IOSR Journal of Applied Chemistry (IOSR-JAC)
e-ISSN: 2278-5736.Volume 14, Issue 10 Ser. I (October 2021), PP 23-37
www.iosrjournals.org

A Review of Insecticidal Plant Extractsand Compoundsfor Stored Maize Protection

Sylvia A. Opiyo
Department of Physical and Biological Sciences, Murang'a University of echnology,P.O Box 75-100200 Murang'a, Kenya

Abstract
Insect pests cause significant losses to maize grains both in the fieldsand in storage. Maize weevil (Sitophilus zeamais) and larger grain borer (Prostephanus truncatus) are among the most destructive pests of maize in Africa. Currently, researchers have focused on identification of insecticidal plant extracts and compound through in-vivo and in-vitro experiments, as an alternative to synthetic chemicals which have been reported to have adverse effect on the environment.The aim of this study was to collate and review the fragmented information on plants extracts and compounds with insecticital activity against S. zeamais and P. truncatus and present recommendations for future research. Peer-reviewed articles were retrieved from Scopus, Science Direct, SciFinder and Google Scholar. This study led to identification of 123 plant species which have been examined for insecticidal activity focusing more on S. zeamais rather than P. truncatus.It is also evident that most studies end with the crude plant extracts. Effort towards identification of insecticidal principles from the plants is negligible despite the fact that insecticidal compounds from nature are preferred because they are environmentally safe. Future studies aimed in isolating and characterizing the active compounds from the plants is necessary. It is also necessary to develop plant based formulations to be used as altenatives in controlling the crop storage pests.
***Keywords**: Post harvest pests;Maize pests;Sitophilus zeamais; Prostephanus truncatus;Plant extracts; insecticidal compounds*

Date of Submission: 08-10-2021 Date of Acceptance: 22-10-2021

I. Introduction

Maize(*Zea mays*)is a major cereal crop grown in abundance in sub-Saharan Africa and is ranked fourth most edible grain after sorghum, millet and rice) [1]. It is rich in carbohydrate, protein, oil and crude fiber[1, 2] and is used as food, feed, fodder and a basic raw material in beverage, confectionery, starch, ethanol, oil, cosmetic, pharmacology, food processing, textile, gum and paper industries.Farmers produce huge tons of maize annually which is more than enough for sale in the markets. However, a huge proportion goes to wastebecause of inadequate storage structures and insect pest attack. Maize weevil (*Sitophilus zeamais* Motchulsky) and larger grain borer (*Prostephanus truncatus Horn*) are among the most important pests of maize in Africa. The extensive tunneling in maize grain by the insects allows the pests to convert maize grain into flour within a very short time[3]. In addition, infestation of the insects results in development of *Aspergillus* which is carcinogic[4]. Small-scale farmers are often forced to sell their produce shortly after harvest to minimize losses during storage, thereby attracting low prices and compromising food security.

Protection of stored products from insect pests is most important to ensure adequate food supply.Chemical control is the most commonly used and most effective method. However,indiscriminate use of synthetic insecticides results in development of resistance and undesirable effects on non-target organisms, human and environmental[6].There is urgent need to develop safe alternatives that are readily available, convenient to use and environmentally friendly. Plantsproduce secondary metabolites that are used in defense against different pests and pathogenic microorganism [7-18]. The use of botanicals for pests and disease control is preferred because they are safe and non-toxic to humans[19-28]. In addition, chances of pests and pathogens developing resistance to botanical pesticides are highly unlikely[29].

Search for insecticidal materials from plants through *in-vivo* and *in-vitro* experiments has led to identification of important compounds including alkaloids, terpenoids, flavonoids, steroids and quinones [30-32]. Such compounds represent an important source of drugs in the process of developing new pharmacologically active compounds. This paper provides a review on plant derived pesticides with emphasis on plant powdered parts, extracts and pure compounds isolated from plants exhibiting insecticidal, repellent, antifeedant oviposition deterrent and adult emergence/ growth inhibitionactivities against maize weevil (*Sitophilus zeamais* Motchulsky) and the larger grain borer (*Prostephanus truncatus Horn*).

II. Some Plants Families with Insecticidal Properties against Maize Pests

Plants belonging to the families of Acanthaceae, Acoraceae, Amaranthaceae, Anacardiaceae, Annonaceae, Apiaceae, Apocynaceae, Aristolochiaceae, Asteraceae, Bignoniaceae, Canellaceae, Caricaceae, Celastraceae, Chenopodiaceae, Convolvulaceae, Cucurbitaceae, Cupressaceae, Euphorbiaceae, Fabaceae, Guttiferae, Lamiaceae, Lauraceae, Liliaceae, Loranthaceae, Lythraceae, Malvaceae, Meliaceae, Monimiaceae, Moraceae, Moringaceae, Myrtaceae, Nitrariaceae, Passifloraceae, Phytolaccaceae, Piperaceae, Poaceae, Pontedeaceae, Rubiaceae, Rutaceae, Salicaceae, Sapindaceae, Schisandraceae, Solanaceae, Verbenaceae and Zingiberaceae (Table 1) have been reported as promising sources of botanical insecticides against maize storage insects[33,34]. The plant extracts cause sterilization of insect pests, disrupting moulting of larvae, nymphs, mating and sexual communication, inhibiting the formation of chitin, impaired fitness and reproductive activity[35]. The extracts also inhibit acetylcholine esterase (AChE), prothoracicotropic hormones and block voltage gated sodium channels in nerve axon[36, 37].

