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Ajao O Folake
Department of Crop Protection, Faculty of Agriculture, Modibbo Adama University Yola, Adamawa State, Nigeria

Ogwiji Matthew
Department of Animal Science and Range Management, Faculty of Agriculture, Modibbo Adama University Yola, Adamawa State, Nigeria.

Adeoti O Adewale
Africa Rice Center, International Institute of Tropical Agriculture Ibadan, Oyo State, Nigeria

Mohammed G Ibrahim
National Cereal Research Institute Badeggi, Bida, Niger State, Nigeria.

Correspondence Author:
Ajao O Folake
Department of Crop Protection, Faculty of Agriculture, Modibbo Adama University Yola, Adamawa State, Nigeria

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

Ajao O Folake, Ogwiji Matthew, Adeoti O Adewale and Mohammed G Ibrahim

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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 repellant 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 *Tagenetes 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 [130, 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 *Callosobrunchus 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 *Ryzopertha 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: Gelechidae] [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 *Challosobruchus 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-

methylehexane (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 allicin'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, repellant 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* [124l]. 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

MIG. The final text was revised and approved for publication by all authors.

References

1. Dougoud J, Toepfer S, Bateman M, Jenner WH. Efficacy of homemade botanical insecticides based on traditional knowledge. A review. Agron Sustain Dev. 2019, 39(37). https://doi.org/https://doi.org/10.1007/s13593-019-0583-1.
2. Adhikari SR, Pandit V, Sharma DR, Subedi RK. Perception on biological pesticide by various levels of stakeholders in Nepal. J Biol. Control. 2019;33(3):173-177.
3. Narasimhamurthy G, Ram K. Field evaluation of some insecticides and Biopesticides against tur pod bug, *Clavigralla gibbosa* (Spinola) in long duration pigeon pea. Afr. J Agric. Res. 2013;8(38):4876-4881.
4. Bergmann EJ, Raupp MJ. Efficacies of common ready to use insecticides against Halyomorpha halys (Hemiptera: Pentatomidae). Fla. Entomol 2014;97(2):791-800. https://doi.org/10. 1653/024.097.0262
5. Prakash A, Rao J, Nandagopal V. Future of Botanical Pesticides in Rice, Wheat, Pulses and Vegetables Pest Management. J Biopestic 2008;1:154-169.
6. Srijita D. Biopesticides: An Eco-friendly Approach for Pest Control. World J Pharm. Pharm. Sci. 2015;6:250-265.
7. Sanjay G, Ashok K, Tiku AK. Toxicity of Solanum xanthocarpum fruit extract against *Alternaria brassicae*, causal agent of Alternaria blight of Indian mustard (*Brassica juncea*). Arch. Phytopathol Plant Prot. 2010;43(3):10:283-289.
8. Melaku Alemu. Trend of Biotechnology Applications in Pest Management: A Review, Int. J Appl. Sci. Biotechnol. 2020;8(2):108-131.
9. Samir AM, Abdelgaleil. Molluscicidal and insecticidal potential of monoterpenes on the white garden snail, Theba pisana (Muller) and the cotton leaf worm, *Spodoptera littoralis* (Boisduval) Appl. Entomol. Zool. 2010;45(3):425-433.
10. Bakkali F, Averbeck S, Averbeck D, Idaomar M. Biological effect of essential oils. Food Chem Toxicol. 2008;46:446-475.
11. Tembo Y, Mkindi AG, Mkenda PA, Mpumi N, Mwanauta R, Stevenson PC, Ndakidemi PA Belmain SR. Pesticidal plant extracts improve yield and reduce insect pests on legume crops without harming beneficial arthropods. Front. Plant Sci. 2018;9:1-10.
