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Insecticidal activity of botanicals and their effectiveness in insects and pests control

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Abstract

Agriculturists in low-income nations, particularly subsistence farmers, frequently use botanical insecticides. The soaring cost and scarcity of commercial insecticides frequently promote the use of them. The identification of botanicals with insecticidal abilities is typically from folklore. Several scientific investigations have been done over the years to ascertain the effectiveness and safety of various botanical principles. Consistent reviews of these investigations are needed to update knowledge and to develop a theoretical foundation for further studies. Thus, the effectiveness of evaluated botanicals as insecticides against acarids and insect pests in agriculture is the primary focus of this article.

Keywords: Insecticide, Acaricide, Pesticide, Insect pest control, Botanicals, Environmental safety

Introduction

About 35% of the world's major crops are said to be lost to yield losses as a result of weeds, diseases, and arthropods [1]. Despite the fact that there are numerous techniques to control or eradicate these insects and pests, each management method has its shortcomings [2, 3, 4]. The majority of synthetic insecticides and pesticides on the market are halogenated hydrocarbons or organophosphates. These chemicals have long environmental half-lives and severer toxicological properties than natural compounds [5, 6]. The need for efficient biodegradable acaricides and pesticides with much more selectivity has grown due to the problems of synthetic residues created by chemicals [7]. Current strategies include search for new alternatives that act against only a specific target species, breakdown into nontoxic chemicals readily and can be utilized in integrated pest management systems [8, 9, 10].

This requirement has been successfully met by natural plant products, and they have a significant impact on current agrochemical research [11, 12]. Globally, 235 families and approximately 2500 plant species have reported biological actions against acarids and insect pests [13, 14]. Many farm studies especially highlight the usage of a range of botanicals for insect pest management [15, 16, 17, 18]. One of the most effective ways of protecting crops, animals, their products, and also the environment from pollution by chemical insecticides is now becoming the use of botanicals extracted from plants as insecticides and pesticides [19, 20]. Terpenoids, alkaloids, and phenols are examples of plant secondary metabolites that have a variety of insecticidal qualities, including toxicity, the ability to prevent insects from feeding, and the ability to repel insect pests [1, 21, 22]. There have been a lot of research using known and previously unexplored plant species that exhibit insecticidal or pesticidal capabilities, and there are still more being done [23, 24]. Therefore, this review article is focused on outlining the insecticidal, acaricidal or repellent activity of ethnobotanical plants towards insects, acarids and pests of agriculture in order to capture applications of ethnomedicinal herbs in entomology and parasitology while creating a theoretical reference for future studies.

Ethnobotanical plants with insecticidal activities

Plants have effectively served as sources of safe and efficacious insecticides in the control of insects and insect pests over the years [25, 26]. For example; pyrethrum (*Tanacetum cinerariifolium*) flowers, neem (*Azadirachta indica*), sabadilla (*Schoenocaulon officinale*), tobacco (*Nicotiana tabacum*), and ryania (*Ryania speciosa*) are sources of some