III. Insecticidal Plant Powders and Extracts

Efficacy of a large number of plants has been evaluated for insecticidal activity against *Sitophilus zeamais* and *Prostephanus truncatus*.Ethanol extracts of *Acorus calamus* L. and *Annona squamosa* L. caused 85 and 91% mortality respectively against *S. zeamais* at a concentration of 40% after 24 hours exposure. The lethal concentration(LC_{50}) values were determined to be 11.73 and 32.34% for *A. calamus* and *A. squamosa* respectively[38]. *Annona muricata* seed hexane extracts had LC_{50} values of 4,009, 3,854 and 3,760 ppm at 24, 48 and 72 hours, respectively in ingestion bioassays while ethyl acetate extract gave LC_{50} values of 3,280, 2,667 and 2,542 ppm respectively against *S. zeamais*[39].The LC_{50} of the hexane extract in the topical application was 9,368 ppm at 72 hours[39]. *Annona muricata* seed acetone extract caused 70 and 100% deaths against*S. zeamais* when toxicity of the extract was tested using dipping method and surface protectant method respectively[40]. Ethanol seed extracts of *Annona Montana*, *Annona mucosa, Annona muricata* and *Annona sylvatica* caused 100% mortality of*S. zeamais* at a concentration of 3,000 mg/kg[33]. Ethanol leaf extracts of *Annona mucosa, Annona Montana, Duguetia lanceolata, Annona muricata and Annona* sp. 2 caused 83, 77.5, 37.5, 34.0 and 16.5% mortality respectively[33]. The extract prepared from *Annona mucosa* (seeds), *Annona muricata* (seeds), *Annona Montana* (seeds) *Annona montana*(leaves) and *Annona mucosa*(leaves) demonstrated LC_{50} values of 288.33, 384.94, 621.70, 1,851.00 and 1,972.00 mg/kg respectively against maize weevil [33]. *Annona mucosa* hexane extracts of seeds, leaves and branches caused 100.0, 61.5 and 1.5% deaths of *S. zeamais* respectively at a concentration of 1500 mg/kg[41]. *Annona mucosa* seeds, leaves and branches dichloromethane extracts caused100, 4 and 0.0% mortality respectively while ethanol extracts of seeds, leaves and branches caused 33.0, 0.5 and 0.0% mortality of *S.* zeamaisrespectively [41]. Hexane and DCM extracts of *Annona Montana* seeds caused 100% mortality of *S. zeamais* while leaf hexane extract of the plant caused 93% mortality at a dosage of 1.5 mg/kg of grains. Hexane extract of *Aristolochia paulistana* branches caused 41% mortalityat a dosage of 1.5 mg/kg of grains[42]. Methanol extract of *Annona mucosa* Jacq leave was found to be toxicity to *S. zeamais* and *P. truncatus*[43]. *Aristolochia ringens* Vahl, *Allium sativum* L., *Garcinia kola* H.and *Ficus exasperata* L. pet-ether extracts caused 100, 85, 50 and 20% mortality of *S. zeamais* respectively at a concentration of 1.50% (w/v) [44].

Mortality of *S. zeamais*in grains treated with powdered leaves of *Cymbopogon citratus* and *Ocimum basilicum*was 5.33 and 0.66% respectively [45]. *Azadirachta indica* leaf powder and*Chrysanthemum cinerariaefolium* flower powder caused 100% mortality of *S. zeamais* at a dosage of 4g/100g of maize grains after 21 days while powdwered *Azadirachta indica* seeds, *Cymbopogon citrates* leaves and *Dodonae angustifolia* leaves caused 95.55, 62.22 and 31.78% mortality respectively at a dosage of 5g/100g of after 28 days[46]. Application of 40%v/v*Piper guineense* caused 100% mortality of *S. zeamais* while application of *Azadirachta indica* gave 52.5% mortality after 96 hours[47]. *Sclerocarya birrea* leaf and bark extracts caused of 97.50 and 91.25% mortality while *Azadiractha indica* leaf extract caused of 92.50% mortality at extract concentration of 0.45 ml/33 cm^2 after 5 days [48]. The percent mortalitiescaused byleaf and seed extracts of eight plants against *S. zeamais* were as follows: *Azadirachta indica* (86.67), *Citrullus colocynthis* (81.66), *Peganum harmala* (76.66), *Curcuma longa* (71.67), *Ocimum basilicum* (66.66), *Ferula assafoetida* (61.66), *Cymbopogon flexousus* (58.33) and *Mentha arvensis* (53.33) at 15% concentration after 6 days of exposure period[3]. *Azadirachta indica,* and *Alstonia boonei*seed and stem bark powders at a dose of 5.0% caused 100% mortality of *S. zeamais* after 72 hours while a dose of 25.0% of *Garcina kola* powder caused 100% deaths after 96 hours[49]. *Moringa oleifera* extract caused 59.4% deaths at adose of 25.0% after 96 hours [49].*Murrayakoenigii, Eicchornia crassipes, Momordica charantia, Piper betel, Carica papaya* and *Coccinia indica* leaf extracts caused 66, 51, 36, 21, 19 and 11% mortality respectively at a dose of 1mg/L of air after 72 hours exposure in fumigation assay[50]. In grain coating assay, 100, 83, 66, 28, 19 and 10% mortalities were recorded for *E. crassipes, P. betel, C. papaya, M. charantia, M. koenigii* and *C. indica* respectively at a dose of 100 mg/20 g of grains [50]. *Carica papaya* flower powder at a dose of 2.5g/30g of maize grains caused 100% mortality of weevils[51].

