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Acaricidal Efficacy of Thirty-Five Egyptian Plants Against the Camel Tick, *Hyalomma Dromedarii*

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Abstract

Purpose Alternative and affordable tick control strategies are crucial to control and prevent tick bites and tick-borne diseases.

Methods In this study, we evaluated the acaricidal efficacy of 35 aqueous plant extracts (17%) against the camel tick, *Hyalomma dromedarii*.

Results The phytochemical profile indicated the presence of various secondary substances. Plants were classified into three groups according to their mortality percentage 15 days post-treatment with 17%. This highly effective group (91%–95%) comprised *Ocimum basilicum*, *Mespilus germanica*, and *Viola alpine* followed by *Carum carvi*, *Cucurbita pepo* (peel), and *Peganum harmala.* A moderately effective group (80%–90%) included *Acacia nilotica*, *Apium graveolens*, *Capsicum annuum*, *Ceratonia siliqua*, *Cucurbita pepo* (seeds), *Equisetum arvense*, *Eruca sativa*, *Ginkgo biloba*, *Plantago psyllium*, *Phyllanthus emblica*, *Punica granatum,* and *Ziziphus spinachristi*. The 20 remaining plants were assigned to the less effective group (< 80%). *Viscum album* (58.3%), which was the least effective reference plant. The high potency of six plant extracts as acaricides may be attributed to the high content of active principles, e.g., phenols, flavonoids, and tannins.

Conclusion All of these highly effective plants are recommended for use as an acaricide, in case of facing acaricidal resistance or limited options for tick control.

Keywords *Phyllanthus* · *Punica* · *Ziziphus* · *Ocimum* · *Mespilus* · *Viola*

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Introduction

Ticks are known vectors for severe infectious diseases [1–8] *Hyalomma dromedarii* (Ixodida: Ixodidae) is a blood-feeding ectoparasite that affects the health of camels [9] and cattle [10]. The application of synthesized pesticides contaminates the environment, milk, and meat products and leads to pesticide resistance [11–15].

Natural and medicinal plant extracts are widely used for their health benefits [16]. Eco-friendly acaricides [11, 17–19] are urgently required. Plant-based pesticides, also known as botanicals, possess parasiticidal [16, 20–24] and insecticidal effects [25, 26], such as ovicidal [27], adulticidal [27–29], larvicidal [28, 30–34], insect regulating effects [35], as well as deterrent and repellent features [29, 36] with different mode of actions and applications [36]. The bioactivity of plants depends on chemical compounds that inhibit the feeding of ticks. Toxic effects on pests are produced by terpenoids, steroids, phenols, flavonoids, tannins, alkaloids, and cyanogenic glycosides [33, 37, 38].

This work screened the novel acaricidal efficacy of 35 locally available and affordable plants against the camel tick, *H. dromedarii*, and compared their lethal times. Moreover, secondary metabolites of the most effective plants were determined.

Materials and Methods

Ticks

Adult males of *H. dromedarii* were collected from areas around camels at Toukh (35 km north of Cairo: 30° 21′ 11.6″N, 31° 11′ 31.5″E), Qalyubia Governorate, Egypt, and ticks were identified [39]. The experiment was conducted according to the guidelines of the Declaration of Benha University and approved by the Ethical Committee of the Faculty of Veterinary Medicine, Benha University (BUFVTM 02-10-22).

Plant Extraction Preparation

34 Plants and an herbal blend were purchased from an herbal market in the summer and identified at the Flora and Phytotaxonomy Section, Botany Department, Faculty of Science, Benha University, Egypt. Plants were dried in an oven at 30–35 °C with an air circulation for 2 days. After drying, each plant was minced before usage. The aqueous extract, 17% as a moderate concentration, of each plant (Table 1) was prepared [15] with a slight modification. Fifty grams of each plant were added to warm distilled water (300 mL) in a glass jar and shaken in a dark condition for 24 h. The extracts were filtered using a Whatman filter paper (No. 1) and freshly used in evaluation in the adult immersion tests.

Adult Immersion Tests

Adult immersion tests, AIT (dipping), were used to evaluate the toxicity of each plant extract against *H. dromedarii* [15] with slight modification using a single concentration for each plant. For each test, ten adult males (per replicate) were immersed for 60 s in 100 mL of 17% of each plant extract diluted in distilled water. The control group was treated with distilled water only. Three replicates were used for each extract (30 ticks were tested for each plant). After immersing, the treated ticks were placed in a Petri dish with filter paper (Whatman N. 1). The tests were conducted at 27 °C ± 2 °C, 80% ± 5% relative humidity, and a photoperiod of 16:8 (light/dark). The mortality (MO) of ticks was monitored up to 15 days post-treatment (PT). The experiments were replicated three times to validate the results.

Chemical Analyses

Chemical analyses of the six most effective plants were performed.

Determination of Total Phenolic Content

The total phenolic content of the aqueous extracts of investigated plants was determined according to a previous study [40]. The absorbance was recorded at 725 nm against a reagent blank, and total phenolics were calculated from a calibration curve as gallic acid equivalents.

Determination of Total Flavonoid Content

Total flavonoids were estimated [41], and the absorbance was measured at 420 nm. Total flavonoid contents were calculated as the quercetin equivalent of a calibration curve.

Determination of Total Anthocyanin Content

Anthocyanins from the investigated plants were extracted overnight with ethanol and 1% HCl (85:15) at 4 °C. The optical density of the extracts was measured at 535 nm. The total anthocyanin concentrations were calculated [42] using the extinction coefficient as follows:

$$\left(E^{1\%}_{1\ \mathrm{cm}} = 98.2 \text{ at } 535\ \mathrm{nm}\right)$$

Table 1 Applied plants for screening tests

	Binomial name	Plant part	English name	Family name
1	*Acacia nilotica*	Seeds	Acacia	Fabaceae
2	*Allium cepa*	Dried cloves	Onion	Amaryllidaceae
3	*Ambrosia maritima*	Leaves	*Ambrosia*	Asteraceae
4	*Angelica archangelica*	Leaves	*Garden Angelica*	Apiaceae
5	*Apium graveolens*	Seeds	Celery	Apiaceae
6	*Ballota saxatilis*	Leaves	Samoa	Lamiaceae
7	*Capsicum annuum*	Fruit	Chili	Solanaceae
8	*Carum carvi*	Seeds	Caraway	Apiaceae
9	*Ceratonia siliqua*	Pods	Carob	Fabaceae
10	*Corchorus olitorius*	Leaves	Jews mallow	Malvaceae
11	*Cucurbita pepo*	Seeds	Pumpkin	Cucurbitaceae
12	*Cucurbita pepo*	Peal	Pumpkin	Cucurbitaceae
13	*Equisetum arvense*	Leaves	Equisetales	Equisetaceae
14	*Eruca sativa*	Seeds	Rocket	Brassicaceae
15	*Ferula assafoetida*		Asafoetida ferula	Apiaceae
16	*Ginkgo biloba*	Leaves	Ginkgo	Ginkgoaceae
17	*Glycyrrhiza glabra*	Leaves	Liquorice	Fabaceae
18	*Hyphaene thebaica*	Palm	Doum	Arecaceae
19	*Lavandula angustifolia*	Leaves	Lavender	Lamiaceae
20	*Lupinus luteus*	Seeds	Lupin	Fabaceae
21	*Mespilus germanica*	Leaves	Hawthorn	Rosaceae
22	*Moringa oleifera*	Leaves	Moringa	Moringaceae
23	*Ocimum basilicum*	Leaves	*Basil*	Lamiaceae
24	*Peganum harmala*	Seeds	esfand, or harmel	Nitrariaceae
25	*Phyllanthus emblica*	Stem	Phyllanthus	Phyllanthaceae
26	*Plantago psyllium*	Seeds	Psyllium	Plantaginaceae
27	*Portulaca oleracea*	Seeds	Portulaca or purslane	Portulacaceae
28	*Punica granatum*	Peal	Pomegranate	Lythracaea
29	*Ruta graveolens*	Leaves	Ruta (Common rue)	Rutacae
30	*Solenostemma argel*	Leaves	Argel	Apocynaceae
31	*Terminalia chebula*	Seeds	Terminalia	Combretaceae
32	*Viola alpine*	Flowers	Violet flower	Violaceae
33	*Viscum album*	Leaves	Mistletose	Santalaceae
34	*Ziziphus spina- christi*	Leaves	Christs thorn Jujube	Rhamnaceae
35	*Herbal blend*	Mainly Leaves (bazil, violt flowers, Sandalwood, saffron, clove puds, rosemary, chamomile, nutmeg seeds, Christs thorn Jujube, aleb)	Almashat	Several families

Determination of Total Tannin Content

Tannin contents of aqueous extracts were determined using modified vanillin hydrochloric acid (MV-HCl) [43]. A total of 5 ml of vanillin–HCl reagent (50:50 mixtures of 4% vanillin and 8% HCl in methanol) was quickly added to 1 ml extract. Then, the color was measured at 500 nm using a spectrophotometer, and a standard curve was obtained, and concentrations of tannins were calculated.

