and revealed an acaricidal efficacy. This is due to plenty of this phytochemical in family Fabaceae and these are in line with several studies such as (Chidambara *et al.*, 2003) who reported alkaloids, phenol, tannins, and flavonoids in *Cissus quadrangularis* to its acaricidal property. Phenols, steroids, flavonoids, saponins, and alkaloids of *Cleome gynandra* (leaves) acetone and ethanol extracts have an attributed to its acaricidal property (Ping 2007).

Phenolic compounds are the most one and extensive groups of substances in the world of plants more than 8000 recognized phenolic structures (Tsao 2010). Phenolic compounds adjust the various metabolic functions such as growth, structure, pigmentation, and are resistant to diverse pathogens in plants (Naumovski 2015). Catelan *et al.* (2015) stated the phenolic compounds have significant differences in toxicity and mortality and mortality for 3rd instar larvae of *Ae. aegypti*. Coumarins, phenolics, alkaloids, and terpenoids are bioactive plant products used as growth-inhibiting and repellent insecticides (Ghosh *et al.*, 2007).

Among the identified fatty acid compounds that present in the three studied extracts were Hexadecanoic acid; Bis(2-ethylhexyl) phthalatehalic acid; 9, 12, 15-Octadecatrienoic acid; Octadecanoic acid (Stearic acid) and linolenic acid. Hexadecanoic acid, linolenic acid, and Octadecanoic acid (Stearic acid) were detected in significant amounts in the methanolic extract which was the highest effect extract similarly. Ragavendran *et al.* (2017) stated that N-Hexadecanoic has insecticidal activity on mosquito larvae *C. quinquefasciatus* and *A. aegypti*. Gobalakrishnan *et al.* (2014) reported the plant wall of *Vitis setosa* to have antimicrobial, antioxidant, and pesticide properties. Various workers have reported that some known FAs such as oleic acid (Kannathan *et al.*, 2008), linolenic acid Green (2011), and lastly linoleic, stearic acids, and palmitic (Figuroa-Brito *et al.*, 2002) have shown insecticidal activity. Dai and Mumper (2010) and Samuel *et al.* (2015) stated that fatty acids have toxicity and have repellent property against insecticide of malaria vector *Anopheles funestus*. Suarez *et al.* (2007) reported that fatty acids act as larvicidal, insecticidal, and repellent against mosquitoes. Yousef *et al.* (2013) reported the linoleic acid was toxic and reduction bodyweight of *S. littoralis* larvae. Silva *et al.* (2016) detected the larvicidal activity of *Solanum lycocarpum* fruits against mosquito *C. quinquefasciatus* at $LC_{50} 0.70 \text{ to } 3.72 \text{ mg/L}$.

Tannins are a significant group of polyphenolics that are divided into condensed and hydrolysable tannins (Porter 1989). The tannin complexes have defense compounds against herbivores insect and furthermore, they might help in regulating plant growth that is extensively distributed in numerous species of plants (Katie *et al.*, 2006). Some secondary metabolism, such as tannins were harmful to insects because they affect digestive enzymes and salivary proteins, which leads to the disruption of protein function. (Kumar *et al.*, 2014). In our study, the presence of tannins in *A. maurorum* extract though in lower quantity is also suggestive of its additional acaricidal property. Tannin rich plant extracts have been reported to have acaricidal effects on many insect and tick larvae (Fernández-Salas *et al.*, 2011).

The effect of tested acaricides on egg production may be due to the interruption of any of the complicated steps in vitellogenesis, hormonal, biochemical, or genetic factors (LaBrecque and Smith 1968). Sharma *et al.* (2011) showed the phytoextracts have significant alterations in the biochemical profiles of anopheline and culicine larvae. The results of this study confirmed that *A. maurorum* plants may be useful as powerful agents in controlling insect pests. This confirms the findings of several studies pointed to the highly mortal effect of plant extracts against stored-product beetles (Zia *et al.*, 2011) and Ghazzay and Abdulbary (2019) reported that the *Rosmarinus officinalis* & *Alhagi maurorum* can be used as insecticides for *T. castaneum*.

Conclusion

We concluded that methanol and petroleum ether and aqueous extracts of *Alhagi maurorum* showed phytoacaricidal activity against citrus red mite, *Panonychus citri* than the synthetic insecticidal (selecron). Therefore, we recommend the use of *Alhagi* plant against citrus red mite and applying within the control programs.

Declaration of interests

The authors declare that there is no conflict of interest

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