12. Adel MM, El-Hawary FM, Abdel-Aziz NF, Sammour EA. Some physiological, biochemical and histopathological effects of *Artemisia monosperma* against the cotton leafworm, *Spodoptera littoralis*. Arch Phytopathol & Plant Prot. 2010;43:1098-1110.
13. Stevenson PC, Isman MB, Belmain SR. Pesticidal plants in Africa: A global vision of new biological control products from local uses. Ind Crop Prod 2017;110:2. https://doi.org/10.1016/j.indcrop.2017.08.034
14. Roy S, Handique G, Muraleedharan N, Dashora K, Roy SM, Mukhopadhyay A, Babu A. Use of plant extracts for tea pest management in India. Appl Microbiol Biotechnol. 2016;100(11):4831. https://doi.org/10.1007/s00253-016-7522-8
15. Fening K, Adama I, Tegbe R. On-farm evaluation of homemade pepper extract in the management of pests of cabbage, *Brassica oleraceae* L., and french beans, *Phaseolus vulgaris* L., in two agro-ecological zones in Ghana. African Entomology. 2014;22(3):552-560.
16. Stephen PN, Gudeta WS, Steven RB, John FK, Brighton MM, Phosiso S, Greenwell KC, Nyirenda, Philip CS. Farmers' ethno-ecological knowledge of vegetable pests and pesticidal plant use in Northern Malawi and Eastern Zambia. Afr J Agric Res. 2017;7(11):001-013.
17. Kamatenesi-Mugisha M, Buyungo JP, Egwang P, Vudriko P, Gakunga JN, Deng A, Ogendo J, Mihale JM. Evaluation of the biosafety of selected botanical pesticide plants used by subsistence farmers around the Lake Victoria basin. In: Ethnobotany and health: Proceedings of the cluster workshop, Lake Victoria Research Institute, Uganda; c2010. p. 45-57.
18. Solomon K, Solomon J, Kanagappan M, Stalin IS, Das SSM. Ethnic storage strategies adopted by farmers of Tirunelveli district of Tamil Nadu, Southern Peninsular India. J Agric Technol. 2008;4(1):1-10.
19. Lengai GM Muthomi JW. Biopesticides and Their Role in Sustainable Agricultural Production. J Biosci. Med. 2018;6(6):7-41.
20. Green P, Belmain S, Ndakidemi P, Farrell I, Stevenson P. Insecticidal activity of *Tithonia diversifolia* and *Vernonia amygdalina*. Ind Crops and Prod. 2017;110:15.
21. FAO. Statistical yearbook of the Food and Agricultural Organization of the United Nations. Food and Agriculture Organization of the United Nations. 2013 http://www.fao.org/docrep/ 018/i3107e/i3107e01.pdf. Accessed 26 May 2023
22. Iqbal T, Ahmed N, Shahjeer K, Ahmed S. Botanical Insecticides and their Potential as Anti-Insect/Pests: Are they Successful against Insects and Pests? In In Global Decline of Insects. 2021 Intech Open, https://doi.org/http://dx.doi.org/10.5772/intechopen.100418
23. Erenso TF, Berhe DH. Effect of neem leaf and seed powders against adult maize weevil (*Sitophilus zeamais* Motschulsky) mortality. Agric. Res 2016;2:90-94.
24. Ogwiji M, Ajao OF, Okwanya MI, Mbaya YP. Beneficial activities of ethnobotanical plants on selected systems and agriculture. J Med. Plants Stud. 2023;11(5):85-95. https://doi.org/10.22271/plants.2023.v11.i5b.1589
25. Arnason JT, Sims SR, Scott IM. Natural products from plants as insecticides, phytochemistry and pharmacognosy. www.eolss.net/Sample-A 2012 llChapter.aspx/C06/E6-151.
26. Sarwar M. Microbial insecticides- an eco-friendly effective line of attack for insect pest's management. Int. J Eng. Adv. Technol. 2015;2:4-9.
27. Bhardwaj U, Chahal KK, Kaur R. *In vitro* evaluation of vetiver oil against rice weevil, *Sitophilus oryzae*. Pestic. Res. J. 2016;28(2):152-158.
28. Ibrahim SIA. Bioactivity of some essential oils against the rice weevil, *Sitophilus oryzae* L. (Curculionidae: Coleoptera). Egypt J Biol. Pest Control. 2016;26(1):123-126.

