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An Evidence-Based Review on Medicinal Plants Used as Insecticide and Insect Repellent in Traditional Iranian Medicine

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Abstract

Context: Insects can be the cause of major ecological problems; they can transmit microbes and parasites that affect humans, and damage food crops, trees, and homes. The total economic cost of insect-related damage and disease is immeasurable. In traditional Iranian medicine (TIM), several medicinal plants have been identified as insecticides or insect repellents, but many of them are still unknown. Therefore, the aim of this study was to review the insecticidal or insect repellent activity of certain medicinal plants described in TIM.

Evidence Acquisition: Information about medicinal plants proposed as insecticides and insect repellents in the TIM was collected from the TIM literature, and searched in modern medical databases to find studies that confirmed their efficacy.

Results: Modern investigations have supported the claims of the insecticidal activity of several plants, including *Allium sativum*, *Artemisia absinthium*, *Citrullus colocynthis*, *Laurus nobilis*, *Mentha pulegium*, *Myrtus communis*, *Nerium oleander*, *Ocimum basilicum*, and *Origanum majorana*. However, in the cases of plants like *Iris florentina* and *Malva sylvestris*, there is not enough evidence in modern medicine to prove their effectiveness with regard to their insecticidal and insect repellent activities.

Conclusions: This study confirmed the Iranian traditional medicine claims of the insecticidal and insect repellent activity of certain plants. Further pharmacological and clinical studies are recommended to evaluate the overall efficacy and possible mechanisms underlying these herbs.

Keywords: Medicinal Plants, Insecticide, Insect Repellent, Traditional Medicine

1. Context

Insects have evolved into over one-million named species that occupy fundamental places in the world's ecosystems. However, some insects carry parasites and microbes that affect humans through various diseases, including malaria, Chagas' disease, Lyme disease, bubonic plague, and dengue fever. They can also affect animals and damage food crops (locusts), trees (gypsy moths), and homes (termites). The total economic cost of insect-caused damage and disease is immeasurable; therefore, some genetically altered insect-resistant crops and various insecticides have been developed to manage insects and insect-related damage and disease (1). However the use of a wide range of synthetic insecticides has been restricted recently, due to the high cost, harmful environmental effects, their non-biodegradable nature, and increasing insecticidal resistance. An efficient alternative source for insecticides is botanical, which can provide a simple and sustainable method of insect control (2).

Herbal medicines have been used for thousands of years as sources of bioactive and therapeutic substances with industrial and agricultural purposes (3, 4). Medicinal plants, and their derivatives or extracts, have been evaluated for different pest control strategies, assessing their toxic, lethal, repellent, antifeedant, fumigant, growth regulation, and deterrent effects on oviposition (5). Moreover, despite conventional insecticides, which are based on a single active ingredient, botanical insecticides containing mixtures of chemical compounds can affect both behavioral and physiological processes. Thus, the chance of pests developing resistance to such substances is very low. It seems that seeking bio-insecticides which are efficient, as well as being suitable and

adaptive to ecological conditions, is essential in obtaining sufficient insect control (2).

Traditional Iranian medicine (TIM) is a reasonable scientific resource, which encompasses unique information in order to prevent and treat diseases (6, 7). For this study, the chapter entitled "Tard al Havam" in the Al Qanun Fil Tibb and the Alaghraz altabyh va almabahesololayee were completely reviewed, and all of the plants reported as possessing insecticidal activity in the Makhzan Al Advieh were studied (8-10).

In the present research, those plants which showed insecticidal and insect repellent activity in the TIM (8-10) were reviewed individually, and evidence of their possible efficacy in the literature was gathered.