commercially prepared insecticides [24]. Several plant substances, including vetiver oil [27], are reportedly effective against *Sitophilus oryzae* and other storage grain insect pests [28]. Likewise, mustard oil, marjoram oil [29], custard apple powder, mango, ginger rhizome powder, *Lantana camera* [30]. Leaf preparations of *Ocimum gratissimum* and *Vernonia amygdalina* used against *S. oryzae* in stored rice grains were effective in controlling the insect pests [31]. It was discovered that both powders exhibited toxic and ovicidal effects in rice weevil. Additionally, both powders tended to reduce weight loss and egg punctures. At 5 g/kg of grains, *O. gratissimum* was shown to be very effective, producing 100% mortality [31]. Even in man the essential oils of *Ziziphora tenuiore*, *Achillea wilhelmsii*, *Myrtus communis*, and *Mentha piperita* demonstrated sufficient repellent activities against human fleas [32]. The efficacy of *Rosmarinus officinalis*, *M. piperita*, and *Coriandrum sativum* oils were obvious when used for organic food protection due to the repellent activity of the essential oils on *Tribolium confusum* [33]. The repellent activities of six *Zanthoxylum* species, namely; *Zanthoxylum dimorphophyllum*, *Z. armatum*, *Z. dimorphophyllum* var. *spinifolium*, *Z. stenophyllum*, *Z. piasezkii*, and *Z. dissitum* essential oils used against two storage pests including *Tribolium castaneum* and *Lasioderma serricorne* adults were discovered [34]. The essential oils of *Cymbopogon citratus* and *Tagetes minuta* were also used to control sand fly (*Phlebotomus duboscqi*) [35]. The various repellent effects on the insects may be related to the various anti-insect defense mechanisms and volatility of the essential oil samples [36]. Siam weed and tobacco aqueous extracts were used in control diamondback moth (*Putella xylostella*) alongside aphids in cabbage [37] and were tolerant to nontarget spiders, hoverflies and ladybirds [38]. Among five (5) different plant powders tested, *Jatropha curcas* L., *Euphorbia balsamifera* L. and *Lawsonia inermis* L. proved effective in protecting sorghum grains against *Sitophilus zeamais* infestation, showing 100% adult mortality within 28 days after treatment [39]. *Melia azadirachta* L. caused high (57%) larval mortality of rice weevil [40]. Leaf and seed of *Azadirachta indica* resulted in 100% larval mortality of rice weevil [41]. Neem seed powder was the most effective for reducing weevil populations in sorghum [42]. The field infestations of legume flower thrips and legume pod borer have also been significantly reduced by *A. indica*. *Azadirachta indica* was said to provide broad-spectrum properties against insect pests, including toxicity, repellency, growth regulation, and antifeedant actions [43]. It has also been reported that *A. indica* and *Cymbopogon citratus* leaf powders were effective in protecting *Irvingia wombolu* kernels from *Oryzaephilus mercator* while in storage [44, 45]. There have been numerous reports on the effectiveness of plant extracts against hemipteran insects, *A. indica* (flowers), and *Lippia sidoides* extracts caused moderately high mortality rates in adults *Podiasus nigrispinus* (Hemiptera; Pentatomidae) [46]. Ethanol leaves extracts of *Petiveria alliaceae* and *Trichilia arborea* exhibited high insecticidal effects on eggs and nymphs of *Bamisia tabaci* (Hemiptera: Aleyroideae). The marigold *Tagetes patula* significantly reduced oviposition of *Bemisia tabaci* and caused significantly high mortality of *Lygus hesperus* Knight (Hemiptera: Miridae) and *B. tabaci* adults [47]. In the field, it was discovered that the plant extracts of *Piper guineense* and *A. indica* were more effective than the synthetic insecticide cypermethrin at defending *Milicia*

excelsa seedlings against *Podosphaera fusca* infestation. *Dermestes maculatus* Degeer's adult emergence and egg hatchability in stored smoked catfish (*Clarias gariepinus*) were prevented by the powdered form of *P. guineense* [48, 49]. It was discovered that powders of *P. guineense* caused adult mortality of *Callosobruchus maculatus*, inhibited their oviposition on cowpea and suppressed F1 adult emergence [49]. It is reported that plant extracts obtained from *Vernonia amygdalina*, *Sida acuta*, *Occimum gratissimum* and *Telfaria occidentalis* were effective against beans weevil [50]. It was previously documented that *Tephrosia vogelli* extracts inhibit the growth of larger grain borer (*Prostephanus truncatus*) [51]. Adult *Callosobruchus maculatus* on cowpea seeds and *Sitophilus zeamais* lived much shorter lives when exposed to high concentrations of *Moringa oleifera* powder [52]. The toxicity of both powder and extract of *Moringa* against *Sitophilus oryzae*, *Oryzaephilus mercator* and *Rhyzopertha dominica* infesting paddy rice have been confirmed [53, 54]. The findings demonstrated that the extract caused a significant amount of insect mortality and also delayed the emergence of adult insects. *Moringa* extract cause 97.5% mortality against angoumois grain moth, *Sitotroga cerealella* (Olivier) [Lepidoptera: Gelechiidae] [55]. *Moringa* extract reduced survival of adults, oviposition and emergence of *C. maculatus* adults significantly [52]. There have been numerous studies about the efficiency of neem-based products, including neem cake, neem leaf powder, neem seed kernel extract, neem oil, and commercial formulations from neem, against significant insect - pests of stored grains [23, 45, 56]. A study on neem leaf powder against *Capsicum chinensis* on green gram revealed that the coating of neem leaf powder (NLP) and neem stem ash powder (NSAP) on green gram seeds at different concentrations afforded protection from damage by *C. chinensis* [56]. A laboratory study on the efficacy of botanical powders in the management of the lesser grain borer, *Rhyzopertha dominica* in stored sorghum revealed that *Acorus calamus* L. rhizomes at 1% was significantly effective in protecting sorghum grains from *R. dominica* up to 180 days after treatment. Similarly, *Annona squamosa* L. seed powder at 5%, and *Azadirachta indica* at 5% showed significant efficacy comparable to malathion [57]. *Piper guineense* and *Moringa oleifera* leaf and seed powders have significant bioactivity against *Trogoderma granarium* [49]. The insecticidal activity of botanical preparations in the management of insect pests of okra and cowpea have also been documented [58, 59, 60]. Important effects of various native plant materials in storage containers against *S. oryzae*, *R. dominica*, and *T. castenium* have been reported [61]. *Ageratum conyzoides*, an annual herb and common weed that grows across the tropics is an important component of many traditional medicine preparations. The essential oils in *A. conyzoides* are thought to be responsible for its poisonous, repulsive, and growth-inhibiting actions [62]. Remarkably, with an IC50 of 1.49 mg/mL, only the essential oil chemotype from *A. conyzoides* displayed acaricidal action towards *Rhipicephalus (Boophilus) microplus* larvae [62, 63]. According to research, *A. conyzoides* oil applied to mung bean seeds after 24 hours of germination killed 97% of adult *Callosobruchus chinensis* and stopped them from laying eggs [64]. From Indian cultivars of *A. conyzoides*, a high concentration of essential oils, specifically chromenes and precocene II, has been isolated. Ageratochromene and 7-methoxy-2, 2-