29. Sivasrinivasu. Evaluation of indigenous products and boric acid against stored grain pests. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad, Karnataka, India; c2001
30. Rajashekar Y, Bakthavatsalam N, Shivanandappa T. Botanicals as grain protectants. Psyche: A J Ento. 2012;13:598325.
31. Ogbomo KE, Enobakhare DA. The use of leaf powders of *Ocimum gratissimum* and *Vernonia amygdalina* for the management of *Sitophilus oryzae* (Linn.) in stored rice. J Entomol. 2007;4(3):253-257.
32. Ghavami M, Poorrastgoo F, Taghiloo B, Mohammadi J. Repellency Effect of Essential Oils of some Native Plants and Synthetic Repellents against Human Flea, Pulex irritans (Siphonaptera: Pulicidae). J Arthropod-Borne Di. 2017;11:105-115.
33. Rahdari T, Hamzei M. Repellency effect of essential oils of *Mentha piperita*, *Rosmarinus officinalis* and *Coriandrum sativum* on *Tribolium confusum* duval (Coleoptera: Tenebrionidae). Chemistry Research Journal. 2017;2(2):107-112.
34. Zhang W, Zhang Z, Chen Z, Liang J, Geng Z, Guo S, *et al*. Chemical composition of essential oils from six Zanthoxylum species and their Repellent activities against two stored-product insects. J Chem. Article ID 1287362, 2017, 7.
35. Kimutai A, Ngeiywa M, Mulaa M, Njagi PGN, Ingonga J, Nyamwamu LB, *et al*. Repellent effects of the essential oils of *Cymbopogon citratus* and *Tagetes minuta* on the sandfly, *Phlebotomus duboscqi*. BMC Research Notes, 2017;10:98. https://doi.org/10.1186/s13104-017-2396-0
36. Julien D, Stefan T, Melanie B, Wade H, Jenner. Efficacy of homemade botanical insecticides based on traditional knowledge. A review. Agronomy for Sustainable Development, 2019, 39(37). https://doi.org/https://doi.org/10.1007/s13593-019-0583-1
37. Amoabeng BW, Gurr GM, Gitau CW, Nicol H, Munyakazi L, Stevenson PC. Tri-trophic insecticidal effects of African plants against cabbage pests. PLoS One. 2013;8(11)e78651. https://doi.org/10.1371/ journal. pone.0078651
38. Amoabeng B, Gurr G, Gitau A, Nicol H, Munyakazi L, Stevenson PC. Tri-trophic insecticidal effects of African plants against cabbage pests. PLoS One. 2013;8(11):e78651. https://doi.org/10.1371/journal.pone.0078651
39. Bahar H, Islam A, Mannan A, Uddin J. Effects of some botanical extracts on bean aphids attacking yard-long beans. J Entomol. 2007;4(2):136.
40. Rizk SA. Efficacy of different extracts of Melia Azedarach leaves against larvae of the Rice Moth, *Corcyra cephalonica* (Staint.) (Lepidoptera: Pyralidae). J Rad Res Appl Sci. 2008;1:17-25
41. Narangoda C, Karunaratne S. Oviposition deterrent and insecticidal activities of some indigenous plant extracts against the rice moth, *Corcyra cephalonica* (Stainton). Vidyodaya J Sci. 2009;4:43-50.
42. Suleiman M, Ibrahim ND, Majeed Q. Control of *Sitophilus zeamais* (Motsch) [Coleoptera: Curculionidae] on Sorghum Using Some Plant Powders. Int. J Agric. For. 2012;2(1):53-57.