Data Analysis

Data were analyzed through SPSS V23 (IBM, USA), and tick mortalities [43] were compared via one-way analysis of variance (one-way ANOVA, Duncan's MRT, P>0.05). Lethal time values were calculated through a Probit analysis and a p value of > 0.05 was deemed non-significant. Mortalities were corrected according to the following equation [44]: Corrected Mortality% = (MT%−MC%)/(100−MC%) * 100.

Relative Toxicities was calculated [27] according to the following formula:

RT = LT_{50} (LC_{90}, LC_{95}, or LT_{99}) for *Viscum album*, the reference plant/LT_{50} (LC_{90}, LC_{95}, or LT_{99}) for plant extract.

The correlation between mortality percentage and phenolic, flavonoids, tannin, and anthocyanins was evaluated using Pearson's correlation, and a correlation matrix was developed.

Results

Acaricidal Efficacy

Based on the obtained results, plants were classified according to their mortality%, 15 days PT, into three groups. The highly effective group, H group (91–95%), included six plants arranged according to their toxicity as follows: *Ocimum basilicum*, *Mespilus germanica*, and

Table 2 Mortality percentage of the plant extracts against ticks treated with 17% concentration

Days post-treatments	1st	2nd	3rd	5th	7th	9th	12th	15th
Plants	Mortality % ± SE							
Acacia nilotica	13.3 ± 0.33^{e}	27.6 ± 0.58^{de}	39.3 ± 0.33^{cd}	55.6 ± 0.58^{bc}	69.2 ± 0.33^{ab}	76.9 ± 0.0^{a}	80.0 ± 0.33^{a}	87.5 ± 0.0^{a}
Allium cepa	16.7 ± 0.33^{d}	24.1 ± 0.33^{d}	46.4 ± 0.58^{c}	48.1 ± 0.33^{bc}	57.7 ± 0.67^{abc}	61.5 ± 0.33^{abc}	68.0 ± 0.33^{ab}	79.2 ± 0.33^{a}
Ambrosia maritima	16.7 ± 0.67^{c}	34.5 ± 0.33^{b}	39.3 ± 0.33^{b}	59.3 ± 0.33^{a}	57.7 ± 0.33^{a}	69.2 ± 0.33^{a}	72.0 ± 0.33^{a}	75.0 ± 0.0^{a}
Angelica archangelica	26.7 ± 0.33^{c}	37.9 ± 0.58^{bc}	50.0 ± 0.33^{b}	74.1 ± 0.33^{a}	73.1 ± 0.33^{a}	80.8 ± 0.33^{a}	80.0 ± 0.33^{a}	79.2 ± 0.33^{a}
Apium graveolens	30.0 ± 0.58^{c}	34.5 ± 0.33^{c}	50.0 ± 0.33^{bc}	63.0 ± 0.67^{ab}	73.1 ± 0.33^{ab}	76.9 ± 0.58^{a}	76.0 ± 0.58^{a}	87.5 ± 0.58^{a}
Ballota saxatilis	20.0 ± 0.58^{e}	20.7 ± 0.33^{de}	25.0 ± 0.58^{cde}	37.0 ± 0.67^{bcd}	38.5 ± 0.33^{abc}	46.2 ± 0.33^{ab}	56.0 ± 0.33^{ab}	58.3 ± 0.33^{a}
Capsicum annuum	30.0 ± 0.58	34.5 ± 0.33	46.4 ± 0.0	55.6 ± 0.58	61.5 ± 0.33	69.2 ± 0.33^{abc}	80.0 ± 0.33^{ab}	87.5 ± 0.58^{a}
Carum carvi	30.0 ± 0.58^{e}	37.9 ± 0.58^{e}	42.9 ± 0.33^{de}	59.3 ± 0.33^{cd}	65.4 ± 0.58^{bc}	73.1 ± 0.33^{abc}	84.0 ± 0.0^{ab}	91.7 ± 0.33
Ceratonia siliqua	16.7 ± 0.33^{d}	34.5 ± 0.67^{cd}	39.3 ± 0.67^{c}	55.6 ± 0.58^{b}	61.5 ± 0.33^{b}	69.2 ± 0.33^{ab}	76.0 ± 0.0^{a}	83.3 ± 0.33^{a}
Corchorus olitorius	10.0 ± 00.0^{e}	20.7 ± 0.33^{de}	32.1 ± 0.88^{cd}	44.4 ± 0.58^{bc}	42.3 ± 0.58^{bc}	50.0 ± 0.33^{abc}	64.0 ± 0.58^{ab}	70.8 ± 0.33^{a}
Cucurbita pepo (seeds)	16.7 ± 0.33^{c}	34.5 ± 0.67^{b}	39.3 ± 0.67^{b}	66.7 ± 0.0^{a}	76.9 ± 0.0^{a}	84.6 ± 0.33^{a}	84.0 ± 0.33^{a}	83.3 ± 0.33^{a}
Cucurbita pepo (Peals)	30.0 ± 0.58^{e}	44.8 ± 0.33^{de}	60.7 ± 0.33^{cd}	70.4 ± 0.33^{bc}	73.1 ± 0.33^{abc}	76.9 ± 0.0^{abc}	84.0 ± 0.33^{ab}	91.7 ± 0.33^{a}
Equisetum arvense	16.7 ± 0.33^{e}	41.4 ± 0.33^{d}	60.7 ± 0.33^{cd}	63.0 ± 0.88^{bc}	76.9 ± 0.58^{abc}	84.6 ± 0.33^{abc}	80.0 ± 0.33^{ab}	87.5 ± 0.0^{a}
Eruca sativa	26.7 ± 0.88^{d}	31.0 ± 0.88^{cd}	42.9 ± 0.33^{bcd}	55.6 ± 0.58^{abc}	69.2 ± 0.33^{ab}	69.2 ± 0.33^{ab}	72.0 ± 0.33^{a}	83.3 ± 0.33^{a}
Ferula assafoetida	30.0 ± 0.58^{d}	34.5 ± 0.67^{cd}	42.9 ± 0.33^{bcd}	48.1 ± 0.33^{bc}	57.7 ± 0.33^{ab}	61.5 ± 0.33^{ab}	72.0 ± 0.33^{a}	79.2 ± 0.33^{a}
Ginkgo biloba	30.0 ± 0.58^{c}	57.1 ± 0.58^{b}	58.6 ± 0.58^{b}	69.2 ± 0.33^{ab}	70.4 ± 0.33^{ab}	76.9 ± 0.0^{ab}	79.2 ± 0.33^{a}	80.0 ± 0.33^{a}
Glycyrrhiza glabre	13.3 ± 0.33^{e}	20.7 ± 0.33^{de}	35.7 ± 0.58^{cd}	51.9 ± 0.33^{bc}	53.8 ± 0.58^{abc}	57.7 ± 0.33^{ab}	68.0 ± 0.33^{ab}	75.0 ± 0.58^{a}
Hyphaene thebaica	26.7 ± 0.33^{d}	41.4 ± 0.88^{cd}	50.0 ± 0.33^{bc}	59.3 ± 0.33^{abc}	69.2 ± 0.33^{ab}	73.1 ± 0.33^{a}	76.0 ± 0.0^{a}	79.2 ± 0.33^{a}
Lavandula angustifolia	20.0 ± 0.58^{e}	37.9 ± 0.00^{d}	46.4 ± 0.58^{cd}	55.6 ± 0.58^{bc}	65.4 ± 0.0^{ab}	69.2 ± 0.33^{ab}	76.0 ± 0.0^{a}	79.2 ± 0.33^{a}
Lupinus luteus	16.7 ± 0.33^{e}	24.1 ± 0.33^{de}	35.7 ± 0.0^{cd}	44.4 ± 0.0^{c}	46.2 ± 0.33^{bc}	50.0 ± 0.67^{bc}	64.0 ± 0.58^{ab}	79.2 ± 0.33^{a}
Mespilus germanica	36.7 ± 0.33^{d}	37.9 ± 0.58^{d}	57.1 ± 0.58^{c}	59.3 ± 0.33^{c}	73.1 ± 0.33^{bc}	84.6 ± 0.33^{ab}	92.0 ± 0.33^{ab}	95.8 ± 0.33^{a}
Moringa oleifera	13.3 ± 0.33^{d}	24.1 ± 0.33^{cd}	32.1 ± 0.33^{c}	63.0 ± 0.33^{b}	65.4 ± 0.0^{b}	73.1 ± 0.33^{ab}	76.0 ± 0.0^{ab}	83.3 ± 0.33^{a}
Ocimum basilicum	50.0 ± 0.58^{d}	51.7 ± 0.33^{d}	57.1 ± 0.0^{cd}	70.4 ± 0.33^{c}	73.1 ± 0.33^{bc}	73.1 ± 0.33^{bc}	92.0 ± 0.33^{ab}	95.8 ± 0.33^{a}
Peganum harmala	30.0 ± 0.58^{d}	41.4 ± 0.33^{cd}	42.9 ± 0.67^{cd}	59.3 ± 0.33^{bc}	65.4 ± 0.58^{b}	69.2 ± 0.33^{ab}	80.0 ± 0.33^{ab}	91.7 ± 0.33^{a}
Phyllanthus emblica	33.3 ± 0.33^{e}	44.8 ± 0.33^{de}	53.6 ± 0.33^{cd}	59.3 ± 0.67^{bcd}	73.1 ± 0.33^{abc}	76.9 ± 0.58^{ab}	80.0 ± 0.67^{ab}	87.5 ± 0.0^{a}
Plantago psyllium	33.3 ± 0.67^{e}	41.4 ± 0.33^{de}	46.4 ± 0.58^{cde}	59.3 ± 0.33^{bcd}	61.5 ± 0.33^{bc}	76.9 ± 0.0^{ab}	80.0 ± 0.33^{ab}	87.5 ± 0.58^{a}
Portulaca oleracea	20.0 ± 0.58^{c}	20.7 ± 0.33^{c}	32.1 ± 0.88^{bc}	37.0 ± 0.88^{bc}	50.0 ± 0.67^{ab}	50.0 ± 0.67^{ab}	68.0 ± 0.33^{a}	75.0 ± 0.0^{a}
Punica granatum	23.3 ± 0.33^{e}	37.9 ± 0.00^{de}	39.3 ± 0.33^{cd}	40.7 ± 0.33^{cd}	50.0 ± 0.33^{bcd}	53.8 ± 0.58^{bc}	68.0 ± 0.33^{ab}	87.5 ± 0.58^{a}
Ruta graveolens	16.7 ± 0.33^{e}	31.0 ± 0.33^{de}	46.4 ± 0.58^{cd}	48.1 ± 0.33^{c}	61.5 ± 0.67^{bc}	69.2 ± 0.33^{ab}	80.0 ± 0.33^{ab}	37.5 ± 0.0^{a}
Solenostemma argel	20.0 ± 0.0^{c}	24.1 ± 0.33^{c}	25.0 ± 0.58^{c}	29.6 ± 0.33^{c}	53.8 ± 0.58^{b}	73.1 ± 0.67^{ab}	80.0 ± 0.33^{a}	79.2 ± 0.33^{a}
Terminalia chebula	26.7 ± 0.33^{d}	34.5 ± 0.67^{cd}	39.3 ± 0.67^{bcd}	48.1 ± 0.88^{abcd}	57.7 ± 0.67^{abc}	61.5 ± 0.33^{ab}	64.0 ± 0.0^{ab}	70.8 ± 0.33^{a}
Viola alpine	13.33 ± 0.33^{e}	17.2 ± 0.00^{e}	28.6 ± 0.33^{de}	48.1 ± 0.88^{cd}	69.2 ± 0.33^{bc}	80.8 ± 0.33^{ab}	88.0 ± 0.58^{ab}	95.8 ± 0.33^{a}
Viscum album	23.3 ± 0.33^{d}	24.1 ± 0.33^{d}	28.6 ± 0.33^{cd}	40.7 ± 0.33^{bc}	38.5 ± 0.33^{bc}	38.5 ± 0.33^{bc}	44.0 ± 0.33^{ab}	58.3 ± 0.33^{a}
Ziziphus spina- christi	20.0 ± 0.58^{e}	24.1 ± 0.33^{e}	46.4 ± 0.0^{d}	51.9 ± 0.33^{cd}	57.7 ± 0.33^{bcd}	65.4 ± 0.0^{bc}	68.0 ± 0.33^{ab}	83.3 ± 0.33^{a}
Herbal blend	26.7 ± 0.33^{e}	37.9 ± 0.58^{de}	42.9 ± 0.33^{cd}	59.3 ± 0.33^{bc}	61.5 ± 0.33^{ab}	69.2 ± 0.33^{ab}	76.0 ± 0.0^{ab}	79.2 ± 0.33^{a}
Control	0.0 ± 0.0^{d}	3.3 ± 0.33^{cd}	6.7 ± 0.33^{bcd}	10.0 ± 0.00^{abcd}	13.3 ± 0.33^{abc}	13.3 ± 0.33^{abc}	16.7 ± 0.33^{ab}	20.0 ± 0.33^{a}