methylexane (precocene I), anti-juvenile hormones, are said to make up 60% of the essential oils found in a Fijian variety's flowers, leaves, and stems [64, 65]. At 20% concentration, *A. conyzoides* exhibited a 90% hatching inhibition of *Rhipicephalus microplus* eggs, while *Artemisia absinthium* presented a 100% inhibition at 5%, 10%, and 20% concentrations [66].

Bioactive components of plants with insecticidal activity

Botanical insecticides affect different insects in different ways depending on the physiological characteristics of the insect species as well as the type of the botanical ingredient or plant. Plants contain bioactive compounds which have been used in managing a variety of crop pests [67]. For instance, plants are protected from insect pests by flavonoids and isoflavonoids, which affects their behavior, growth, and development [68, 69]. Tannins, saponins, flavonoids, steroids, and alkaloids are among the phytoconstituents present in the leaf extract of *Khaya senegalensis* that may have been responsible for the mortality of *Dinoderus porcellus* [70]. Sulfur-containing chemicals that result from allacin's enzymatic breakdown have been shown to have a pesticidal effect on plants [71, 72, 73, 74].

Acaricidal and insecticidal effects of garlic extracts against coleopteran, dipteran, lepidopteran, and hemipteran pests have been demonstrated in laboratory tests [75, 76]. Garlic extracts in laboratory trials have been shown to have acaricidal [77, 75] and insecticidal activities against coleopteran, dipteran, lepidopteran, and hemipteran pests [72, 73, 74, 75, 76, 77]. A key constituent of marigold tree essential oil, a monoterpenoid called α -pinene, showed insecticidal activities against coleopteran storage pests [47, 78]. Sesquiterpene lactones in tree marigold have been reported to be toxic to the coleoptera *Callosobruchus maculatus* [20]. A product of neem tree, Azadirachtin caused 100% mortality to *Sitophilus oryzae* [79]. The seeds, fruits, and leaves of the Moringa plant all contain potential active ingredients [80, 81]. Lectins found in Moringa seeds exhibit larvicidal effect against larva of the flour moth *Anagasta kuehniella* [82].

Protective effect of botanicals on stored grains

Botanical insecticides have been classified into; toxins, chemosterilants, feeding deterrents/antifeedants, growth retardants, repellents, and attractants [30]. Many insects that live in stored harvests have been killed as a result of toxins in botanical insecticide preparations [83]. In order to be effective, some of these insecticides must be consumed making it a stomach toxin [84]. Botanicals have been shown to be extremely toxic to adults of *S. oryzae*, possibly as a result of the ease of their penetration through the insect cuticle [53]. Granary weevil adults were successfully fumigated and killed by *Lavandula angustifolia* essential oil. Additionally, granary weevil orientation to a desirable host substrate can be disrupted by potent repellent activity of botanicals [85]. Fumigant toxicity against stored grain pest *Callosobruchus chinensis*, has also been reported [86]. In two different trials, ground plant materials from Chinaberries successfully suppressed coleopteran storage pests [87, 88] and led to a reduction of grain damage, even though a separate study reported a nonsignificant effect on the pest population [89]. Neem and moringa seed oils used to preserve cowpea grains against *C. maculatus* were said to have anti-feedant

property and more potent at higher concentrations [90]. According to laboratory tests, moringa seed oil had antifeedant and insecticidal activities against the fall armyworm *Spodoptera frugiperda* [91]. In storage, coleopteran pests have been controlled with ground moringa leaves as well [92, 93, 94]. Quercetin and rutin glycosides present in *Arachis hypogaea* increased mortality of tobacco armyworm (*Spodoptera litura*) [95]. In rice, flavone glucosides inhibited digestion in insects and function as repellent agents in *Nilaparvata lugens* [96].