43. Ugwu JA. Insecticidal activity of some botanical extracts against legume flower thrips and legume pod borer on cowpea *Vigna unguiculata* L. Walp. J Basic Appl. Zool. 2020;81(1):13. https://doi.org/10.1186/s41936-020-00153-3.
44. Ullah S, Ullah R, Shakir L, Ullah R. Cheek list of ethno botanical plants of tehsil colony, Samarbagh, District Dir lower, Khyber Pakhtunkhwa Pakistan. Int. J Agric. Nutr. 2021;3(1):41-49. DOI: 10.33545/26646064.2021.v3.i1a.63
45. Gianotti RL, Bomblies A, Mustata M, Duchemin JB. Efficacy of local neem extract for sustainable malaria vector in African village. Medicine Industry and other purposes; c2008. p. 385-389.
46. Poderoso JCM, Correia-Oliveira ME, Chagas TX, Zanuncio JC, Ribeiro GT. Effects of plant extracts on developmental stages of the predator *Podisus nigrispinus* (Hemiptera: Pentatomidae). Fla Entomol. 2016;99(1):113-116. https://doi.org/10.1653/024.099.0121
47. Fabrick JA, Yool AJ, Spurgeon DW. Insecticidal activity of marigold *Tagetes patula* plants and foliar extracts against the hemipteran pests, *Lygus hesperus* and *Bemisia tabaci*. PLoS ONE. 2020;15(5):e0233511. https://doi.org/10.1371/journal.pone.0233511.n
48. Idoko JE, Adesina JM. Evaluation of the powder of Piper guineense and pirimiphos-methly F for the control of cowpea beetle *Callosobruchus maculatus* (F.). J Agric. Sci. Technol. 2012;8(4):1365-1374. https:// www.researchgate.net/publication/282866424
49. Babarinde SA, Pitan OR, Ogunfiade AT. Bioactivity of *Piper guineense* Schum and Thonn seed and *Moringa oleifera* Lam. leaf powder against *Trogoderma granarium* Evert (Coleoptera: Dermestidae). Arch. Phytopathol. Plant Prot. 2001;44(3):298-306.
50. Adeniyi SA, Orjiekwe CL, Ehiagbonare JE, Arimah BD. Preliminary phytochemical analysis and insecticidal activity of ethanolic extracts of four tropical plants (*Vernonia amygdalina*, Sida acuta, *Ocimium gratissimum* and *Telfaria occidentalis*) against beans weevil (*Acanthoscelides obtectus*). Intl. J Phys. Sci. 2010;5(6):753-762.
51. Mukanga M, Deedat Y, Mwangala FS. Toxic effects of five plant extracts against the larger grain borer, *Prostephanus truncatus*. Afr. J Agric. Res., 2010;5(24):3369-3378.
52. Race MO, Karabo M, Obopile B, Tiroesele R, Mmolotsi M, Rampart ABN Tshegofatso. Effects of Moringa oleifera root and leaf powder on reproductive capacity and damage caused on stored cowpea seed by *Callosobruchus maculatus* (F). J Agric. Sci. Technol. 2012;8(7):2319-2329.
53. Adane T, Abaynew JJ, Melesech M. Survey of storage insect pests and management of rice weevil, using botanicals on sorghum (L.) at Jawi District, Northwestern Ethiopia, Arch. Phytopathol. Plant Prot; c2021.
54. Bhanderi GR, Radadia GG, Patel DR. Ecofriendly management of rice weevil *Sitophilus Oryzae* (Linnaeus) in Sorghum. Indian J entomol. 2015;77:210-213.
55. Ashamo MO, Akinnawonu O. Insecticidal efficacy of some plant powders and extracts against the Angoumois grain moth, *Sitotroga cerealella* (Olivier)