Numbers in the same column followed by the same small letter were not significant (one-way ANOVA, Duncan's MRT, $P > 0.05$)

Viola alpine, followed by *Carum carvi*, *Cucurbita pepo* (peel), and *Peganum harmala* (Table 2).

The moderately effective group (80–90%), M group, clustered 12 plant species, as follows: *Acacia nilotica*, *Apium graveolens*, *Capsicum annuum*, *Ceratonia siliqua*, *Cucurbita pepo* (seeds), *Equisetum arvense*, *Eruca sativa*, *Ginkgo biloba*, *Plantago psyllium*, *Phyllanthus emblica*, *Punica granatum*, and *Ziziphus spina-christi*. The other plants were allocated in the less effective group (L group) (<80%). *Viscum album* (58.3%) was the least effective and reference plant (Table 2).

The lowest LT_{50} values were recorded for *Ocimum basilicum* and *Ginkgo biloba* (1.1 days), and they were able to kill ticks eight times faster compared to the reference plant. The LT_{99} values of the H and M groups ranged from 19.428 (*Acacia nilotica*) to 25.920 days (*Punica granatum*), respectively, and killed ticks twice as fast as *Viscum album*, except for *Mespilus germanica* and *Viola alpine* (2.5 and 2.6 times, respectively) (Table 3).

Chemical Profile

The chemical profile of the highly effective group indicated contents of total phenolic, flavonoid, tannin, and anthocyanin compounds. Although all aqueous extracts possess active principles, *Viola alpine* extract contained the highest active compounds among the investigated plants as follows: 314.01 ± 1.73, 167.57 ± 1.40 mg/g and 15.37 ± 0.16 mg/100g for contents of phenols, flavonoids, and anthocyanins, respectively, which resulted in efficiency in killing ticks that reached 95.8 ± 0.33% at the end of the experiment (Table 4).

Mespilus germanica and *Ocimum basilicum* extracts also exhibited high efficiency against ticks (95.8% ± 0.33%); they comprised a relatively high content of phenols, flavonoids, and tannins (135.53 ± 0.40, 42.63 ± 0.38, 4.24 ± 0.25, and 42.43 ± 0.269, 9.76 ± 0.140, and 0.93 ± 0.040, respectively). However, *Carum carvi* contained the highest total tannin content (41.50 ± 0.464 mg/g DW) and achieved 91.7% ± 0.33% mortality (Table 4). Pearson's correlation matrix between the tick mortality rate and the concentrations of four phytochemicals (phenolics, flavonoids, tannins, and anthocyanins) was revealed (Fig. 1). The correlation matrix plot showed that there was a positive correlation between the tick mortality rate and the concentrations of phenolic, flavonoids, and anthocyanins in plant extracts, comprised that these compounds may have acaricidal properties. Additionally, the high correlation between phenolic, flavonoids, and anthocyanins suggested that these compounds may work synergistically to enhance their acaricidal activity.

Discussion

Eco-friendly pest control is important for preventing vector-borne diseases [25, 26, 45–47]. Thus, this study evaluated the novel use of 35 plants against *H. dromedarii.* An ALT bioassay was used for this study as it is the closest test to a spot-on (topical) application and requires a small amount of the applied extracts used by farmers. Our findings indicate that *C. carvi*, *C. pepo*, *M. germanica*, *O. basilicum*, *P. harmala*, and *V. alpine* induced the highest (91%–95%) mortality. *O. basilicum* and *G. biloba* (LT_{50} = 1.1 days) killed ticks eightfolds swifter than *V. album*.

Because these applied plants were novel against *H. dromedarii*, their efficacies against other pests were also examined in the literature. Analogous to our results, it was previously determined that *Carum carvi* oil effectively killed *Sitophilus zeamais* and *Tribolium castaneum* adults (LD50 values = 3.07 and 3.29 mg/adult, respectively) and provoked strong fumigant toxicity (lethal Concentration 50, LC_{50}, values = 3.37 and 2.53 mg/L, respectively) [48]. *Carum carvi* was also effective against *Callosobruchus maculatus* (Coleoptera: Bruchidae) [49] (repellence = 66.29%) and the house dust mite *D. pteronyssinus* [50].

Like findings of this investigation, other studies indicated that some plants of the highly effective group induced pesticidal effects as follows: *Cucurbita maxima*, 2%, showed effects against *Cephalopina titillator* larvae at 24 h PT [28]; *Ocimum basilicum* induced pesticidal effect against *Rhipicephalus* (*Boophilus*) *microplus* [51, 52]; the toxicity indices three days PT with *Vitex castus* and *Zingiber officinale* extracts were 96.72 and 100.00% against *Hyalomma dromedarii* [53].