Types of botanical insecticides

Botanical insecticides have been categorized into Pyrethrum, Rotenone, Quassia, Sabadilla, RYANIA, and Essential oils on the basis of their source.

Pyrethrum

The most commonly used botanical insecticide worldwide [97]. Pyrethrum has been successfully produced commercially from dried flowers of *Tanacetum cinerariifolium* (Asteraceae). Pyrethrin has been extensively used in agricultural and veterinary practices over the years [25, 98, 99]. They are fast-acting contact toxins that reach the nervous system. They attached to sodium channels in nerve cells, extending their opening and triggering the insect's death [100]. Pyrethrin harms the nervous systems of insects by obstructing nerve connections, which causes knockdown, paralysis, and death [99, 25]. Pyrethrin disintegrates quickly when exposed to light, air, water, and high temperatures; as a result, they don't accumulate in food chains or groundwater and do not stay in the environment for more than a few weeks [99, 101]. Pyrethrin has activity on wide range of insects and mites, including flies, fleas, beetles, and spider mites [102].

Rotenone

The majority of commercial sources of rotenone, an isoflavonoid that is a naturally occurring plant toxin, are made from the roots and rhizomes of tropical Fabaceae species [25, 99]. It serves as a pesticide in industry. It is neurotoxic and a metabolic inhibitor. It causes respiratory failure which results from interference with the electron transport pathway in the mitochondria [101]. Shortly after being exposed to rotenone, insects stop feeding and eventually die. It works against several insect species, including caterpillars, aphids, suckers, trips, and other pests of fruits and vegetables [22, 99, 100]. Rotenone degrades quickly in light, air, heat, and alkaline environments and is not a permanent component of the environment. It benefits the environment as a result [99, 103]. In organic farming in Europe, rotenone-containing formulations are used for preventive purposes [104].

Quassia

The Simaroubaceae family includes Quassia shrub (*Quassia amara* L.), which grows in tropical forests. It is one of the most widely used and effective pesticides before synthetic alternatives were developed [22, 99, 105]. This plant species produces wood that contains 0.14-0.28 percent quassinoids (quassin), which have potent insecticidal properties. One of the few botanicals with systemic effects, it is a stomach and contact toxin [25, 99]. Quassia was resistant to aphids, caterpillars, Colorado potato beetles, and sawflies. It has

also shown nematocidal effect and selectivity for beneficial insects like ladybirds and honeybees [99, 101, 105].

Sabadilla

The sabadilla lily (*Schoenocaulon officinale*), a tropical plant native to Central and South America, provides the seeds from which this alkaloid is processed. The veratrin, an alkaloid derived from sabadilla, has strong insecticidal properties [101, 25, 99]. Veratrin is produced by several other species, most notably the European white hellebore. Sabadilla damages the membranes of nerve cells, which causes loss of nerve function, paralysis, and death. By contact or ingestion, it eliminates caterpillars, leafhoppers, thrips, stink bugs, and squash bugs. Honeybees are severely poisoned by this alkaloid, and it disintegrates swiftly in air and sunlight with little risk of environmental contamination [22, 99, 106].

Ryania

South America is native to *Ryania speciosa* Vahl. (Flacourtiaceae). This plant has ryanoids in its woody stems, a group of alkaloids with insecticidal properties. By contrast, 9, 21-dehydroryanodine is the least active ryanoid while ryanodine is the most active [22, 101]. Less than 1% of the ground stem wood contains ryanoid [99, 107]. These alkaloids prevent the release of calcium from muscle tissue, preventing the formation of neuromuscular connections. They have been successfully used to manage corn earworm, European corn borer, citrus thrips, Codling moth, caterpillars, and leaf-eating beetles. Insects stop eating soon after ingesting this stomach poison though it takes a while for it to take full effect [25, 99, 106, 108].