(Lepidoptera: Gelechiidae), Arch. Phytopathol and Plant Protection. 201245(9):1051-1058. DOI:10.1080/03235408.2012.655153
56. Chandrakala A, Prabha AR, Chitra D, Muralidharan S, Saravanababu S. Toxic effect of neem leaf powder (*Azadirachta indica*) against *Callosobruchus chinensis* infestation (Bruchidae: Coleoptera) on the green gram (*Vigna radiata*) seeds. Int. J Pure Appl. Zool. 2013;1(1):86-91.
57. Kayode DI, Ogungbite OC. Entomocidal activity of powders and extracts of four medicinal plants against *Sitophilus oryzae* (L), *Oryzaephilus mercator* (Faur) and *Ryzopertha dominica* (Fabr.). Jordan J Biol. Sci. 2014;7(1):57-62.
58. Adebayo TA. Efficacy of mixture formulations of synthetics and botanical insecticides in the control of insect pests of okra and cowpea. Ph.D. Thesis submitted to Ladoke Akintola University of Technology, Ogbomoso, Nigeria; c2003. p. 154-169.
59. Benson GAS. Efficacy of Selected Insecticides and Botanicals in the Control of Field Insect Pest of Okra (*Abelmoschus Esculentus*) in Akure. International Journal of Forestry and Horticulture (IJFH). 2017;3(4):1-5. http://dx.doi.org/10.20431/2454-9487.0304001
60. Kusi F, Nboyine JA, Abudulai M, Seidu A, Agyare YR, Sugri I, *et al*. Cultivar and insecticide spraying time effects on cowpea insect pests and grain yield in northern Ghana. Ann Agric. Sci. 2019;64(1):121-127. DOI: 10.1016/j.aoas.2019.03.001
61. Kumar B, Misra A, Kumar S, Kumar ASR, Singh RY, Ghosh S, *et al*. Antitick potential and chemical variability among *Ageratum conyzoides* L. germplasms collected from Eastern and Western Ghats of India, Inter. J Acarol. 2019;45(8):488-496. DOI: 10.1080/01647954.2019.1677772
62. do Rosário CJRM, Lima AS, Mendonça CJS, Soares IS, Júnior EBA, Gomes MN, *et al*. Essential oil *Ageratum conyzoides* chemotypes and anti-tick activities. Vet Parasitol. 2023 Jul;319:109942. DOI: 10.1016/j.vetpar.2023.109942. Epub 2023 May 4. PMID:37178553.
63. Kumar KG, Tayade AB, Kumar R, Gupta S, Sharma AK, Nagar G, *et al*. Chemo-profiling and bioassay of phytoextracts from *Ageratum conyzoides* for acaricidal properties against *Rhipicephalus* (Boophilus) microplus (Acari: Ixodidae) infesting cattle and buffaloes in India. Ticks Tick Borne Dis. 2016 Mar;7(2):342-349. DOI: 10.1016/j.ttbdis.2015.12.005. Epub 2015 Dec 9. PMID:26723275.
64. Vasu M, Surjeet K, Radha K, Himanshu Th. Host plant resistance and botanicals, as potential management tactics for insect pests of stored grains. J Exp. Zool. India. 2021;24(2):1431-1443.
65. Vasantharani S, Thirugnanasampandan R, Bhuvaneswari G. Qualitative and quantitative analysis of Precocene II, estimation of enzymatic, nonenzymatic antioxidant, and cytotoxic potentials of methyl jasmonate-elicited shoot culture of *Ageratum conyzoides* Linn. J Appl Biol Biotech. 2023;11(01):93-99.
66. Parveen S, Godara R, Katoch R, Yadav A, Verma PK, Katoch M, Singh NK. *In vitro* Evaluation of Ethanolic Extracts of *Ageratum conyzoides* and *Artemisia absinthium* against Cattle Tick, *Rhipicephalus microplus*. Sci World J; c2014. p. 1-6. DOI: 10.1155/2014/858973