Ocimum basilicum and *Lavandula officinalis Chaix* showed effects against tetranychid mites, *Tetranychus urticae* (Koch), and *Eutetranychus orientalis* [54]; meanwhile, *Peganum harmala* was effective against *Tribolium castaneum* [55]. Comparatively, *Viola* alpine oil provided 8 h of protection against *Aedes, Anopheles,* and *Culex* mosquitoes [56]. The novel acaricidal effect of myrrh (*Commiphora molmol*) and ginger (*Zingiber officinale*) extracts (96.0 and 84.01% mortality, 15 days PT) and their silver nanoformulations through laser ablation (100% mortality, reached 7 and 9 days PT with 12%, respectively) led to increased speed and efficacy of the aqueous extracts against *H. dromedarii* [15]. Also, the extracts of *Araucaria heterophylla* and *Commiphora molmol* were very effective against camel and cattle ticks, and flies, which may be attributed to the high contents of active principles, e.g., phenols, flavonoids, and tannins. *V. alpine* extract included the uppermost active compounds among the investigated

Table 3 The lethal time values of aqueous plant extracts (17%) and their relative effects against the tick of camels, *Hyalomma dromedarii*

Plants	LT_{50} Upper Lower limits	LT_{90} Upper Lower limits	LT_{95} Upper Lower limits	LT_{99} Upper Lower limits	Chi df sig	Regression R^2	Relative toxicity (RT) LT_{50}	LT_{90}	LT_{95}	LT_{99}
Acacia nilotica	4.837	12.875	15.153	19.428	2.598	y = 0.78 + 0.15*x	1.9	2.1	2.1	2.1
	2.302	10.134	11.809	14.850	6					
	6.788	19.463	23.601	31.464	0.857[a]					
Allium cepa	5.673	16.646	19.756	25.591	2.083	y = 0.69 + 0.12*x	1.6	1.6	1.6	1.6
	2.257	12.430	14.532	18.377	6					
	8.397	30.507	37.557	50.878	0.912[a]					
Ambrosia maritima	5.023	16.422	19.654	25.716	2.457	y = 0.58 + 0.11*x	1.8	1.6	1.6	1.6
	0.949	12.153	14.318	18.270	6	0.818				
	7.724	31.213	38.882	53.379	0.873[a]					
Angelica archangelica	2.739	14.125	17.353	23.408	3.960	y = 0.27 + 0.11*x	3.4	1.9	1.8	1.8
	−3.725	10.361	12.547	16.475	6	0.722				
	5.399	27.546	35.631	50.970	0.682[a]					
Apium graveolens	3.260	13.611	16.545	22.050	1.775	y = 0.38 + 0.12*x	2.8	2.0	1.9	1.9
	−1.668	10.167	12.196	15.854	6	0.882				
	5.672	24.560	31.240	43.921	0.939[a]					
Ballota saxatilis	8.725	22.630	26.572	33.966	0.514	y = 0.82 + 0.09*x	1.1	1.2	1.2	1.2
	5.478	15.837	18.275	22.780	6	0.945				
	15.044	56.086	68.219	91.048	0.998[a]					
Capsicum annuum	3.983	14.301	17.226	22.713	0.434	y = 0.49 + 0.12*x	2.3	1.9	1.9	1.8
	−0.235	10.720	12.734	16.385	6	0.972				
	6.373	25.600	32.142	44.541	0.999[a]					
Carum carvi	3.698	12.827	15.415	20.269	0.323	y = 0.51 + 0.14*x	2.5	2.1	2.1	2.0
	0.013	9.784	11.624	14.945	6	0.982				
	5.849	21.344	26.666	36.781	0.999[a]					
Ceratonia siliqua	4.851	14.618	17.387	22.580	1.655	y = 0.65 + 0.13*x	1.9	1.8	1.8	1.8
	1.557	11.146	13.085	16.614	6	0.896				
	7.166	24.619	30.346	41.198	0.949[a]					
Corchorus olitorius	7.480	18.310	21.379	27.138	1.854	y = 0.95 + 0.12*x	1.2	1.5	1.5	1.5
	4.802	13.748	15.821	19.637	6	0.864				
	10.785	32.921	39.659	52.372	0.933[a]					
Cucurbita pepo (seeds)	2.214	12.205	15.038	20.351	1.701	y = 0.26 + 0.12*x	4.2	2.2	2.1	2.0
	−3.685	9.065	11.046	14.575	6	0.894				
	4.655	22.213	28.823	41.412	0.945[a]					
Cucurbita pepo (peel)	3.866	12.273	14.657	19.128	4.720	y = 0.55 + 0.14*x	2.4	2.2	2.2	2.2
	0.708	9.535	11.282	14.430	6	0.786				
	5.874	19.095	23.599	32.176	0.580[a]					
Equisetum arvense	3.038	12.366	15.011	19.971	4.583	y = 0.4 + 0.13*x	3.1	2.2	2.1	2.1

Table 3 (continued)

Plants	LT_{50} Upper Lower limits	LT_{90} Upper Lower limits	LT_{95} Upper Lower limits	LT_{99} Upper Lower limits	Chi df sig	Regression R^2	Relative toxicity (RT) LT_{50}	LT_{90}	LT_{95}	LT_{99}
	−1.323	9.383	11.271	14.657	6	752.000				
	5.265	20.785	26.331	36.891	0.598[a]					
Eruca sativa	4.329	15.102	18.156	23.885	1.381	$y=0.51+0.12*x$	2.1	1.8	1.8	1.7
	0.098	11.268	13.349	17.132	6	0.904				
	6.824	27.631	34.614	47.836	0.967[a]					
Ferula assafoetida	4.735	17.274	20.829	27.496	0.317	$y=0.48+0.1*x$	2.0	1.6	1.5	1.5
	−0.373	12.450	14.752	18.953	6	0.97				
	7.682	37.155	46.845	65.136	0.999[a]					
Ginkgo biloba	1.093	15.563	19.665	27.359	2.687	$y=0.08+0.08*x$	8.5	1.7	1.6	1.5
	−15.692	10.707	13.262	17.831	6	0.724				
	4.596	46.007	62.675	94.166	0.847[a]					
Glycyrrhiza glabra	6.425	16.915	19.889	25.467	2.426	$y=0.083+0.12*x$	1.4	1.6	1.6	1.6
	3.542	12.790	14.826	18.558	6	0.849				
	9.200	29.586	35.952	47.978	0.877[a]					
Hyphaene thebaica	3.352	15.573	19.038	25.536	1.745	$y=0.34+0.1*x$	2.8	1.7	1.7	1.6
	−3.205	11.270	13.548	17.670	6	0.848				
	6.135	32.776	42.154	59.896	0.942[a]					
Lavandula angustifolia	4.294	15.568	18.764	24.759	2.009	$y=0.49+0.11*x$	2.2	1.7	1.7	1.7
	−0.312	11.514	13.665	17.575	6	0.848				
	6.893	29.594	37.231	51.681	0.919[a]					
Lupinus luteus	6.763	17.870	21.018	26.925	0.956	$y=0.8+0.12*x$	1.4	1.5	1.5	1.5
	3.806	13.310	15.421	19.298	6	0.932				
	9.890	33.101	40.265	53.784	0.987[a]					
Mespilus germanica	2.702	10.491	12.700	16.842	0.486	$y=0.42+0.16*x$	3.4	2.6	2.5	2.5
	−0.967	8.031	9.648	12.530	6	0.98				
	4.640	16.912	21.326	29.755	0.998[a]					
Moringa oleifera	5.160	13.733	16.163	20.721	3.553	$y=0.79+0.15*x$	1.8	2.0	2.0	2.0
	2.525	10.745	12.508	15.716	6	0.838				
	7.238	21.215	25.744	34.338	0.737[a]					
Ocimum basilicum	1.104	11.347	14.251	19.698	0.508	$y=0.16+0.13*x$	8.4	2.4	2.2	2.1
	−7.174	8.244	10.257	13.792	6	0.966				
	3.778	22.465	30.120	44.721	0.998[a]					
Peganum harmala	3.678	13.656	16.484	21.790	0.500	$y=0.48+0.13*x$	2.5	2.0	1.9	1.9
	−0.584	10.268	12.232	15.782	6	0.97				
	5.999	24.086	30.325	42.164	0.998[a]					

Table 3 (continued)