2. Evidence Acquisition

Several medicinal plants have been perceived to have insecticidal and insect repellent properties in TIM. Therefore the present review was conducted to verify the insecticidal activity of some of the medicinal plants used frequently in TIM. The authors searched the TIM literature for "medicinal plants," "insecticide," and "insect repellent." Additionally, information from important TIM books was collected and added to scientific reports derived from modern medical databases like PubMed, Scirus, ScienceDirect, Google Scholar, and Scopus. All of the retrieved articles were published between 1997 and 2014, and any in vitro, in vivo, or clinical evidence for efficacy and pharmacological mechanisms related to the insecticidal and insect repellent properties of plants were considered for inclusion. Those studies chosen for inclusion in this review revealed either the apparent beneficial function of these remedies or demonstrated their effectiveness indirectly on the mechanisms involved in insecticidal and insect repellent activity. Only published articles written in English were included in this review. The search terms included "insecticide" or "insect repellent" in the title and abstract, and the name of each mentioned plant in the whole text. The primary search results were evaluated by 2 independent investigators. Those articles in languages other than English, review studies, papers that evaluated a mixture of the plant with drugs other than herbs, case reports, and case control studies were excluded. The references of the included papers were also reviewed for additional, suitable studies. Finally, the included papers were reviewed for mention of the scientific names of the plant, their parts, and extracts, as well as the active components and species of insects.

3. Results

In this study, 20 herbal species were reported as insecticides or insect repellents in the Persian medical literature. Table 1 shows all of the data pertaining to the plant species, listed according to the scientific name, family, common name, traditional Iranian name, mode of application, and traditional use. Moreover, all of the details related to the pharmacological effects and mechanisms of action of the plants are reviewed in Table 2. Overall, these plants belong to 16 different families and, among them, Lamiaceae is represented by the greatest number of taxa (4), followed by Apiaceae (2).

Based on the traditional resources, insecticidal or insect repellent plants have been used in various routes of application, including the crude plant, decoction, incense, powder, extract, embrocation, and local administration.

The TIM resources have divided the plants into two groups: I) plants which exhibit a general anti-insect effect, and II) plants that act against a specific insect, like bees, ants, mosquitoes, flies, moths, fleas, termites, and scorpions. According to the Iranian traditional texts, the plants had either insecticidal or insect repellent actions, whereas modern phytotherapy describes different mechanisms of action for these purposes. The biological mechanisms of these plants were searched in the literature using the following terms: repellency, insecticidal, larvicidal, acaricidal, ovicidal, adulticidal, oviposition, fumigant toxicity, arrestant, and antifeedant effects against insects.

Among the 20 studied plants, four of them showed greater activity against insects, and the most active plants are discussed below:

3.1. Allium sativum L.

A. sativum has demonstrated numerous insecticidal activities on a wide range of insect spices; for example, its juice had insecticidal activity against *Delia radicum* and *Musca domestica* (11). Garlic extract has shown larvicidal effects against *Anopheles stephensi* and *Culex quinquefasciatus* mosquitoes (12), and acaricidal activity against *Tetranychus cinnabarinus* (13). In addition, the extract of cloves has shown larvicidal activity against the eggs, larvae, and adults of *Callosobruchus maculatus* (14). Essential oil bulbs exhibited larvicidal activity against *Culex pipiens* (15), fumigant toxicity against *Camptomyia corticalis* (16), insecticidal and larvicidal potential against *Lycoriella ingenue* (17), and acaricidal properties against all stages of *Boophilus annulatus* (18). Moreover, the leaf (ASAI) and bulb (ASAII) agglutinins from *A. sativum* exhibited insecticidal activity against the cotton leafworm, *Spodoptera littoralis* (19). The garlic lectins, ASAI and ASAII, have also revealed insecticidal properties against *Acyrthosiphon pisum* (pea aphids) (20).