67. Thiruppathi S. Antimicrobial activity of *Aloe vera* (L.) Burm. f. against pathogenic microorganisms. J Biosci. and Res. 2010;4:251-258.
68. Simmonds MS. Flavonoid-insect interactions: Recent advances in our knowledge. Phytochemistry. 2003;64:21-30. https://doi.org/10.1016/S0031-9422(03)00293-0
69. Simmonds MS, Stevenson PC. Effects of isoflavonoids from cicer on larvae of *Heliocover paarmigera*. J Chem. Ecol. 2001;27:965-977. https://doi.org/10.1023/A:1010339104206
70. Loko LY, Alagbe O, Dannon EA, Datinon B, Orobiyi A, Thomas-Odjo A, Tamò M. Repellent effect and insecticidal activities of *Bridelia ferruginea*, *Blighia sapida*, and *Khaya senegalensis* leaves powders and extracts against *Dinoderus porcellus* in infested dried yam chips. Psyche; c2017. p. 1-18. Article ID 5468202.
71. Huang Y, Chen SX, Ho SH. Bioactivities of methyl allyl disulfide and diallyl trisulfide from essential oil of garlic to two species of stored-product pests, *Sitophilus zeamais* (Coleoptera: Curculionidae) and *Tribolium castaneum* (Coleoptera: Tenebrionidae). J Econ Entomol. 2000;93(2):537. https://doi.org/10.1603/0022-0493-93.2.537
72. Prowse GM, Galloway TS, Foggo A. Insecticidal activity of garlic juice in two dipteran pests. Agric Forest Ent 8(1):1. https://doi.org/ 10.1111/j.1461-9555.2006;00273.x
73. Yang FL, Zhu F, Lei CL. Insecticidal activities of garlic substances against adults of grain moth, *Sitotroga cerealella* (Lepidoptera: Gelechiidae). Insect Sci. 2012;19(2):205. https://doi.org/10.1111/j.1744-7917.2011.01446.x
74. Zhao NN, Zhang H, Zhang XC, Luan XB, Zhou C, Liu QZ, *et al*. Evaluation of acute toxicity of essential oil of garlic (*Allium sativum*) and its selected major constituent compounds against overwintering *Cacopsylla chinensis* (Hemiptera: Psyllidae). J Econ Entomol. 2013;106(3):1349. https://doi.org/10.1603/EC1219
75. Dabrowski ZT, Seredynska U. Characterization of the two-spotted spider mite [*Tetranychus urticae* Koch, Acari: Tetranychidae] response to aqueous extracts from selected plant apecies. J Plant Prot Res. 2007;47:113-124.
76. Plata-Rueda A, Martínez LC, Santos MHD, Fernandes FL, Wilcken CF, Soares MA, *et al*. Insecticidal activity of garlic essential oil and their constituents against the mealworm beetle, *Tenebrio molitor* Linnaeus (Coleoptera: Tenebrionidae). Sci Rep. 2017 Apr 20;7:46406. DOI: 10.1038/srep46406.
77. Abiodun AD. Bioactivity of Powder and Extracts from Garlic, *Allium sativum* L. (Alliaceae) and Spring Onion, *Allium fistulosum* L. (Alliaceae) against *Callosobruchus maculatus* F. (Coleoptera: Bruchidae) on Cowpea, *Vigna unguiculata* (L.) Walp (Leguminosae) Seeds. Psyche: J Entomol. 2010;(2):1-5 https://doi.org/10.1155/2010/958348
78. Fabrick JA, Yool AJ, Spurgeon DW. Insecticidal activity of marigold *Tagetes patula* plants and foliar extracts against the hemipteran pests, *Lygus hesperus*