Plants	LT_{50} Upper Lower limits	LT_{90} Upper Lower limits	LT_{95} Upper Lower limits	LT_{99} Upper Lower limits	Chi df sig	Regression R^2	Relative toxicity (RT) LT_{50}	LT_{90}	LT_{95}	LT_{99}
Phyllanthus emblica	2.549	13.635	16.777	22.673	0.992	$y=0.27+0.11*x$	3.6	2.0	1.9	1.8
	−3.964	9.998	12.130	15.954	6	0.920				
	5.163	26.619	34.527	49.537	0.986[a]					
Plantago psyllium	3.333	13.974	16.991	22.650	0.477	$y=0.39+0.12*x$	2.8	1.9	1.9	1.8
	−1.757	10.375	12.438	16.163	6	0.963				
	5.797	25.930	33.012	46.445	0.998[a]					
Portulaca oleracea	6.976	17.848	20.930	26.711	0.616	$y=0.83+0.12*x$	1.3	1.5	1.5	1.5
	4.167	13.376	15.458	19.285	6	0.957				
	10.094	32.239	39.046	51.892	0.996[a]					
Punica granatum	5.617	16.801	19.972	25.920	0.820	$y=0.67+0.12*x$	1.7	1.6	1.6	1.6
	2.097	12.443	14.563	18.444	6	0.94				
	8.418	31.818	39.266	53.331	0.992[a]					
Ruta graveolens	4.869	13.846	16.391	21.165	1.420	$y=0.71+0.14*x$	1.9	1.9	1.9	2.0
	1.960	10.701	12.519	15.826	6	0.925				
	7.020	22.226	27.197	36.625	0.965[a]					
Solenostemma argel	6.188	14.899	17.369	22.002	1.486	$y=0.9+0.14*x$	1.5	1.8	1.8	1.9
	3.847	11.677	13.460	16.721	6	0.927				
	8.439	22.971	27.527	36.157	0.960[a]					
Terminalia chebula	5.315	19.501	23.523	31.066	0.752	$y=0.48+0.09*x$	1.7	1.4	1.4	1.3
	−0.510	13.610	16.100	20.663	6	0.903				
	8.873	50.370	63.647	88.659	0.993[a]					
Viola odorata	5.176	10.941	12.575	15.641	0.990	$y=1.12+0.21*x$	1.8	2.5	2.5	2.6
	3.521	8.921	10.178	12.465	6	0.971				
	6.723	15.078	17.720	22.747	0.986[a]					
Viscum album	9.288	26.936	31.939	41.323	0.668	$y=0.68+0.07*x$	1.0	1.0	1.0	1.0
	5.130	17.317	20.118	25.304	6	0.897				
	25.327	135.850	167.835	227.903	0.995[a]					
Ziziphus spina- christi	5.271	15.797	18.781	24.379	1.894	$y=0.66+0.12*x$	1.8	1.7	1.7	1.7
	1.840	11.882	13.924	17.651	6	0.886				
	7.810	28.100	34.658	47.061	0.929[a]					
A herbal blend	4.053	15.973	19.352	25.691	1.145	$y=0.43+0.1*x$	2.3	1.7	1.7	1.6
	−1.309	11.649	13.882	17.941	6	0.903				
	6.779	32.384	41.082	57.530	0.980[a]					

LT lethal time values, Chi-square; *df* degree of freedom, *Sig* significance, R^2 R squared

[a] Since the significance level is less than .050, a heterogeneity factor is used in the calculation of confidence limits

Viscum album is the reference material (the least effective plant) plants. *Commiphora molmol* extracts contain sesquiterpenes, fatty acid esters, and phenols, while *Araucaria heterophylla* extracts possess monoterpenes, sesquiterpenes, terpene alcohols, fatty acids, and phenols. Both plant extracts had a clear effect on killing many insect pests [57].

The toxicity of secondary metabolites (phenolic compounds) plays an essential role in plant–herbivore and pathogen interaction. Phenolic compounds exhibit antioxidant properties, which are the main reason for the pesticide effect in nature [37]. A previous study evaluated phenolic compounds such as rutin, vanillic, and synaptic acid in pepper (*Capsicum annum*) and reported strong effects on larval development and response of the adult moth (Oriental leafworm, *Spodoptera litura*) [58]. The phenolic crude extract of *Artocapus lakoocha* leaves (1600 µg/ml) was effective (72%) in getting rid of cattle ticks, *R. (Boophilus) microplus* using AIT and its LC50 of the extract was 1050 µg/ml [59].

Tannins possess astringent properties and cause insect tissue to pull together, which restricts blood flow and results in insect death. Tannins also turn insect skin into leather by binding proteins to form water-insoluble substances resistant to proteolytic enzymes. The activity and toxicity of extracts depend on the concentration and exposure time, but every extract contains different concentrations and different active principles (which are likely the reason for biological activity). Moreover, the combination of active constituents in the extract could have a synergistic effect and increase the biological activity of the extract. The anthelmintic activity of some medicinal plants may be attributed to their content of secondary metabolites, tannins, flavonoids, alkaloids, coumarins, triterpenoids, and essential oils. The results of previous studies confirm the use of medicinal plants in combating intestinal parasites [21].

The M group plants in this study (80–90 MO%) included *Acacia nilotica*, *Apium graveolens*, *Capsicum annuum*, *Ceratonia siliqua*, *Cucurbita pepo (seeds)*, *Equisetum arvense*, *Eruca sativa*, *Ginkgo biloba*, *Plantago psyllium*, *Phyllanthus emblica*, *Punica granatum*, and *Ziziphus spina-christi*). Similarly, the hydrodistilled seed oil of *Acacia nilotica* results in a strong larvicidal activity against *Anopheles stephensi* ($LC_{50} = 5.239$, $LC90 = 9.713$ mg/L), *Aedes aegypti*, ($LC50 = 3.174$, $LC90 = 11.739$ mg/L), and *Culex quinquefasciatus* ($LC_{50} = 4.112$, $LC90 = 12.325$ mg/L) [60]. In addition, toxic and oviposition deterrence effects that were observed against *Alcaria vulgaris* and *Apium graveolens* L were also reported against the potato tuber moth, *Phthorimaea operculella* [61].

Like our observations, some M group plants were also found to be effectively toxic to other pests such as *Acacia nilotica* and *Punica granatum* against *Rhipicephalus (Boophilus) annulatus* [62]; *Phyllanthus emblica* against the adult cattle tick *Haemaphysalis bispinosa and Culex tritaeniorhynchus* [63]; *Apium graveolens* against *Lucilia sericata* [64]; and *Eruca sativa* against *Culex pipiens* [65]. In addition*, Lupinus pilosus* and *Punica granatum* repelled the carmine spider mite, *Tetranychus cinnabarinus*, and affected its eggs [66]. In contrast*, Equisetum arvense* ethanolic extract had no acaricidal effect against *Tetranychus merganser* [63].

Overall, The L group plants in this study were less effective against *H. dromedarii*. A similar effect was reported for *Portulaca oleracea* against *Dermanyssus gallinae* [67] and *Ruta graveolens* against the red palm mite, *Raoiella indica* [67], but it had an acaricidal effect against *R. microplus* [68, 69]. In contrast, some of the L group plants effectively controlled other pests such as *Allium cepa* against *Boophilus annulatus* [70], *Ferula pseudalliacea* against *Varroa destructor* (Acari: Varroidae) [71], Allium cepa and Lupinus luteus against *Cephalopina titillator* [28], and *Solenostemma argel* against *Culex pipiens L.* [72].

Some plants that were not applied in this survey showed pesticidal effects in some other studies such as the commercial oils of rosemary, neem, cyperus, and garlic against *H. dromedarii* [73]; *Saussurea costus* extracts against blood-sucking arthropods of camel and cattle such as *H. dromedarii, Rhipicephalus (Boophilus) annulatus,* the louse fly, *Hippobosca maculata*, and the cattle lice, *Haematopinus eurysternus*.

More botanicals were effective like A*rtemisia absinthium* against *Ixodes ricinus* [74]; *Azadirachta indica* against *Sarcoptes scabiei var. cuniculi* [23]*; Aloe vera* L. against the carmine spider mite *Tetranychus cinnabarinus* (Boisduval) [24]; components of botanical acaricides against *Psoroptes* spp. [75]; and *Vernonia amygdalina*, *Calpurnia aurea*, *Schinus molle*, *Ricinus communis*, *Croton macrostachyus*; and *Nicotiana tabacum* against *R.* (*Boophilus*) *decoloratus* and *Rhipicephalus pulchellus* [76]. In another study, the extent of the danger of the newovel photosensitizers against male H. dromedarii ticks was evaluated. Methylene blue, safranin, and field stain dye showed a wide absorption area, indicating greater photosynthetic activity and better phototoxicity, and could be used as replacement agents for synthetic insecticides [14]. Various findings in pest control may be attributed to the species and location of the plants, pests, and extraction methods [77, 78]. In another study, the extent of the danger of the novel photosensitizers against male *H. dromedarii* ticks was evaluated. Methylene blue, safranin, and field stain dye showed a wide absorption area, indicating greater photosynthetic activity and better phototoxicity, and could be used as replacement agents for synthetic insecticides [14].

Table 4 Total content of active compounds in aqueous extracts of the investigated plants

Plant name	Total Phenols (mg gallic/g D.W.)	Total Flavonoids (mg Querstine /gD.W)	Tannins (mg gallic /g D.W.)	Anthocyanins (mg/100 g)
Carum carvi	13.66 ± 0.201	10.58 ± 0.218	41.50 ± 0.464	–
Ocimum basilicum	42.43 ± 0.269	9.76 ± 0.140	0.93 ± 0.040	–
Viola odorata	314.01 ± 1.73	167.57 ± 1.40	–	15.37 ± 0.16
Cucurbita pepo peel	114.99 ± 0.345	29.99 ± 0.235	–	–
Mespilus germanica	135.53 ± 0.40	42.63 ± 0.38	4.24 ± 0.25	–
Peganum harmala	36.74 ± 0.252	7.30 ± 0.245	2.95 ± 0.01	–

Data are means ± standard deviation of triplicate experiments

Conclusions

Alternative and affordable tick control strategies are needed to prevent tick bites and tick-borne diseases. This study screened the toxicity of 35 plants (17%), and *Carum carvi*, *Cucurbita pepo*, *Mespilus germanica*, *Ocimum basilicum*, *Peganum harmala*, and *Viola alpine* showed highly effective results. Even though the applied plants were novel against *H. dromedarii*, few of these plants induced pesticide effects against other pests. Using such plant extracts by farmers as natural alternative acaricides, especially when facing acaricidal resistance or due to limited options for tick control is recommended. These extracts also would reduce reliance on conventional acaricides and their health and environmental drawbacks. it is recommened to develop effective formulations for tick elimination in the form of shampoos or tick sprays to be applied to cattle as well as other animals. Future studies should be directed toward improving their toxicity through nanoformulations and assessing their field applications and eco-toxicological profiles.