Monodora myristica seeds, *Lantana camara* leavesand *Euphorbia lateriflora* stemhexane extracts caused 96, 73.3 and 50% mortalities of *S. zeamais*respectively after 24 hours exposure[52].The LD_{50} values recorded were 1.48, 6.96 and 9.62 g/100 in grains treated with *M. myristica, L. camara*and *E. lateriflora*extracts respectively[52]. *Lantana camara* leaves methanolextract caused74% mortality at concentration of 10 (w/w)[53]. *Peumus boldus* Molina powder and hexane extract caused 100% mortality of *S. zeamais* after 24 h exposure at all concentrations tested (0.5, 1.0 and 2.0%)while water and ethanol extracts caused 100% mortality at 72 h[54]. Toxicity of powder, ethanol and essential oil extracts of *Delonix regia* (Bojer ex Hook.) Raf. seed were tested against *Sitophilus zeamais* (Motschulsky) at concentration levels of 0.5%, 1.0%, 1.5% and 2.0% by mixing the test material with maize grains[55].*Delonix regia* oil caused 100% mortality at 120 hours post-treatment at all concentrations [55].*Chenopodium ambrosioides, Cucurbita pepo and Corymbia citriodora* ethereal, ethyl and aqueous extracts caused 23-40, 29-45 and 24-25 mortalities respectively against *S. zeamais* at dose of 25µl [56]. *Anisomeles malabarica, Vitex negundo and Murraya koenigii* hexane leafextracts caused 47.7- 96.2, 10.9-74.6 and 10.4-54.1% mortality respectively against*S. zeamais* after 24 hours[57]. The extracts recorded LD_{50} values of1.44, 6.90 and 9.64 g/100ml for *A. malabarica, V. negundo and M. koenigii* respectively [57]. *Psychotria prunifolia, Tithonia diversifolia, Senna obtusifolia* and *Adenocalymma nodosum*ethanol extracts exhibited lethal times (LT_{50}) of 89.73, 111.92, 112.24 &122.09 hours respectively when corn grains were treated with 2% of the extract[75]. Garlic (*Allium sativum* L.) juice caused 87-100% mortalityof *S. zeamais*28 dys after treatment[59].

The mortality caused by *Dennetia tripetala* leaf powder ranged from 57.50 to 61.25% after 96 hours[60]. *Jatropha curcas* seed acetone extract caused 90 and 100% mortality of *S. zeamais* in dipping and surface protectant methods respectively[40].*Melia azedarach* supercritical extract gave LC_{50} value of 165.5 µl/ml after 96 hours exposureto maize weevil [61]. The dusts from leaves of *Laurusnobilis*at a dose of 30% w/w caused 86% mortality*S. zeamais*[62]. *Illicium verum* fruit methanol, ethyl acetate and pet-etherextracts caused 69.70-85.43, 76.46-94.50 and 74.17-91.08% mortalityof *S. zeamais* [63]. *Curcuma longa* (L.) rhizome hexane extract caused 13% mortality of maize weevils at 45 µg per insect [64]. *Phytolacca dodecandra* leaves extract at concentrations of 150 to 300 mg/mL caused 100% mortality of *S. zeamais* at 3 days after treatment while the root extract caused 80-81% mortality at concentration range of 250 to 300 mg/mL at 21 days after treatment [65]. *Ocimum basilicum* leafhexane-methanol blend and hexane extractscaused 78.21and 74.36% mortality respectively within 96 hours at 100% concentration [66]. *Haloxylon recurvum* (Khar boti) whole plant ethanolic extract had an LD_{50} value of 16.47µg/insect while that of chlorantraniliprole was 0.0358 µg/ insect after 24 hours of exposure in contact toxicity assay [67]. Methanol and ethyl acetate extractsfrom *Ocimum kilimandscharicum* Guerke leavesexhibited $LC_{50}$of 22.55 and 78.05 µg/mL respectively, against *S. zeamais*[21]. The extracts from the plant also gave LC_{50} of 31.95 and 56.29µg/mL for methanol and ethyl acetate extracts respectively against *P. truncatus* [21].

Extracts from *Leonotis nepaetefolia*, *Passiflora cincinnata* and *Momordica charantia* L. caused 100% mortality;*Schinus terebinthifolius* Raddi and *Mimosa tenuiflora* Willd caused 90% mortality against *S. zeamais* while*Melissa officinalis* L. and *Chenopodium ambrosioides* L. causes 70% mortality of *S. Zeamais*[68]. *Methanolic leaf extracts of Euphorbia balsamifera Aiton, Lawsonia inermis L., Mitracarpus hirtus (L.) DC and Senna obtusifolia L.* caused65-100, 55-100, 67.5-100, 55-100% deaths of *S. zeamais*within 72 hours [69, 70].*Acanthus montanus, Argyreia nervosa* and *Acanthospermum hispidum* powders caused 65.0, 52.5 and 32.5% mortality respectively after 24 hours while *Acanthus montanus* leaf powder caused 100% mortality of weevil 5 days after treatment; *Acanthus montanus*, *Argyreia nervosa* and *Acanthospermum hispidum* leaf extracts caused 80, 67.5 and 50.0% mortality of *S. zeamais* respectively after 24 hours while *Acanthus montanus* leaf extract caused 100% mortality of weevil 2 days after application [12]. *Tephrosia vogelii*, *Hyptissuaveolens* and *Alstonia boonei* leaf ethanol extracts caused42.50-83.21, 25.00-64.89 and 21.50-60.52% mortality of *S. zeamais* respectively [71]. The lethal concentrations (LC_{50}) of *T. vogelii*, *H. suaveolens* and *A. boonei* were 4.85, 5.27 & 7.79 mg/L and 1.94, 4.26 & 3.63 mg/L after 24 and 48 hours respectively [71]. *Eleaodendron schweinfurthianum* extracts caused43.43-73.2% mortality of *S. zeamais.* Ethyl acetate extract exhibited the highest toxicity followed by n-hexane extract[72]. Methanol extracts of *Lantana camara, Moringa oleifera, Citrus sinensis* and *Hyptis suaveolens*caused mortality of 35.2-66.1 and 45.0-61.7% against *S. zeamais* and *P. truncatus* respectively four days after treatment [73]. The mortality levels of the organic extracts of *Warburgia ugandensis* against S. zeamais ranged from 18.3 to 78.0% with n-hexane exhibiting the highest toxicity followed by ethyl acetate extract;hexane and ethyl acetate extracts killed 76 and 71% of *P. truncatus* after exposure for 21 days [15, 74]. *Dimorphandra mollis* extracts were found to be toxic to the weevils[75].Toxicity levels of leaf extracts *Ocimum suave* against *S. zeamais* ranged from 43.5 to 69.4% with n-hexane exhibiting the highest toxicity followed by ethyl acetate extract[76, 77].