Essential oils

Due to their appeal with organic growers and environmental tolerance, essential oils obtained from aromatic plants have been used more frequently as pesticides and acaricides. They have effects on a range of insects, including those that are repellent, insecticidal, antifeedant, growth inhibitor, oviposition inhibitor, ovicidal, and growth-reducing [107, 108, 109, 110, 111, 112]. In an evaluation of the effectiveness of essential oils against *Sitotroga cerealella*, the oils of *Cinnamomum camphora*, *Cymbopogon flexuosus*, *A. conyzoides*, and *Ocimum gratissimum* were recorded as significantly effective. These essential oils had noteworthy larvicidal effect on the larvae of *Limantria dispar* (Lepidoptera: Lymantridae, the gypsy moth), insecticidal activity, repellent effect on ants, cockroaches, bedbugs, head lice, and moths, and were poisonous to termites [113, 114]. *Mentha piperita* oil is efficient against *Callosobruchus maculatus* and *Tribolium castaneum* as well as ants, flies, lice, and moths [115]. The rice weevil, *S. oryzae*, and the red flour beetle, *T. castaneum*, were significantly repelled by essential oils extracted using the aqueous preparation of *Eucalyptus globulus* and *Ocimum basilicum* leaves [116]. After 24 and 72 hours, respectively, essential oils extracted from *Pinus longifolia*, *Eucalyptus oblique*, and *Coriandrum sativum* showed substantial fumigant and contact action [117]. The test insect *R. dominica* in wheat grains was considerably disoriented or repelled by the leaves, bark, and seeds of *M. azedarach* powder [118].

Ethnobotanicals in the control of acarida

More and more, ectoparasite - caused animal diseases are being managed with plant extracts, particularly essential oils (EOs) [119]. Their impact on ectoparasites is frequently

linked to their effect on the nervous systems. These effects arise from inhibition of acetylcholinesterase release, which is necessary for their activity and synaptic transmission, or from their action on octopamine, which disrupts the nervous system to the point of total collapse [120]. Botanical anti-ectoparasitic agents are employed for insecticidal and acaricidal effects, as well as their repellent action [121]. Ticks are deadly bloodsucking ectoparasites that feed on livestock and wild animals, resulting in significant financial losses and food insecurity [122]. The annual cost of control and productivity losses from ticks is estimated to be in excess of USD 7 billion worldwide [123]. When six medicinal plants—*Vernonia amygdalina*, *Calpurnia aurea*, *Schinus molle*, *Ricinus communis*, *Croton macrostachyus*, and *Nicotiana tabacum* — were tested for their ability to kill ticks, particularly *Rhipicephalus (Boophilus) decoloratus* and *Rhipicephalus pulchellus*, the results demonstrated that the extracts' acaricidal properties increased with exposure time and concentration. All examined plants could be employed as a possible substitute for currently available commercial drugs, against *Rhipicephalus (Boophilus) decoloratus* and *Rhipicephalus pulchellus* [124]. In the adult immersion test (AIT) and larval packet test (LPT), essential oils of *Tagetes minuta* demonstrated dose-dependent efficacy against four species of ticks (*Rhipicephalus microplus*, *Rhipicephalus sanguineus*, *Amblyomma cajennense*, and *Argas miniatus*), with a concentration of 20% showing more than 95% efficacy [125]. With IC50 values of 2.0 mg/mL, 5.5 mg/mL, and 6.0 mg/mL, respectively, essential oil of *Ocimum gratissimum* demonstrated strong larvicidal activity against three different tick species: *R. microplus*, *Amblyomma sculptum*, and *R. sanguineus* [126]. Yipel *et al.* [127] assessed the *in vivo* efficacy of essential oils of *Allium sativum*, *Origanum majorana*, and ozonated olive oil against *Otodectes cynotis*, and found that nearly all oils resulted in significant eradication of the parasite within 30 days after therapy. Hence research has focused on using natural products, mostly acaricides derived from botanical sources, to reduce tick populations. This is primarily due to the growing prevalence of tick strains that are resistant to synthetic acaricides [128, 129].

Conclusion

Ethnobotanical plant preparations have become a practical alternative to the rising insect and agricultural pest resistance, problems of chemical residues, and environmental safety. Leveraging their accessibility, cost, and environmentally beneficial and biodegradable nature. Acaricidal and insecticidal ethnobotanical plants may hold the secret to secure integrated pest/insect management strategies. Therefore, it is essential to regularly update information on the ethnomedicinal plants with insecticidal action that are now available, develop standards for their use, and take note of gaps in the knowledge of these botanicals.

Conflict of Interest

The authors declare that none of the studies listed in this article was influenced by any known competing financial or personal interests.

Authors contribution

The study was conceptualized by AFO. Different sections of this piece of writing were written by AFO, OM, AOA, and

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