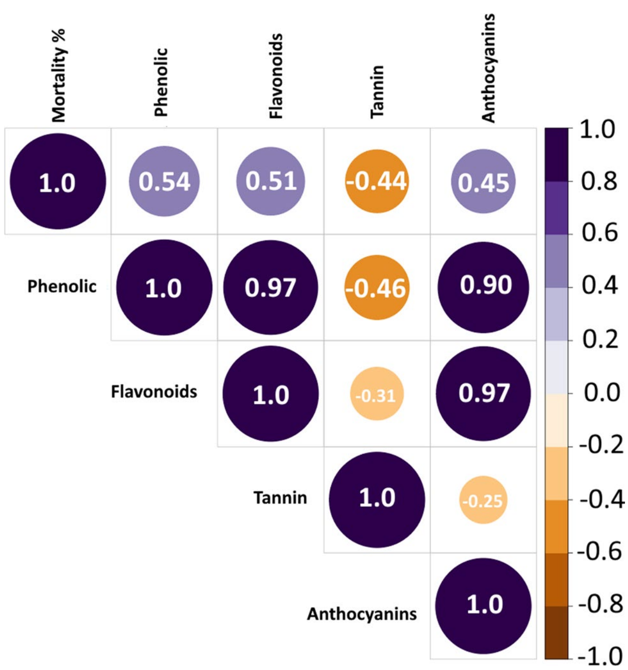

Fig. 1 Pearson's Correlation Matrix of Tick Mortality Rate and Plant Phytochemicals concentrations. Positive correlations are displayed in purple and negative correlations are displayed in orange. The color intensity and the size of the circle are proportional to the Pearson's correlation coefficient

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Author Contributions All authors conceived, planned, and designed the research. HK, SG, and MB conducted experiments. AS and IR helped with data collection. HK and AM analyzed data. HK and EB writing the original draft preparation. HT extracted and determined the chemical profile. AM and SK are help in writing, reviewing, and editing the manuscript. All authors read and approved the manuscript.

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Data availability Available upon request.

Declarations

Conflict of interest The authors declare that there were no conflicts of interest.

Ethical approval The protocol of this work was approved by the Ethical Committee related to the Faculty of Veterinary Medicine at Benha University, Egypt (BUFVTM 02-10-22).

References

1. Ali S, Ijaz M, Ghaffar A, Oneeb M, Masud A, Durrani AZ et al (2020) Species distribution and seasonal dynamics of equine tick

infestation in two subtropical climate niches in Punjab, Pakistan. Pak Vet J 40(1):25–30. https://doi.org/10.29261/pakvetj/2019.095
2. Ceylan O, Uslu A, Ceylan C, Sevinc F (2021) Predominancy of *Rhipicephalus turanicus* in tick-infested sheep from Turkey: a large-scale survey. Pak Vet J 41(429):433. https://doi.org/10.29261/pakvetj/2021.036
3. Ceylan O, Uslu A, Ozturk O, Sevinc F (2021) Serological investigation of some vector-borne parasitic and rickettsial agents in dogs in the western part of Turkey. Pak Vet J 41:386–392
4. Farooq R, Hafeez MA, Oneeb M, Rafique A, Ashraf K, Aslam F et al (2020) Molecular characterization and phylogenetic analysis of *Babesia* species isolated from domestic cattle. Pak Vet J. https://doi.org/10.29261/pakvetj/2020.003
5. Hegab A, Fahmy M, Omar H, Abuowarda M, Gattas S (2020) Investigation of tick-borne pathogens within naturally infected brown dog tick (Ixodidae: *Rhipicephalus sanguineus*) in Egypt by light and electron microscopy. Int J Vet Sci. https://doi.org/10.37422/IJVS/20.064
6. Selim A, Abdelhady A, Alahadeb J (2020) Prevalence and first molecular characterization of *Ehrlichia canis* in Egyptian dogs. Pak Vet J. https://doi.org/10.29261/pakvetj/2020.061
7. Selim A, Khater H (2020) Seroprevalence and risk factors associated with Equine piroplasmosis in North Egypt. Comp Immunol Microbiol Infect Dis 73:101549. https://doi.org/10.1016/j.cimid.2020.101549.32950955
8. Peter S (2020) Zoonotic *Anap*lasma and *Ehrlichia infections* and their potential reservoirs: a review. Int J Vet Sci 91–99
9. Perveen N, Muzaffar SB, Vijayan R, Al-Deeb MA (2020) Microbial communities associated with the camel tick, *Hyalomma dromedarii*: 16S rRNA gene-based analysis. Sci Rep. https://doi.org/10.1038/s41598-020-74116-7
10. Al-Deeb MA, Muzaffar SB, Abu-Zeid YA, Enan MR, Karim S (2015) First record of a spotted fever group Rickettsia sp. and *Theileria annulata in Hyalomma dromedarii* (Acari: Ixodidae) ticks in the United Arab Emirates. Fla Entomol 98(1):135–139. https://doi.org/10.1653/024.098.0123
11. Abbas RZ, Zaman MA, Colwell DD, Gilleard J, Iqbal Z (2014) Acaricide resistance in cattle ticks and approaches to its management: the state of play. Vet Parasitol 203(1–2):6–20. https://doi.org/10.1016/j.vetpar.2014.03.006
12. Anwar MI, Sadiq N, Aljedani DM, Iqbal N, Saeed S, Khan HAA, Khan KA (2022) Toxicity of different insecticides against the dwarf honey bee, *Apis florea Fabricius* (Hymenoptera: Apidae). J King Saud Univ Sci 34(1):101712. https://doi.org/10.1016/j.jksus.2021.101712
13. Mani AMM, Araji RRA (2022) Determination of pyrothyroid (Deltamethrin) pesticides and ivermectine residues in local sheep milk and mutton by high performance liquid chromatography (HPLC). J Vet Med Anim Sci 5(1):1106
14. Mohammed SH, Baz MM, Ibrahim M, Radwan IT, Selim A, Dawood AFD et al (2023) Correction: acaricide resistance and novel photosensitizing approach as alternative acaricides against the camel tick, Hyalomma dromedarii. Photochem Photobiol Sci 22(3):693. https://doi.org/10.1007/s43630-022-00329-6
15. Nabil M, Khater HF, Selim A, Baz MM, Govindarajan M, Taie HA, Negm S (2023) Acaricidal efficacy of silver nanoformulations of Commiphora molmol and Zingiber officinale against the camel tick, Hyalomma dromedarii (Ixodida: Ixodidae). Inorg Chem Commun 147:110229. https://doi.org/10.1016/j.inoche.2022.110229
16. Khater HF, Ziam H, Abbas A, Abbas RZ, Raza MA, Hussain K et al (2020) Avian coccidiosis: recent advances in alternative control strategies and vaccine development. Agrobiol Rec. https://doi.org/10.47278/journal.abr/2020.004
17. Khater HF, Ramadan MY (2007) The acaricidal effect of peracetic acid against *Boophilus annulatus* and Argas persicus. Acta Sci Vet 35(1):29–40. https://doi.org/10.22456/1679-9216.15806
18. Khater HF, Seddiek SA, El-Shorbagy MM, Ali AM (2013) Erratum to: the acaricidal efficacy of peracetic acid and deltamethrin against the fowl tick, *Argas persicu*s, infesting laying hens. Parasitol Res 112(10):3669–3678. https://doi.org/10.1007/s00436-013-3563-4
19. Khater H, Hendawy N, Govindarajan M, Murugan K, Benelli G (2016) Photosensitizers in the fight against ticks: safranin as a novel photodynamic fluorescent acaricide to control the camel tick *Hyalomma dromedarii* (Ixodidae). Parasitol Res 115(10):3747–3758. https://doi.org/10.1007/s00436-016-5136-9
20. Abbas RZ, Zaman MA, Sindhu D, Sharif M, Rafique A, Saeed Z (2020) Anthelmintic effects and toxicity analysis of herbal Dewormer against the infection of *Haemonchus contortus* and *Fasciola hepatica* in goat. Pak Vet J 40(4):455–460. https://doi.org/10.29261/pakvetj/2020.083
21. Degla LH, Kuiseu J, Olounlade PA, Attindehou S, Hounzangbe-Adote MS, Edorh PA, Lagnika L (2022) Use of medicinal plants as alternative for the control of intestinal parasitosis: Assessment and perspectives. Agrobiol Rec 7:1–9. https://doi.org/10.47278/journal.abr/2021.011
22. Seddiek SA, Ali MM, Khater HF, El-Shorbagy MM (2011) Anthelmintic activity of the white wormwood, *Artemisia herba-alba* against *Heterakis gallinarum* infecting turkey poults. J Med Plants Res 5(16):3946–3957. https://doi.org/10.5897/JMPR.9000085
23. Seddiek SA, Khater HF, El-Shorbagy MM, Ali AM (2013) The acaricidal efficacy of aqueous neem extract and ivermectin against *Sarcoptes scabiei var. cuniculi* in experimentally infested rabbits. Parasitol Res 112(6):2319–2330. https://doi.org/10.1007/s00436-013-3395-2
24. Seddiek ShA, El-Shorbagy MM, Khater HF, Ali AM (2014) The antitrichomonal efficacy of garlic and metronidazole against *Trichomonas gallinae* infecting domestic pigeons. Parasitol Res 113(4):1319–1329. https://doi.org/10.1007/s00436-014-3771-6
25. Ahmed N, Alam M, Saeed M, Ullah H, Iqbal T, Al-Mutair KA et al (2021) Botanical insecticides are a non-toxic alternative to conventional pesticides in the control of insects and pests. In: Dr. Hamadttu El-Shafie, Global Decline of Insects. IntechOpen, https://doi.org/10.5772/intechopen.100416. https://www.intechopen.com/chapters/79121
26. Iqbal T, Ahmed N, Shahjeer K, Ahmed S, Al-Mutairi KA, Khater HF, et al (2021) Botanical insecticides and their potential as anti-insect/pests: are they successful against insects and pests? In: Dr. Hamadttu El-Shafie, Global Decline of Insects. IntechOpen. https://doi.org/10.5772/intechopen.100418. https://www.intechopen.com/online-first/78945
27. Khater HF, Geden CJ (2018) Potential of essential oils to prevent fly strike and their effects on the longevity of adult *Lucilia sericata*. J Vector Ecol 43(2):261–270. https://doi.org/10.1111/jvec.12310
28. Khater HF (2014) Bioactivities of some essential oils against the camel nasal botfly, *Cephalopina titillator*. Parasitol Res 113(2):593–605. https://doi.org/10.1007/s00436-013-3688-5
29. Khater HF, Geden CJ (2019) Efficacy and repellency of some essential oils and their blends against larval and adult house flies, *Musca domestica* L. (Diptera: Muscidae). J Vector Ecol 44(2):256–263. https://doi.org/10.1111/jvec.12357
30. Khater HF, Hanafy A, Abdel-Mageed AD, Ramadan MY, El-Madawy RS (2011) Control of the myiasis- producing fly, *Lucilia sericata*, with Egyptian essential oils. Int J Dermatol 50(2):187–194. https://doi.org/10.1111/j.1365-4632.2010.04656.x
31. Murugan K, Panneerselvam C, Samidoss CM, Madhiyazhagan P, Suresh U, Roni M et al (2016) In vivo and in vitro effectiveness of