and *Bemisia tabaci*. PLoS ONE. 2020;15(5):e0233511. https://doi.org/10.1371/journal. pone.0233511
79. Athanassiou CG, Kontodimas DC, Kavallieratos NG, Anagnou Veroniki M. Insecticidal effect of Neem Azal against three stored-product beetle species on rye and oats. J Eco. Entom. 2005;98:1499-1505.
80. Coldebella PFMR, Fagundes-Klen L, Nishi KC, Valverde EB, Cavalcanti OA, Andreo dos Santos R, Bergamasco. Potential effect of chemical and thermal treatment on the Kinetics, equilibrium, and thermodynamic studies for atrazine biosorption by the *Moringa oleifera* pods. Can. J Chem. Eng. 2017;95:961-973.
81. Lennon AA, Charleston OB, Luis FC, Marcela FS, Leticia N, Raquel GG, *et al*. *Moringa oleifera* biomass residue for the removal of pharmaceuticals from water. J Environ Chem Eng. 2018;6:7192-7199.
82. Agra-Neto AC, Napoleão TH, Pontual EV, Santos ND, Luz Lde A, de Oliveira CM, *et al*. Effect of *Moringa oleifera* lectins on survival and enzyme activities of Aedes aegypti larvae susceptible and resistant to organophosphate. Parasitol. Res. 2014;113(1):175.
83. Padin SB, Fuse C, Urrutia MI, DalBello GM. Toxicity and repellency of nine medicinal plants against *Tribolium castaneum* in stored wheat. Bull. Insectology. 2013;66(1):45-49.
84. Isman MB. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annu. Rev. Entomol. 2006;51;45-66. https://doi.org/10.1146/annurev.ento.51.110104.151146
85. Germinara GS, Distefano MG, Acutis LD, Pati S, Delfne S, Cristofaro AD, *et al*. Bioactivities of *Lavandula angustifolia* essential oil against the stored grain pest *Sitophilus granaries*. Bull. Insectology, 2017;70(1):129-138.
86. Trivedi A, Nayak N, Kumar J. Fumigant toxicity study of different essential oils against stored grain pest *Callosobruchus chinensis*. J Pharmacog. Phytochem. 2017;6(4):1708-1711.
87. Hafez M, Dimetry NZ, Abbass MH. Efficacy of some plant products as protectants against *Callosobruchus maculatus* (F.) on mungbean seeds, *Vigna radiata* L. (Wilczek). Egypt J Biol Pest Control. 2014;24(2):353.
88. Espinoza ME, Silva G, Tapia M, Rodríguez JC, Lagunes A, Santillán Ortega C, *et al*. Insecticidal activity of *Melia azedarach* L. against *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). Agro-Ciencia. 2012;28(2):81.
89. Akbar R, Khan IA, Alajmi RA, Ali A, Faheem B, Usman A, *et al*. Evaluation of Insecticidal Potentials of Five Plant Extracts against the Stored Grain Pest, *Callosobruchus maculatus* (Coleoptera: Bruchidae). Insects. 2022;13:1047. https://doi.org/10.3390/insects13111047
90. Ilesanmi JO, Gungula DT. Preservation of cowpea (*Vigna unguiculata* (L.) Walp) grains against cowpea bruchids (*Callosobruchus maculatus*) using neem and moringa seed oils. Int J Agron. 2010;2:1-8. https://doi.org/10.1155/2010/235280
91. Kamel A. Can we use Moringa oil as a botanical insecticide against *Spodoptera frugiperda*. Academic J Entomol. 2010;3(2):59-64.
92. Longe O. Evaluating the efficacy of some plant powders on the bean weevil [*Callosobruchus maculatus* (fabricius) (Coleoptera: Bruchidae)] affecting stored cowpea seeds (*Vigna unguiculata*). Asian Journal of Science and Technology (AJST). 2016;7(2):2486.
93. Ojo JA, Olunloyo AA, Akanni EO. Efficacy of *Moringa oleifera* leaf powder against *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae) on stored cowpea (*Vigna unguiculata* L. Walp). Research. 2013;5(12):240.
94. Osipitan AA, Lasisi AM, Mumuni HM, Ewedairo BI. Evaluation of some plant products for the management of *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) in stored maize (*Zea mays*) and their effect on nutritional composition of the kernels. Arch Phytopathol Plant Protect. 2014;47(9):1072. https://doi.org/10.1080/03235408.2013.829983
95. Mallikarjuna N, Kranthi KR, Jadhav DR, Kranthi S, Chandra S. Influence of foliar chemical compounds on the development of *Spodoptera litura* in interspecific derivatives of groundnut. J Appl Entomol. 2004;128:321-328. https://doi.org/10.1111/jen.2004.128.issue-5
96. Wafaa M Hikal, Rowida S Baeshen, Hussein AH Said-Al Ahl, Karol Ujházy (Reviewing Editor). Botanical insecticide as simple extractives for pest control, Cogent Biology. 2017;3:1. DOI:10.1080/23312025.2017.1404274
97. Sun W, Shahrajabian MH, Cheng Q. Pyrethrum an organic and natural pesticide. J Biol. Environ. Sci. 2020;14(40):41-44.
98. California Department of Pesticide Regulation. Summary of Pesticide Use Report Data 2016 Indexed by Chemical.
99. Grdisa M, Grsic K. Botanical Insecticides in Plant Protection. Agriculturae Conspectus Scientificus. 2013;78(2):85-93.
100. Tomlin CDS. The Pesticide Manual. In Crop Protection. BCPC Publications; c2001. p. 20.
101. Hikal WM, Baeshen RS, Ahl HAHS, Hikal WM, Baeshen RS, Ahl HA. Botanical insecticide as simple extractives for pest control. Cogent Biology. 2017;35(1). https://doi.org/10.1080/23312025.2017.1404274
102. Casida JE. Pyrethrum flowers and pyrethroid insecticides. Environmental Health Perspectives. 1980;34:189-202.
103. Holm A, Molander P, Lundanes E, Greibrokk T. Determination of rotenone in river water utilizing packed capillary column switching liquid chromatography with UV and time-of-flight mass spectrometric detection. J Chromatogr. A 2003;(983):43-50.
104. Bogumiła H, Jerzy Z, Maria K, Danuta B, Anna CR, Alicja M. Synthesis and fungicidal activity of 2-methylalkyl isonicotinates and nicotinates, Med Chem. Res. 2017;509-517
105. Mancebo F, Hilje L, Mora GA, Salazar R. Antifeedant activity of *Quassia amara* (Simaroubaceae) extracts on *Hypsipyla grandella* (Lepidoptera: Pyralidae) larvae. Crop Prot. 2000;19:301-305.
106. Dayan FE, Cantrell CL, Duke SO. Chemistry Natural products in crop protection. Bioorganic & Medicinal Chemistry. 2009;17:4022-4034. https://doi.org/10.1016/j.bmc. 01.046