IV.

V. Repellent Plant Powders and Extracts

Azadirachta indica, *Lantana camara*,*Cymbopogon citratus*, *Ocimum basilicum* and *Tagetes erecta*repelled*S. zeamais* by 6.43, 6.23, 5.21, 4.98 and 4.88 cm respectively which were comparable to Carbaryl

(7.00 cm)[45]. *Lantana camara* leaf powder exhibited 90% repellence on *S. zeamais* at a dose of 10% (w/w) after 24 hours of exposure [53].*Cupressus arizonica, Eucalyptus grandis, Ocimum gratissimum* and *Vetiveria zizanioides* repelled 68.4, 60.4, 39.6 and 86.8% of maize weevil respectively [78].*Chenopodium ambrosioides, Corymbia citriodora* and *Cucurbita pepo* extracts were tested for repellence activity against *S. zeamais* at doses of 5µl, 10µl, 15µl, 20µl, and 25µl (for the ethereal, ethyl and aqueous extracts) and 0.3 g for powder. For*Chenopodium ambrosioides* extracts, the Preference Index (PI) of the ethereal, ethyl acetate and aqueous extracts varied from -0.18 to -0.41, -0.18 to -0.43 and -0.23 to -0.45 respectively; for *Eucalyptus Citriodora*, the PI of the ethereal, ethyl acetate and aqueous extracts ranged between -0.22 to -0.62, 0.27 to -0.42 and -0.28 to -0.53 respectively while for *Cucurbita pepo* the PI of the ethyl acetate and aqueous extracts varied from -.23 to -0.68 and -0.23 to -0.53 respectively[56]. Repellency of *Illicium verum* against *S. zeamais*were 47.46-57.14, 69.57-86.08 and 65.67-73.24% in methanol, ethyl acetate and pet-ether fruit extracts respectively at a concentration of 125.79 µg/cm[263]. *Phytolacca dodecandra* leaf extract demonstrated a moderate repellence ranging from 15.85% at 50 mg/mL to 57% at 300 mg/mL for *S. zeamais*[65].Hexane extract of*Zingiber cassumunar*(Roxb.) showed 99% repellence against *Sitophilus zeamais* after 8 hours; methanol extract of *Curcuma longa* (L.), showed 87% repellence at concentration of 1,415 µg/cm^2 after 7 hours; hexane, and DCM extracts of *Kaempferia pulchra* (Ridl.) showed 77% repellence at concentration of 786 µg/cm^2 after exposure duration of 4 and 5 hours respectively[64]. Repellence of methanol, hexane and hexane-methanol blend (1:1) extracts from *Ocimum basilicum* ranged between 72-87, 75-90 and 72-97.5% respectively at 5 hours[66]. Dichloromethane and ethyl acetateextracts from *Tithonia diversifolia* repelled 33-96 and 35-92% of *S. zeamais* respectively while *Vernonia lasiopus* dichloromethane and ethyl acetate extractsrepelled 51-91 and 26-81% insects respectively at extract concentrations of 25, 50, 75, and 100%[79].

Warburgia ugandensis hexane, ethyl acetate and methanol extracts exhibited repulsion activity against *S. zeamais* and *P. truncatus*[15, 74, 80]. Extracts from *Elaeodendron schweinfurthianum* exhibited repellence activityagainst maize weevil.Hexane extracts was the most repellent (mean repellency = 4.61cm) followed by ethyl acetate extract (mean repellency = 3.66 cm)[72]. Repellence activity of leaf extracts from *Ocimum suave* was testedagainst maize weevil results were recorded after 24 hours of exposure. The distance moved by the insects away from the center of the tube were 4.3, 3.6, 3.5 and 1.8 cm for n-hexane extract, leaf powder, ethyl acetate extract and methanol extract respectively [76, 77].

VI. Antifeedant Plant Powders and Extracts

Hexane, chloroform and ethyl acetate extracts of stem bark of *Erythrina variegata* L. showed antifeedant activity against *Sitophilus zeamais*[81]**.** Bioassay-directed fractionation of the stem bark extract of the plant resulted in the isolation of two alkaloids, erysopineand erysovine. Erysopine and erysovine possessed antifeedant activity against *S. zeamais* adults with EC_{50} values of 108.5 and 89.7 ppm, respectively[81].Antifeedant activity of n-hexane, ethyl acetate and methanol extracts of *Ocimum kilimandscharicum* Guerke leaves were tested at doses of 100.0, 300.0, 500.0 and 1000.0µg/mL. The MeOH extract exhibited the highest feeding deterrence activity against. *S. zeamais* and *P. truncatus* with an AFI_{50} (concentration that causes 50% feeding deterrence) values of 26.39 and 31.85µg/mL respectively [21]. Leaf methanol extract of *Annona mucosa* Jacq exhibited antifeedant activity against *S. zeamais* and *P. truncatus*[43]. *Phytolacca dodecandra* leaf and root extracts at 150 mg/mL concentration and above deterred *S. zeamais* from damaging maize grains similar to Actellic gold[65]. In repellency test, the proportions of *S. zeamais* in the treated area were significantly reduces to 0.029, 0.096, 0.113, 0.122, 0.156 and 0.252 in treatment with *Croton heliotropiifolius, Senna obtusifolia, Duguetia furfuraceae, Vernonia scopus, Senna occidentalis* and*Magonia pubescens* respectivelycompared to the negative control[82].