3.2. Citrullus colocynthis L. Schrad.

Citrullus colocynthis leaf extracts have shown larvicidal, ovicidal, and repellency properties against the *Culex quinquefasciatus* mosquito (21), and larvicidal effects against the early fourth instar larvae of *Aedes aegypti* and *Culex quinquefasciatus* (22). In addition, the extract of the whole plant has been examined in different studies, and showed larvicidal activity against the early fourth instar larvae of *Anopheles stephensi* (23, 24), *Aedes aegypti*, and *Culex quinquefasciatus* (23). Its fruit extracts have suppressed the

overall egg laying ability of *Bactrocera zonata* (25), caused mortality against adult stages of *Lipaphis erysimi (26)*, and had insecticidal activity against *Tribolium custaneum* (27). The seed extracts have revealed larvicidal properties against the 3rd instar larvae of *Culex quinquefasciatus*, *Anopheles stephensi*, and *Aedes aegypti* (28).

3.3. Laurus nobilis L.

The pure essential oil of *Laurus nobilis* has shown aphidicidial activity against *Brevicoryne brassicae* (29). Moreover, the essential oil of the leaves has shown fumigant toxicity against all of the life stages of *Tribolium confusum* (30); repellent potential against *Tribolium custaneum*, *Rhyzopertha dominica* (31), and *Tenebrio molitor* larvae (32); insecticidal effects against adult *Sitophilus zeamais* (33), *Rhyzopertha dominica*, and *Tribolium castaneum* (31); and cytotoxicity toward *Artemia salina* (34). Finally, the essential oil of the branches repelled *Aedes aegypti* (35), while the dust of the leaves caused insecticidal effects against *Sitophilus zeamais* adults (36).

3.4. Ocimum basilicum L.

The essential oil of the *Ocimum basilicum* plant has shown insecticidal activity against *Acyrthosiphon pisum*, *Myzus persicae* (37), and *Musca domestica* (38). It has also exhibited repellency against *Aedes aegypti*, *Anopheles stephensi*, *Culex quinquefasciatus* (39), and adult female *Culex pipiens* (40), as well as antifeedant properties against *Lymantria dispar* (41). In addition, volatile toxicity against *Sitophilus oryzae*, *Rhyzopertha dominica*, and *Cryptolestes pusillus* has been observed (42). Furthermore, the stem extract has revealed larvicidal activity against *Culex quinquefasciatus* (43).

Table 1. Anti-Insect Plants in Traditional Iranian Medicine

Scientific Name	Family	Common Name	TIM Name	Mode of Application	Traditional Use
***Allium sativum* L.**	Liliaceae	Garlic	Som	Decoction; Incense	Lousicide; Bee repellent
***Artemisia absinthium* L. [XE "*Artemisia absinthium* L."]**	Asteraceae	Wormwood	Afsantin	Powder Poultice	Insect repellent Mosquito repellent
***Boswellia carterii* Bir. [XE "*Boswellia carterii* Bir."]**	Burseraceae	Frankincense	Kondor	Decoction	Killing flies
***Citrullus colocynthis* L. Schrad.**	Cucurbitaceae	Colocynth	Hanzal	Decoction	Killing fleas Repelling fleas
***Dorema ammoinacum* D.Don.**	Apiaceae	Ammoniacum	Oshagh	Embrocating	Insect repellent, Used in insecticide mixtures
***Ferula asafoetida* L.**	Apiaceae	Asafetida	Anjodan	Incense Powder rubbed onto surface	Insect repellent Ant repellent
***Iris germanica* L.**	Iridaceae	Orris	Susan	Incense of root	Insect repellent
Laurus nobilis L.	Lauraceae	Bay leaf	Ghaar	Incense Powder; Smoke of leaves and fruits	Insect repellent; Insecticide
***Malva sylvestris* L.**	Malvaceae	High mallow	Khobazi	Extract	Bee repellent
***Mentha pulegium* L.**	Lamiaceae	Pennyroyal	Fudanaj	Burning the plant; Incense Powder; Entire plant	Insecticide; Insect repellent; Clothes moth repellent
***Myrtus communis* L.**	Myrtaceae	Myrtle	Aas	Incense of leaves	Insect repellent (especially for mosquitoes)
***Nerium oleander* L.**	Apocynaceae	Oleander	Defli	Leaves	Flea repellent
***Ocimum basilicum* L.**	Lamiaceae	Basil	Shahasfaram	Fragrance	Insect repellent
***Origanum majorana* L.**	Lamiaceae	Marjoram	Marzanjush	Incense	Insect repellent
***Peganum harmala* L.**	Nitrariaceae	African rue	Harmal	Incense	Mosquito repellent
***Picea orientalis* (L.) Peterm.**	Pinaceae	Oriental spruce	Senobar	Wood ashes; Smoke of wood	Insect repellent; Mosquito repellent
***Platanus orientalis* L. [XE "*Platanus orientalis* L."]**	Platanaceae	Oriental planetree	Dolb	Incense of leaves	Termite repellent
***Punica granatum* L.**	Lythraceae	Pomegranate	Romman	Incense Powdering surfaces	Insect repellent
***Ruta graveolens* L.**	Rutaceae	Common rue	Sodab	Decoction	Mosquito repellent
***Vitexagnus-castus* L.**	Lamiaceae	Chaste tree	Banjankosht	Incense Powdering surfaces	Insect repellent Insecticide