107. Khater FA. Prospects of botanical biopesticides in insect pest management. J Appl. Pharm. Sci. 2012;2(9)244-259.
108. Regnault-Roger C, Vincent C, Arnason JT. Essential Oils in Insect Control: Low-Risk Products in a High-Stakes World. Annual Review of Entomology. 2012;57:405-424. https://doi.org/10.1146/annurev-ento120710-100554
109. Suthisut D, Fields PG, Chandrapathya A. Contact toxicity, feeding reduction and repellency of essential oils from three plants from the ginger family (Zingiberaceae) and their major components against *Sitophilus zeamais* and *Tribolium castaneum*. J Econ. Entomol. 2011;104(4):1445-1454.
110. Tripathi AK, Prajapati V, Khanuja SPS, Kumar S. Effect of d-limonene on three stored-product beetles. J Econ. Entomol. 2003;96:990-995. https://doi.org/10.1093/jee/96.3.990
111. Elzen GW, Hardee DD. United state department of agricultural-agricultural research on managing insect resistance to insecticides. Pest Manag. Sci. 2003;59:770-776.
112. Pereira SG, Sanaveerappanavar VT, Murthy MS. Geographical variation in the susceptibility of the diamond back moth *Ptlutella xylostella* L. to *Bacillus thuringiensis* products and acylurea compounds. Pest Management. 2006;15:26-26.
113. Shelton M, Zhao JZ, Roush RT. Economic, ecological, food safety, and social consequences of the deployment of B-transgenic plants. Annual Review of Entomology. 2002;47:845-881. https://doi.org/10.1146/annurev.ento.47.091201.145309
114. Geetanjly, Tiwari SN. Evaluation of Four Essential Oils against Angoumois Grain Moth, *Sitotroga cerealella* (Olivier). J Plant Sci. Res. 2015;2(2):127.
115. Minoretti N, Weisser WW. The Impact of Individual Ladybirds (*Coccinella septempunctata*, Coleoptera: Coccinellidae) on Aphid Colonies. Eur. J Entomol. 2000;97:475-480. http://dx.doi.org/10.14411/eje.2000.073
116. Mishra BB, Tripathi SP, Tripathi CPM. Repellent effect of leaves essential oils from Eucalyptus globulus (Mirtaceae) and *Ocimum basilicum* (Lamiaceae) against two major stored grain insect pests of Coleopterons. J Nat. Sci. 2012;10(2):50-54.
117. Kudachi DC, Balikai RA. Efficacy of botanicals for the management of lesser grain borer, *Rhizopertha dominica* Fab. in sorghum during storage. Karnataka J Agric. Sci. 2009;22(3):487-490.
118. Rani PU. Fumigant and contact toxic potential of essential oils from plant extracts against stored product pests. J Biopestic. 2012;5(2):120-12.
119. Panda SK, Daemen M, Sahoo G, Luyten W. Essential Oils as Novel Anthelmintic Drug Candidates. Molecules. 2022 Nov 29;27(23):8327. DOI:10.3390/molecules27238327. PMID:36500419;PMCID:PMC9735941.
120. Abbas A, Abbas RZ, Masood S, Iqbal Z, Khan MK, Saleemi MK, *et al*. Acaricidal and insecticidal effects of essential oils against ectoparasites of veterinary importance. Bol Latinoam Caribe Plant Med Aromat. 2018;17(5):441-452.
121. Adenubi O, Salihu T, Mbaoji C, Ojogbo I, Abdullahi MA. Review of Ethnoveterinary Botanicals Used for Tick Control in Wukari, Taraba State, North Eastern Nigeria. Egyp. J Vet. Sci. 2020;51(3):421-437. DOI:10.21608/ejvs.2020.27056.1167.
122. Habeeb SM. Ethno-veterinary and medical knowledge of crude plant extracts and its method of application (traditional and modern) for tick control. World Appl. Sci J 2010;11(9):1047-1054.
123. Nchu F, Magano SR, Eloff JN. *In vitro* anti-tick properties of the essential oil of *Tagetes minuta* L. (Asteraceae) on *Hyalomma rufipes* (Acari: Ixodidae) Onderstepoort J Vet. Res., 2012, 79(1). DOI:10.4102/ojvr. v79i1.358.
124. Kemal J, Zerihun T, Alemu S, Sali K, Nasir M, Abraha A, Feyera T. *In vitro* Acaricidal Activity of Selected Medicinal Plants Traditionally Used against Ticks in Eastern Ethiopia. J Parasitol Res. 2020 Feb 18;2020:7834026. DOI:10.1155/2020/7834026. PMID:32148933;PMCID:PMC7049414.
125. Garcia MV, Matias J, Barros JC, Lima DP, de., Lopes R. da S, Andreotti R. Chemical identification of *Tagetes minuta* Linnaeus (Asteraceae) essential oil and its acaricidal effect on ticks. Revista Brasileira De Parasitologia Veterinária. 2012;21(4):405-411. https://doi.org/10.1590/S1984-29612012000400011
126. Ferreira TP, Cid YP, Alves MCC, Santos GCM, Avelar BR, Freitas JP, *et al*. *In vitro* acaricidal activity of *Ocimum gratissimum* essential oil on *Rhipicephalus sanguineus*, *Amblyomma sculptum* and *Rhipicephalus microplus* larvae. Revista Virtual de Quimica. 2019;11:1604-1613.
127. Yipel FA. Effect of some essential oils (*Allium sativum* L., *Origanum majorana* L.) and ozonated olive oil on the treatment of ear mites (*Otodectes cynotis*) in cats. Turkish J Vet. Anim. Sci. 2016;40:782-787.
128. Klafke GM, Thomas DB, Miller RJ, Pérez de León AA. Efficacy of a water-based botanical acaricide formulation applied in portable spray box against the southern cattle tick, *Rhipicephalus* (*Boophilus*) *microplus* (Acari: Ixodidae), infesting cattle. Ticks and Tick-Borne Diseases. 2021;12(4):101721. DOI:10.1016/j.ttbdis.2021.10172
129. Nwanade CF, Wang M, Wang T, Yu Z, Liu J. Botanical acaricides and repellents in tick control: current status and future directions. Exp. Appl. Acarol; c2020. DOI:10.1007/s10493-020-00489-z
130. Ugwu JA, Omoloye AA, Obasaju FT. Potentials of *Azadirachta indica* (A. Juss) and *Cymbopogon citratus* (Staph) powder for the control of *Oryzaephilus mercator* (Fauvel) on *Irvingia wombolu* kernel. J Sustain. Environ. Manag. 2012;4:75-80.