VII. Oviposition Deterrent Plant Powders Extracts

The number of eggs laid by *S. zeamais* were reduced by 82.41-95.38, 77.77- 87.97, 58.33-78.72, 51.86-74.08 and 39.83-66.66% with the application of *Datura stramonium* L., *Jatropha curcas* L., *Lantana camara* L., *Cinnamomum camphora* L. and *Moringa oleifera* L. extracts respectively at doses of 0.0, 3.0, 6.0 and 9.0g /100g of maize grains[83].*Carica papaya L.* leaf, stem bark, root and flower powders exhibited anti-oviposition activity at concentrations of 0.5, 1.0, 1.5, 2.0 and 2.5g per 30g of maize grain; the flower powder had the lowest eggs laid (2.4) compared to the negative control which had 24.1laid eggs[51]. *Acanthus montanus, Acanthospermumhispidum*, *Argyreianervosa* and *Alchornealaxiflora* seed powders reduced the number of egg laid by *S. zeamais* to 0.0, 6.0, 1.00 and 3.00 eggs respectively compared to negative control that recorded 42.50 eggs [12]. In *A. montanus, A. hispidum, A. nervosa and A. laxiflora* extracts treated seeds, the numbers of eggs laid was reduced to 0.0, 2.0, 0.0 and 0.0 respectively compared to untreated control that recorded 40 eggs [12].

Application of 8.0 mg/L of ethanol extracts of leaves of *Tephrosia vogelii*, *Hyptis suaveolens*, and *Alstonia boonei* reduced the number of eggs laid by *S. zeamais* to 30.11, 28.11 and 32.33 eggs respectively from 90.31-95.06 eggs laid in the untreated control[71]. *Methanolic leaf extracts of Euphorbia balsamifera Aiton,* *Lawsonia inermis L., Mitracarpus hirtus (L.) DC and Senna obtusifolia L.* caused oviposition deterrence ranging between 58.51 and 94.68%[70]. The number of eggs laid by *P. truncatus* and *S. zeamais* on grains treated with *Lantana camara, Moringa oleifera, Citrus sinensis* and *Hyptis suaveolens* methanol extracts at the rate of 0.05 g/mL and 0.1 g/mL were significantly reduced compared to the untreated control [73].

VIII. Growth Deterrent Plant Powders and Extracts

Petroleum-ether extracts of *Aristolochia ringens, Allium sativum, Garcinia kolaand* and*Ficus exasperate* at1.5% (w/v) concentration reduced the number of emerged *S. zeamais* to 1.00, 9.67, 10.33 and 50.00% compared to 82.67% emergence recorded in the negative control after 7 weeks storage[44]. Ethyl acetate and hexane extracts of *Annona muricata* gave 100% emergence inhibition when *S. zeamais* adults were exposed to 2,500 ppm dosage of the extracts while methanol extract of the plant caused 100% emergence inhibition at a dosage of 5,000 ppm [39]. *Eicchornia crassipes* (Solmn.), *Piper betel* (L.), *Carica papaya* (L.), *Momordica charantia* (L), *Murraya koenigii* (L.) and *Coccinia indica* (Wight and Arn.) extracts caused 97,90, 84, 42,28 and 22% reduction of F1 progeny respectively at a dose of 100 mg/20 g of grains [50]. Dusts from leaves of*Laurus nobilis*, *Nerium oleander* and *Lonchocarpussericeus*at 30% w/w concentration reducedF1 progeny emergence of*S. zeamais*up to57, 68 and 70%, respectively[62]. The methanol suspensions (2% v/v) from*Momordica charantia*, *N. oleander* and *Ptaeroxylon obliquum*reduced the F1 progeny emergence up to 58, 91 and 94% respectively[62].

The emergence inhibition effect of seed and stem bark powders of *Azadirachta indica, Alstonia boonei, Garcina kola* and *Moringa oleifera* on *S. zeamais was tested* on stored wheat grainsat concentrations of 0.0, 2.5, 5.0, 12.5 and 25.0% (w/w) after 42 days[49].*Azadirachta indica* and *A. boonei* powders completely inhibited the development of *S. zeamais*. From seeds treated with *G. kola* powder at 2.5, 5.0, 12.5 and 25.0% w/w concentration, an average of 3, 2, 1 and 0 adult insect emerged respectively while *M. oleifera* powder had an average emergence of 36, 31, 27 and16 insects respectively [49]. *Annona mucosa* hexane, dichloromethane and ethanol leaf, branch and seed extracts were subjected to growth inhibition test against *S.zeamais* at doses of 300 and 1500 mg/kg of maize grains. The numbers of emerged insects were 0.0, 5.6 and 39.1 in grains treated with 1500 mg/kg hexane extracts of seed, leaf and branched respectively compared to 37.0 insects in the negative control experiment. The numbers of emerged insects were 0.10, 19.60 and 22.50 in grains treated dichloromethane extracts of seed, leaf and branched respectively compared to 30.20 insects in the negative control experiment while in grains treated with ethanol extracts of seed, leaf and branched, the numbers of emerged insects were 6.60, 35.70 and 42.40 compared to 37.20 insects in the negative control [41]. The adult emergence inhibition efficacy of hexane, dichloromethane and ethanol extracts from *Annona Montana, Aristolochia paulistana* and *Casearia sylvestris* was assessed against *S. zeamais* at doses of 300 and 1500 mg/kg in maize grains. The numbers of the emerged insects were 0.0 and 0.4 respectively in grains treated with 1500 mg/kg of *Annona montana* dichloromethane and hexane leaf extracts respectively. The numbers of emerged insects were 12.1 and 19.3 in grains treated with dichloromethane *Casearia sylvestris*and hexane *Aristolochia paulistana* branch extracts respectively [42].