Table 2. Efficiency of Action of Traditional Iranian Anti-Insect Plants

Part/extract	Active Constituent	Efficiency	Ref
Allium sativum			
Garlic juice	-	Insecticidal against *Delia radicum* and *Musca domestica*	-(11)
Tuber extract	-	Larvicidal against *Anopheles stephensi* and *Culex quinquefasciatus*	(12)
Fruit extract	-	Acaricidal against *Tetranychus cinnabarinus*	(13)
Cloves extract	-	Larvicidal against eggs, larvae, and adults of *Callosobruchus maculates*	(14)
Essential oil of bulbs	-	Larvicidal against *Culex pipiens*	(15)
Essential oil of bulbs	-	Fumigant toxicity against *Camptomyia corticalis*	(16)
Essential oil of bulbs	-	Insecticidal and larvicidal against *Lycoriella ingenua*	(17)
Essential oil of bulbs	-	Acaricidal on all stages of *Boophilus annulatus*	(18)
Leaves and bulb	Lectins, (ASAI) (ASAII)	Insecticidal against *Spodoptera littoralis*	(19)
Garlic lectins	ASAI and ASAII	Insecticidal against *Acyrthosiphon pisum*	(20)
***Artemisia absinthium*[XE "*Artemisia absinthium* L."]**			
Essential oil	-	Repellency against *Rhodnius prolixus*	(44)
Essential oil of leaves	Oxygenated monoterpenes	Repellency against *Ixodes ricinus*	(45)
Leaf extract	-	Developmental inhibition of *Sarcoptes scabieivar. suis*	(46)
***Boswellia carterii*[XE "*Boswellia carterii*."]**			
Essential oil of resin	-	Larvicidal against *Lycoriella ingenua*	(17)
Essential oil of resin	-	Fumigant toxicity against *Sitophilus oryzae*	(47)
Essential oil	-	Larvicidal against *Aedes aegypti*, *Anopheles stephensi*, and *Culex quinquefasciatus*	(48)
Essential oil	-	Repellency against *Aedes aegypti* and *Culex quinquefasciatus*	(39)
Citrullu scolocynthis			
Leaf extract	-	Larvicidal, ovicidal, and repellency against *Culex quinquefasciatus*	(21)
Leaf extract	-	Larvicidal against *Aedes aegypti* and *Culex quinquefasciatus*	(22)
Whole plant extract	Oleic acid and linoleic acid	Larvicidal against *Aedes aegypti*, *Anopheles stephensi*, and *Culex quinquefasciatus*	(23)
Whole plant extract	-	Larvicidal against the *Anopheles stephensi*	(24)
Fruit extract	-	Suppress overall egg laying of *Bactrocera zonata*	(25)
Fruit extract	-	Insecticidal against adult stage of *Lipaphis erysimi*	(26)
Fruit extract	-	Insecticidal against *Tribolium castaneum*	(27)
Seed extract	-	Larvicidal against *Culex quinquefasciatus*, *Anopheles stephensi*, and *Aedes aegypti*	(28)
Ferula asafetida			
Stem extract	-	Moderate antifeedant against *Leptinotarsa decemlineata* larvae	(49)
Root extract	-	Toxicity against *Anabasis aphylla*	(50)
Laurus nobilis			
Pure essential oil (purchased)	-	Aphidicidial activity against *Brevicoryne brassicae*	(29)
Essential oil of leaves	-	Fumigant toxicity against all life stages of *Tribolium confusum*	(30)
Essential oil of leaves	1,8-cineole, linalool, and isovaleraldehyde	Repellency and toxicity against *Rhyzopertha dominica* and *Tribolium castaneum*	(31)
Essential oil of leaves	-	Repellency against *Tenebrio molitor* larvae	(32)
Essential oil of leaves	-	Insecticidal against adult *Sitophilus zeamais*	(33)
Essential oil of leaves	-	Cytotoxicity toward *Artemia salina*	(34)