Azadirachta indica-synthesized silver nanocrystals against *Plasmodium berghei* and *Plasmodium falciparum*, and their potential against malaria mosquitoes. Res Vet Sci 106:14–22. https://doi.org/10.1016/j.rvsc.2016.03.001
32. Alkenani NA, Ahmed MMM, Al-Solami HM, Anwar Y, Alghamdi KM, Ahmad MS (2021) Molecular identification and bio-control of mosquitoes using black seeds extract in Jeddah. Pak Vet J. https://doi.org/10.29261/pakvetj/2021.025
33. Baz MM, Hegazy MM, Khater HF, El-Sayed YA (2021) Comparative evaluation of five oil-resin plant extracts against the mosquito larvae, *Culex pipien*s say (diptera: culicidae). Pak Vet J. https://doi.org/10.29261/pakvetj/2021.010
34. Baz MM, Selim AM, Radwan IT, Khater HF (2022) Plant oils in the fight against the West Nile Vector, *Culex pipiens*. Int J Trop Insect Sci. https://doi.org/10.1007/s42690-022-00762-1
35. Radwan IT, Eltaly RI, Baz MM, Yousif M, Selim A, Taie HA, Manaa AA, Khater HK (2023) Novel acaricidal and growth-regulating activity of Aloe vera and Rheum rhabarbarum extracts and their oil/water nanoemulsions against the camel tick, *Hyalomma dromedarii*. Sci Rep 13:16802. https://doi.org/10.1038/s41598-023-43776-6
36. Khater HF, Ali AM, Abouelella GA, Marawan MA, Govindarajan M, Murugan K et al (2018) Toxicity and growth inhibition potential of vetiver, cinnamon, and lavender essential oils and their blends against larvae of the sheep blowfly, *Lucilia sericata*. Int J Dermatol 57(4):449–457. https://doi.org/10.1111/ijd.13828
37. Ogbonna O, Ogbonna P, Dike M (2016) Phytochemical screening, quantitative estimates of bioactive compounds in *Spondias mombin* and *Azadirachta indica.* Res J Chem Sci ISSN 2016X. 2231606
38. Abd Elgawad S, Baz M, Taie H, Mustafa S, Khater H (2023) Novel acaricidal efficacy of nine Egyptian plants against the camel tick, *Hyalomma dromedarii* (Ixodida: Ixodidae). Persian J Acarol 12:121–136. https://doi.org/10.22073/pja.v12i1.76977
39. Apanaskevich DA, Schuster AL, Horak IG (2008) The genus Hyalomma: VII. Redescription of all parasitic stages of *H*.(*Euhyalomma*) *dromedarii* and *H*.(*E.*) *schulzei* (Acari: Ixodidae). J Med Entomol 45(5):817–831. https://doi.org/10.1093/jmedent/45.5.817
40. Makkar HPS, Becker K, Abel H, Pawelzik E (1997) Nutrient contents, rumen protein degradability and antinutritional factors in some colour- and white-flowering cultivars of *Vicia faba beans*. J Sci Food Agric 75(4):511–520. https://doi.org/10.1002/(SICI)1097-0010(199712)75:4%3c511::AID-JSFA907%3e3.0.CO;2-M
41. Ordonez A, Gomez J, Vattuone M, Lsla M (2006) Antioxidant activities of Sechium edule (Jacq.) Swartz extracts. Food Chem 97(3):452–458. https://doi.org/10.1016/j.foodchem.2005.05.024
42. Francis J (1982) Analysis of anthocyanins. In: Markakis P (ed) Anthocyanins as good colors. Academic Press, London, pp 181–208
43. Maxson ED, Rooney LW (1972) Two methods of tannin analysis for *Sorghum bicolor* (L.) Moenchgrain 1. Crop Sci 12(2):253–254. https://doi.org/10.2135/cropsci1972.0011183X001200020035x
44. Abbott WS (1925) A method of computing the effectiveness of an insecticide. J Econ Entomol 18(2):265–267. https://doi.org/10.1093/jee/18.2.265a
45. Khater HF (2012) EcosmartBiorational insecticides: alternative insect control strategies. In: Farzana P (ed.) Insecticides - Advances in Integrated Pest Management. InTech, Rijeka, Croatia. 17–60. 43. https://doi.org/10.5772/27852. Available from http://www.intechopen.com/books/insecticides-advances-in-integrated-pest-management/ecosmart-biorational-insecticides-alternative-insect-control-strategies
46. Khater HF (2012) Prospects of botanical biopesticides in insect pest management. Pharmacologia 3(12):641–656. https://doi.org/10.5567/pharmacologia.2012.641.656
47. Salman M, Abbas RZ, Israr M, Abbas A, Mehmood K, Khan MK et al (2020) Repellent and acaricidal activity of essential oils and their components against *Rhipicephalus* ticks in cattle. Vet Parasitol 283:109178. https://doi.org/10.1016/j.vetpar.2020.109178
48. Fang R, Jiang CH, Wang XY, Zhang HM, Liu ZL, Zhou L et al (2010) Insecticidal activity of essential oil of *Carum carvi* fruits from China and its main components against two grain storage insects. Molecules 15(12):9391–9402. https://doi.org/10.3390/molecules15129391
49. Hatami Bavarsad S, Zandi Sohani N, Rajab Poor A (2020) Fumigant toxicity and repellency of some essential oils against *Callosobruchus maculatus* (Col: Bruchidae). IJMAPR 36(3):404–416. https://doi.org/10.22092/ijmapr.2020.128639.2674
50. El-Zemity S, Rezk H, Farok S, Zaitoon A (2010) Acaricidal activity of some essential oils and their monoterpenoidal constituents against the house dust mite, Dermatophagoides pteronyssinus (Acari: Pyroglyphidae). Trends Acarol. https://doi.org/10.1631/jzus.2006.B0957
51. dos Santos FCC, Vogel FSF, Monteiro SG (2012) Essential basil oil effect (*Ocimum basilicum* L.) on cattle tick Rhipicephalus (Boophilus) microplus in in vitro experiments. Semin Cienc Agrar 33(3):1133–1140. https://doi.org/10.5433/1679-0359.2012v33n3p1133
52. Martinez-Velazquez M, Castillo-Herrera GA, Rosario-Cruz R, Flores-Fernandez JM, Lopez-Ramirez J, Hernandez-Gutierrez R, Lugo-Cervantes Edel C (2011) Acaricidal effect and chemical composition of essential oils extracted from *Cuminum cyminum*, Pimenta dioica and *Ocimum basilicum* against the cattle tick *Rhipicephalus (Boophilus) microplus* (Acari: Ixodidae). Parasitol Res 108(2):481–487. https://doi.org/10.1007/s00436-010-2069-6
53. Eltaly RI, Baz MM, Radwan IT, Yousif M, Abosalem HS, Selim A, Taie HAA, Farag AAG, Khater HF (2023) Novel acaricidal activity of *Vitex castus* and *Zingiber officinale* extracts against the camel tick, *Hyalomma dromedarii*. Int J Vet Sci 12(2):255–259. https://doi.org/10.47278/journal.ijvs/2022.184
54. Refaat M, Momen FM, Amer SAA (2002) Acaricidal activity of sweet basil and French lavender essential oils against two species of mites of the family Tetranychidae (Acari: Tetranychidae). Acta Phytopathol Entomol Hung 37(1–3):287–298. https://doi.org/10.1556/APhyt.37.2002.1-3.28
55. Jbilou R, Sayah F (2007) Effects of Peganum harmala (Zygophyllaceae) seed extracts on the development of *Tribolium castaneum* (Coleoptera: Tenebrionidae). Int J Trop Insect Sci 27(3–4):199–209. https://doi.org/10.1017/S1742758407850971
56. Amer A, Mehlhorn H (2006) Larvicidal effects of various essential oils against *Aedes, Anopheles,* and *Culex larvae* (Diptera, Culicidae). Parasitol Res 99(4):466–472. https://doi.org/10.1007/s00436-006-0182-3
57. Baz MM, Khater HF, Baeshen RS, Selim A, Shaheen ES, El-Sayed YA, Hegazy MM (2022) Novel pesticidal efficacy of *Araucaria heterophylla* and *Commiphora molmol* extracts against camel and cattle blood-sucking ectoparasites. Plants 11(13):1682
58. Movva V, Pathipati UR (2017) Feeding- induced phenol production in Capsicum annuum L. influences *Spodoptera litura* F. larval growth and physiology. Arch Insect Biochem Physiol 95(1):e21387. https://doi.org/10.1002/arch.21387
59. Srisanyong W, Bunyaluk D, Srinontong P, Chitsanoor S (2021) Acaricidal activity of phenolic crude extract from *Artocapus lakoocha* leaves against cattle tick *Rhipicephalus (Boophilus) microplus*. Int J Vet Sci 10:307–311. https://doi.org/10.47278/journal.ijvs/2021.063
60. Vivekanandhan P, Venkatesan R, Ramkumar G, Karthi S, Senthil-Nathan S, Shivakumar MS (2018) Comparative analysis of major mosquito vectors response to seed-derived essential oil