Emergence inhibition of ethanol seed extracts of *Azadirachta indica* A. Juss and *Piper guineense* Schum and Thonn at concentrations of 10, 20, 30 and 40 %v/v, was tested against *S. zeamais.* Application of *P. guineense* at 40 %v/v resulted to 1.0% adult emergence while application of *Azadirachta indica* had 2.0% emergence compared to 52.25% adult emergence in negative control. The adult emergence inhibition efficacy of *Azadirachta indica* and *Piper guineense*were comparable to that ofPirimiphos–methylwhich resulted in 0.75% adult emergence [47]. *Dennetia tripetala* leaf powder was evaluated for growth inhibition efficacy against *S. zeamais* as a direct admixture at 0, 5 and 10% dosage levels. The number of emerged insects ranged from 333.4 to 366.0 compared to 602.4 emerged insects in the untreated control[60]. Ethanol seed extracts of *Annona montana*, *Annona mucosa*, *Annona muricata* and *Annona sylvatica*c completely inhabited the emergence of the insects [33]. In grains treated with ethanol leaf extracts from *Annona mucosa, Annona montana, Duguetia lanceolata* and*Annona muricata*, the insects that emerged were 6.1, 8.4, 17.0 and 25.9 respectively compared to 51.4 in the negative control [33]. Methanol, hexane and hexane-methanol blend (1:1) extracts from leaves of *Ocimum basilicum* were evaluated for their adult emergence inhibition activity against *S. zeamais* at 25, 50, 75 and 100% concentrations. High inhibition rate ranging between 86 and 100% were recorded in every treatment [66]. Adult emergence inhibition efficacy of five plant powders, *Cinnamomum camphora* L., *Datura stramonium* L., *Jatropha curcas* L., *Lantana camara* L. and *Moringa oleifera L.* was evaluated against *S. zeamais* at doses of 0.0, 3.0, 6.0 and 9.0g /100g of maize grains. The percent reduction of emerged adult was highest in grains treated with *Datura stramonium* L. (83.22- 97.52%) followed by *Jatropha curcas* L. (78.88-94.40%), *Lantana camara* L. (73.90-91.31%), *Cinnamomum camphora* L. (62.11-75.15%) and *Moringa oleifera L.* (40.36-60.86%)[83].

A laboratory trial was conducted to determine the toxicity of powdered leaves of Siam weed (*Chromolaena odorata*), Wire weed (*Sida acuta*), Gmelina (*Gmelina arborea*) and Spear grass (*Imperata* *cylindrica*) at different dosages (0, 2.5, 5.0 and 7.5g) against *S. zeamais*. Significantly lower mean progeny emergence was recorded in *I. cylindrica* and *S. acuta* (3.0 and 3.5 respectively) compared with *C. odorata* and *G. arborea* (9.3 and 15.0 respectively) in 7.5g/100g grains[84-86]. *Millettia ferruginea* leaf chloroform, n-hexane, ethanol, acetone, methanol and distilled water extracts were tested for repellency against maize weevils and the red flour beetles at dosages of 2.5%, 5% and 10%. Significantly (P <0.05) higher percentage weevils and beetles (>55%) repellency was recorded in all *M. ferruginea* leaf polar solvent extracts applied at rates of 5% and 10%, at 2 days after treatment than nonpolar and partial polar solvent extract. Total repellence (100%) of weevils and beetles was recorded in all *M. ferruginea* leaf polar extract treatments applied at rates of 10%, at 3 days after treatment[87]. Adult emergence inhibition efficacy of leaf powders and extracts of *Acanthus montanus, Acanthospermum hispidum, Alchornea laxiflora and Argyreia nervosa* against *Sitophilus zeamais* were evaluated. There was no sign of progeny development in maize grains treated with A*canthus montanus, Argyreia nervosa* and *Alchornea laxiflora* leaf powders and extracts. However, *Acanthospermum hispidum* powder treated grains had 15.4% adult emergence whichlower than emergence in untreated grains which was 70%[12].

Hyptis suaveolens, *Alstonia boonei* and *Tephrosia vogelii* leaf ethanol extracts were tested for anti-oviposition activity against *S. zeamais* at concentrations of 0.5, 1.0, 2.0, 4.0 and 8.0 mg/L. The numbers of emerged insects were reduced from between 78.12-84.15 in the untreated grains to 6.65, 7.73 and 9.13 insects in grains treated with 8.0 mg/L concentration of *T. vogelii, H. suaveolens* and *A. boonei*[71]. Adult emergence in the grains treated with the leaf powder, n-hexane, ethyl acetate and methanol extracts of *W. ugandensis*was 4.7, 4.0, 15.0 and 21.7%, respectively compared to 40.0% in the negative control [15]. Adult emergences of *P. truncatus* were 15.2, 19.4 and 31.1% in maize grains treated with *n*-hexane, ethyl acetate and methanol extracts respectively[74].

IX. Grain Damage Deterrent Plant Powders and Extracts

Petroleum-ether extracts of *Aristolochia ringens* (Vahl), *Allium sativum* (L), *Ficus exasperata* (L) and *Garcinia kola* (H) were evaluated for grain protection activity against *S. zeamais* at 0.5, 1.0 and 1.5% (w/v) concentrations. The grain damage were *A. ringens* (0.42%), *A. sativum* (2.81%), *G. kola* (4.22%) and *F. exasperata* (21.83%) while the negative control recorded 37.81% grain damage [44]. Methanol suspension (2% v/v) from *Momordica charantia, Neriumoleander* and*Ptaeroxylon obliquum*reduced the number of holes in grains by 75, 91 and 97%, respectively [62]. Grain weight loss prevention efficacy of seed and stem bark powders of *Azadirachta indica, Alstonia boonei, Garcina kola* and *Moringa oleifera was tested* on stored wheat grains against *S. zeamais*at concentrations of 0.0, 2.5, 5.0, 12.5 and 25.0% (w/w). There was neither seed damage nor weight loss recorded in wheat seeds treated with *A. indica* and *A. boonei* powders. Wheat seeds treated with 12.5 and 25.0% of *Garaina kola* powder had 0.4 and 0.0% seed damage respectively while grains treated with 12.5 and 25.0% of *M. oleifera* had 3.0 and 1.7% seed damage respectively[49].