Essential oil of branches	-	Repellency against *Aedes aegypti*	(35)
Dust of leaves	-	Insecticidal against adult *Sitophilus zeamais*	(36)
Mentha pulegium			
Essential oil (Purchased)	-	Acaricidal on *Dermatophagoides farinae* and *D.pteronyssinus*	(51)
Essential oil (Purchased)	-	Fumigant toxicity against *Camptomyia corticalis*	(16)
Essential oil of leaves	-	Fumigant and insecticidal against *Musca domestica*	(38)
Essential oil of leaves	-	Larvicidal (fumigation) against *Spodoptera littoralis*	(52)
Myrtus communis			
Essential oil of Leaves	-	Repellency against *Culex quinquefasciatus*	(39)
Essential oil of Leaves	-	Larvicidal against *Aedes aegypti*, *Anopheles stephensi*, and *Culex quinquefasciatus*	(48)
Essential oil of Leaves	Linalool	Insecticidal against adults of *Ephestia kuehniella*, *Plodia interpunctella*, and *Acanthoscelides obtectus*	(53)
Nerium oleander			
Leaf extract	-	Larvicidal against the larvae and pupae of *Anopheles stephensi*	(54)
Dust of flowers and its suspension	-	Insecticidal and repellency against adult *Sitophilus zeamais*	(36)
Plant (leaves, roots, and stem) extract	-	Inhibitory effect on the development of *Ceratovacuna lanigera*	(55)
Ocimum basilicum			
Essential oil (aerial parts)	-	Insecticidal against *Acyrthosiphon pisum* and *Myzus persicae*	(37)
Essential oil of the plant	-	Insecticidal against *Musca domestica*	(38)
Essential oil (purchased)	-	Repellency against *Aedes aegypti*, *Anopheles stephensi*, and *Culex quinquefasciatus*	(39)
Essential oil of leaves	-	Repellency against the adult females of *Culex pipiens*	(40)
Essential oil of leaves	Linalool	Antifeedant properties against *Lymantria dispar*	(41)
Essential oil of leaves	Methyl eugenol, estragole, and linalool chemotypes	Volatile toxicity against *Sitophilus oryzae*, *Rhyzopertha dominica*, and *Cryptolestes pusillus*	(42)
Stem extract	-	Larvicidal against *Culex quinquefasciatus*	(43)
Origanum majorana			
Essential oil of leaves	Linalool	Fumigant toxicity against *Ephestia kuehniella* eggs and adults	(56)
Essential oil (purchased)	-	Moderate fumigant toxicity against *Camptomyia corticalis*	(16)
Aerial part extract	-	Insecticidal and larvicidal against *Spodoptera littoralis*	(52)
Aerial part extract	-	Insecticidal against *Musca domestica* L.	(38)
Aerial part extract	-	Repellency against *Thrips tabaci*	(57)
Peganum harmala			
Seeds extract	-	Repellency against *Bactrocera zonata*	(25)
-	Harmaline	Larvicidal against *Plodia interpunctella*	(58)
Seeds extract	-	Insecticidal against *Tribolium castaneum*	(59)
Punica granatum			
Fruit pericarp extract	-	Antifeedant against *Sitophilus zeamais* and *Tribolium castaneum*	(60)
Leaves extract	-	Acaricidal against *Tetranychus cinnabarinus*	(13)
Ruta graveolens			
Essential oil of aerial parts	-	Repellency and larvicidal against *Aedes aegypti*	(61)
Vitexagnus-castus			
Seeds extract	-	Repellency against *Ixodes ricinus* and *Rhipicephalus sanguineus*	(62)
Seeds extract	-	Repellency against *Pediculus humanus capitis*	(63)