and seed pod-derived extract from *Acacia nilotica*. Int J Environ Res Public Health 15(2):388. https://doi.org/10.3390/ijerph15020388

61. Hatami A, Mohammadi D, Evazian N (2020) Lethal effects and oviposition deterrency of celery, *Apium graveolens*, and sickleweed, *Falcaria vulgaris*, against the potato tuber moth, *Phthorimaea operculella* in laboratory conditions. J Appl Res Plant Prot 8(4): 1–13. https://www.sid.ir/en/journal/ViewPaper.aspx?id=797061
62. Guneidy RA, Amer MA, El Hakim AE, Abdel-Shafy S, Allam SA (2021) Effect of polyphenols extracted from *Punica granatum* and *Acacia saligna* plants on glutathione S-transferase of the cattle tick *Rhipicephalus (Boophilus) annulatus* (Acari: Ixodidae). J Parasit Dis. https://doi.org/10.1007/s12639-020-01323-4
63. Bagavan A, Kamaraj C, Elango G, Abduz Zahir A, Abdul Rahuman A (2009) Adulticidal and larvicidal efficacy of some medicinal plant extracts against tick, fluke and mosquitoes. Vet Parasitol 166(3–4):286–292. https://doi.org/10.1016/j.vetpar.2009.09.007
64. Khater HF, Khater DF (2009) The insecticidal activity of four medicinal plants against the blowfly *Lucilia sericata* (Diptera: Calliphoridae). Int J Dermatol 48(5):492–497. https://doi.org/10.1111/j.1365-4632.2009.03937.x
65. Khater HF, Shalaby AA (2008) Potential of biologically active plant oils to control mosquito larvae (*Culex pipiens*, Diptera: Culicidae) from an Egyptian locality. Rev Inst Med Trop Sao Paulo 50(2):107–112. https://doi.org/10.1590/s0036-46652008000200008
66. Mansour F, Azaizeh H, Saad B, Tadmor Y, Abo-Moch F, Said O (2004) The potential of middle eastern flora as a source of new safe bio-acaricides to *control Tetranychus cinnabarinus*, the carmine spider mite. Phytoparasitica 32(1):66–72. https://doi.org/10.1007/BF02980862
67. Rajabpour A, Mashhadi ARA, Ghorbani MR (2018) Acaricidal and repellent properties of some plant extracts against poultry red mite, *Dermanyssus gallinae* (Mesostigmata: Dermanyssidae). Persian J Acarol. https://doi.org/10.22073/pja.v1i1.34098
68. de Monteiro CM, Maturano R, Daemon E, Catunda-Junior FEA, Calmon F, Senra Tde S et al (2012) Acaricidal activity of eugenol on *Rhipicephalus microplus* (Acari: Ixodidae) and *Dermacentor nitens* (Acari: Ixodidae) larvae. Parasitol Res 111(3):1295–1300. https://doi.org/10.1007/s00436-012-2964-0
69. de Carvalho AV, Lübeck I, da Rocha MB, Güez CM, Machado MM, de Oliveira LFS (2015) Evaluation of the tickcide, genotoxic, and mutagenic effects of the *Ruta graveolens* L. (Rutaceae). Acta Sci Biol Sci 37(4):491–497. https://doi.org/10.4025/ACTASCIBIOLSCI.V37I4.27576
70. Ramezanipour O, Yakhchali M (2020) Study on the effect of *Ferula pseudalliacea* (Family: Apiaceae) extract on Varroa destructor (Acari: Varroidae) infestation in honeybee (Hymenoptera: Apidae, Apis melifera). Iran J Vet Res 15(4):85–92. https://doi.org/10.22055/ivj.2019.126094.2031
71. Al- Doghairi M, El-Nadi A, Elhag E, Al-Ayedh H (2004) Effect of *Solenostemma argel* on oviposition, egg hatchability and viability of Culex pipiens L. larvae. Phytother Res 18(4):335–338. https://doi.org/10.1002/ptr.1432
72. Abdel-Ghany H, Allam SA, Khater H, Selim A, Abdel-Shafy S (2023) Effects of commercial oils on the camel tick *Hyalomma dromedarii* (Acari: Ixodidae) and their enzyme activities. Persian J Acarol 12:137–149. https://doi.org/10.22073/pja.v12i1.76404
73. Jaenson TG, Pålsson K, Borg-Karlson AK (2005) Evaluation of extracts and oils of tick-repellent plants from Sweden. Med Vet Entomol 19(4):345–352. https://doi.org/10.1111/j.1365-2915.2005.00578.x
74. Zhang Q, Ding L, Li M, Cui W, Ding W, Luo J, Zhang Y (2013) Action modes of *Aloe vera* L. extracts against Tetranychus cinnabarinus Boisduval (Acarina: Tetranychidae). Agric Sci 04(3):117–122. https://doi.org/10.4236/as.2013.43018
75. Fang F, Li M, Jiang Z, Lu X, Guillot J, Si H (2020) Comparing acaricidal and ovicidal activity of five terpenes from essential oils against *Psoroptes cuniculi*. Parasitol Res 119(12):4219–4223. https://doi.org/10.1007/s00436-020-06823-z
76. Kemal J, Zerihun T, Alemu S, Sali K, Nasir M, Abraha A, Feyera T (2020) In vitro acaricidal activity of selected medicinal plants traditionally used against ticks in Eastern Ethiopia. J Parasitol Res 2020:7834026. https://doi.org/10.1155/2020/7834026
77. Baz MM, Eltaly RI, Debboun M, Selim A, Radwan IT, Ahmed N, Khater HF (2023) The contact/fumigant adulticidal effect of Egyptian oils against the house fly, Musca domestica (Diptera: Muscidae*)*. Int J Vet Sci 12(2):192–198. https://doi.org/10.47278/journal.ijvs/2022.180
78. Taha LS, Taie HA, Hussein MM (2015) Antioxidant properties, secondary metabolites and growth as affected by application of putrescine and moringa leaves extract on jojoba plants. J App Pharm Sci 5(1):030–036

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