Hexane, dichloromethane and ethanol leaf, branch and seed extracts from *Annona mucosa* were subjected to grain damage prevention assay against *S. zeamais* at doses of 300 and 1500 mg/kg of maize grains[41]. The damage was 0.00, 22.39 and 91.75% in grains treated with 1500 mg/kg hexane extracts of seed, leaf and branched respectively compared to 84.76% in the negative control. The damagewas 1.12, 57.90 and 64.97 in grains treated dichloromethane extracts of seed, leaf and branched compared to 81.74% in the negative control experiment while the damagewas 38.60, 87.16 and 92.24 in grains treated with ethanol extracts of seed, leaf and branched compared to 94.61% in the negative control experiment[41]. Grain damage prevention efficacy of hexane, dichloromethane and ethanol extracts from *Annona Montana, Aristolochia paulistana* and *Casearia sylvestris* was assessed against *S. zeamais* at doses of 300 and 1500 mg/kg in maize grains[42]. The damage was 0.3 and 1.9% in grains treated with *Annona Montana* seeds dichloromethane and hexane extracts respectively at1500 mg/kg dosage[42].Ethanol seed extracts of *Annona Montana*, *Annona mucosa, Annona muricata* and *Annona sylvatica* completely protected maize grains from damage from *Sitophilus zeamais while in grains treated with ethanol leaf* extracts of*Annona mucosa and Annona Montana* the percent grain damage were 13.0, 54.0 and 17.71% compared to 89.97% damage recorded in negative control experiment[33].

Treatment with *Azadirachta indica* seed, *Cymbopogon citrates* leaf, *Chrysanthemum cinerariaefolium* flower, *Dodonae angustifolia* leaf and *Azadirachta indica* leaf powders reduced maize grain damage by *S. zeamais* to 1.67, 2.17, 2.33, 2.67 and3.33 % compared to the untreated control which recorded 12.67% grain damage[46]. Ethanol seed extracts of *Azadirachta indica* A. Juss and *Piper guineense* Schum and Thonn at concentrations of 10, 20, 30 and 40 %v/v, was tested for crop protection against seed damage caused by *S. zeamais*[47]. Application of *P. guineense* at 40 %v/v resulted to 0.73% seed damage while application of *Azadirachta indica* gave 2.22% compared to 33.33% seed damage in negative control. The seed damage protection activity of *Azadirachta indica* and *Piper guineense were comparable to that of* Pirimiphos–methyl which resulted in 0.72% seed damage [47]. Application of *P. guineense* at 40 %v/v resulted to 0.06% maize grain weight loss while application of *Azadirachta indica* gave 1.63% compared to 0.03% weight loss in Pirimiphos-methyl application[47]. *Dennetia tripetala* leaf powder was evaluated for grain weight loss prevention efficacy against *S. zeamais* as a direct admixture at 0, 5 and 10% dosage levels. Weight loss was reduced to 0.88% at a dosage of 10% compared to 7.24% weight loss in the untreated control[60].

Grain weight loss prevention efficacy of*Cinnamomum camphora* L., *Datura stramonium* L., *Jatropha curcas* L., *Lantana camara* L. and *Moringa oleifera L*. powders was testedon*S. zeamais* at doses of 0.0, 3.0, 6.0 and 9.0g /100g of maize grains. The least weight loss was recorded in grains treated with *Datura stramonium* L. (0.70%), followed by *Jatropha curcas* L. (1.03%), *Lantana camara* L. (1.38%), *Cinnamomum camphora* L. (1.92%) and *Moringa oleifera L*. (2.44%) at 9.0g /100g of maize grains compared to untreated control (9.74%)[83].A laboratory trial was conducted to determine the toxicity of powdered leaves of Siam weed (*Chromolaena odorata*), Wire weed (*Sida acuta*), Gmelina (*Gmelina arborea*) and Spear grass (*Imperata cylindrica*) at different dosages (0.0, 2.5, 5.0 and 7.5g) against *S. zeamais*. Significantly lower grain weight loss was recorded in *I. cylindrica* and *S. acuta*, (1.1 and 1.30 g respectively) compared to *C. odorata* and *G. arborea* (2.9 and 4.3 g respectively) in 7.5g/100g grains[84]. *Acanthus montanus*, *Acanthospermum hispidum*, *Argyreia nervosa* and *Alchornea laxiflora* leaf extracts completely prevented infestation and damage of treated maize grains. There was neither seed damage nor weight loss recorded in the treated maize grains and weevil Perforation Index (PI) was zero at day 5after application[12]. Pawpaw powdered plant parts (leaf, stem bark, root and flower) were tested for adult mortality. The flower powder, at concentration of 2.5g/ 30g of maize grains gave the lowest grain damage loss (1.4 %) compared to the 40% weight loss in the control experiment[51].

X. Insecticidal Compounds from plants

Bioassay guided fractionation of plant extracts have led to isolation of some potent insecticidal compounds (Table 2)such as arotenone from *Derris elliptica*, azadirachtin from *Azadirachta indica* and pyrethrin from *Chrysanthemum cinerariifolium* [88-90].Chromatographic fractionation of methanol extract of *Annona mucosa* Jacq leave led to isolation of compounds with promising insecticidal activities against *S. zeamais* and *P. truncatus* identified as quercetin 3-*O*-β-D-glucoside (**1**), quercetin 3-*O*-α-D-arabinoside (**2**) and kaempferol 3-*O*-β-D-galactoside (**3**)[43]. Quercetin-3-*O*-β-D-glucoside (**1**) gave AFI_{50} values of 14.9 and 16.8 µg/mL compared to azadirachtin (AFI_{50} values 12.2 and 12.4 µg/ml) against *S. zeamais* and *P. truncatus*, respectively. Quercetin 3-*O*-α-D-arabinoside **(2)** gave AFI_{50} values of 17.3 and 20.0µg/ml while kaempferol 3-*O*-β-D-galactoside (**3**)gave AFI_{50} values of 21.6 and 20.2 µg/mL against *S. zeamais* and *P. truncatus*, respectively [43]. Quercetin 3-*O*-β-D-glucoside (**1**) was the most toxic to *S. zeamais* and *P. truncatus* with LC_{50} values of 20.9 and 22.2 µg/ml, respectively. Compound **2** exhibited LC_{50} values of 21.7 and 24.9 µg/ml and compound **3** had LC_{50} valuesof 29.3 and 24.2 µg/ml respectively against *S. zeamais* and *P. truncatus* respectively[43].