4. Conclusions

In order to stop the spread of insect borne diseases and damage, save the environment, and improve the quality of public health, significant effort should be made to find new insect control strategies. The main approaches to insect control have consisted of using synthetic pesticides such as organochlorine and organophosphorus compounds, which have not been very successful, especially from an ecological point of view (2). Synthetic insecticides not only kill insects, but contaminate the food and cause air, water, and soil pollution. They are hazardous to the environment, man, and other creatures. To prevent the harmful effects of these pesticides, the above mentioned plant derived products can be used for insect control. Plant extracts having insecticidal properties should be made available to farmers, since scientific formulations of these plants are easily available in the area (55).

One beneficial example of herbal-based insecticides is "neem," which is derived from the plant *Azadirachta indica* A. Juss. In addition to its wide range of effects, such as antifeedancy, repellency, growth inhibition, oviposition, insecticidal, and larvicidal activity, neem has shown no toxicity or allergies toward humans. It has only slight environmental impacts (over 90% pollution free), and no known chemical reactions of concern (64). Therefore, it would be a good model for developing plant-derived insecticides.

Several plants have been used in Traditional Iranian medicine as powerful insecticides, and for their insect repellent activities. Recent investigations support the claims of TIM about the efficacy of many of these plants, including *Allium sativum*, *Apium graveolens*, *Artemisia absinthium*, *Carum carvi*, *Citrullus colocynthis*, *Laurus nobilis*, *Mentha pulegium*, *Myrtus communis*, *Nerium oleander*, *Ocimum basilicum*, and *Origanum majorana*. For some of the herbal products used in TIM, such as *Iris florentina*, *Dorema ammoinacum*, *Malva sylvestris*, *Picea orientalis*, and *Platanus orientalis*, there are no (or not enough) studies to confirm their insecticidal activity. These studies suggest that indigenous knowledge and traditional practice can make valuable contributions to domestic food production in countries where the strict enforcement of pesticide regulations is impractical.

Overall, many medicinal plants have been used traditionally as insecticidal agents, and the biological actions of a wide range of anti-insect plants have been evaluated in recent investigations. Further studies evaluating the efficacy and safety of these herbs are recommended. In addition, understanding the pharmaceutical and pharmacological aspects of these plants is required in order to produce natural anti-insect agents.

Footnotes

Authors' Contribution: Mina Cheraghi Niroumand suggested the topic, collected and analyzed data, and wrote the manuscript. Mohamad Hosein Farzaei contributed to the development of the protocol and writing the manuscript. Elahe Karimpour Razkenari collected the data. Mohammad Reza Shams-Ardekani and Gholamreza Amin contributed to the development of the protocol. Mahnaz Khanavi and Tahmineh Akbarzadeh suggested the topic of the article and contributed to the development of the protocol.

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