Insecticidal compounds from *Ocimum kilimandscharicum* were identified as 2α-hydroxy-3-oxodammara-20,24- diene (**4**), 2α,3β-dihydroxy dammara-20, 24-diene (**5**), apeginin7-*O*-neohespeiridoside (**6**), quercetin (**7**), turkesterone (**8**), fesitin (**9**), apeginin (**10**), chrysin (**11**), lupeol (**12**), stigmasterol (**13**), friedelin (**14**), α- amyrin acetate (**15**) and n-octacosonoic acid (**16**)[21]. Turkesterone (**8**) was the most toxic to *S. zeamais* and *P. truncatus* with LC_{50} values of 21.64 and 16.06 µg/mL respectively. Apeginin7-*O*-neohesperidoside (3) gave LC_{50} values of 23.41 and 26.20 µg/mL against *S. zeamais* and *P. truncatus* respectively[21].Turkesterone (**8**) was the most antifeedant with AFI_{50} values of 17.50 and 21.33 µg/ml against *S. zeamais* and *P. truncatus* respectively respectively[21].Pescticidal compounds from*E. schweinfurthianum* were identified to be 3-oxofriedelane **(14)**, 3α-hydroxyfriedelane **(17)**, 3-oxo-29-hydroxyfriedelane **(18)**, 3-oxofriedelan-28-al **(19)**, α-amyrin **(20)**, α-amyrin acetate **(15)**, β-sitosterol **(21)**, stigmasterol **(13)** and lanosterol **(22).** 3-Oxo-29-hydroxyfriedelane (**18**) and 3-Oxofriedelane were the most toxic to the weevils (70.0 and 58.4% respectively) 21 days after treatment[72]. The insecticidal principles from *Warburgia ugandensis*were determined to be polygodial (**23**), warbuganal (**24**), ugandensolide (**25**), ugandensidial (**26**), muzigadial (**27**) and mukaadial (**28**)[15, 74, 80]. *Dimorphandra mollis* extracts were found to be toxic to the weevils and the active compound was determined to be Astilbin (**29**)[75]. Azadirachtin (**30**), nimbolide (**31**) and salannin (**32**) from *Azadirachta indica* (A. Juss) were earlier reported to be the compounds responsible for the insecticidal activity of the plant [45]. *Ocimum suave* extracts were found to exhibit insecticidal properties against maize weevilsand the active compounds were identified to be β-sitosterol **(21)**, stigmsterol **(13)**, β-amyrin **(33)**, lupeol **(12)** and betulinic acid **(34)**[76, 77]. Antifeedantprinciples from*Erythrina variegata* L. against *Sitophilus zeamais* were determined as erysopine (**35**) and erysovine (**36**) having EC_{50} values of 108.5 and 89.7 ppm, respectively[81.]

XI. Conclusion

In this study, reports on 123 plants that have been studied for insecticidal activity against *S. zeamais* and *P. truncatus* were retrieved. It is evident that most studies have focused more on *S. zeamais* compared to than *P. truncatus.*This could be an indication that *S. zeamais* infestation in maize is more common. It is also evident that most studies end after determining the insecticidal properties the crude extracts. Information oncompounds responsible for the insecticidal properties of the plantsis scanty despite the fact that insecticidal compounds from plantsarepreferred because they are considerered to be environmentally safe. Future studies aimed at isolating and characterizing insecticidal compounds from the plants is highly recommended. It is also necessary to develop plant based formulations to be used in controlling the crop insect pests.

Table no 1: Plant extracts with insecticidal activity against maize storage pests

S/no	Plant species	Plant family	Parts used	Activity exhibited	Ref.
1.	Acanthus montanus	Acanthaceae	leaf powders and extracts	Toxicity, oviposition and emergence inhibition	12
2.	*Acorus calamus* L.	Acoraceae	Rhizome ethanol extract	Toxicity	38
3.	*Chenopodium ambrosioides* L.	Amaranthaceae	Aerial part ethereal, ethyl acetate, methanol, aqueous extracts and powder	Toxicity and repellent	56
4.	*Schinus terebinthifolius* Raddi	Anacardiaceae	Leaf methanol extract	Mortality	68
5.	*Sclerocarya birrea* A. Rich	Anacardiaceae	leaf and bark	Mortality	48
6.	*Anaxagorea dolichocarpa* Sprague & Sandwith	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
7.	*Annona acutiflora* Mart.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
8.	*Annona cacans* Warm.	Annonaceae	Leaves, branches, and seeds ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
9.	*Annona dolabripetala* Raddi	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
10.	*Annona emarginata* (Schltdl.) H.Rainer	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
11.	*Annona montana* Macfad.	Annonaceae	branches, leaves, and seeds hexane, dichloromethane and ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33,42
12.	Annona mucosa	Annonaceae	leaf, branch and seed hexane, dichloromethane and ethanol extracts	Toxicity, antifeedant, emergence inhibition and weight loss prevention	33, 41
13.	*Annona muricata* L.	Annonaceae	Leaf, branch, and seed DCM, acetone and ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33, 39, 40
14.	*Annona reticulata* L.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
15.	*Annona* sp	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
16.	*Annona squamosa* L.	Annonaceae	Seed ethanol extract	Toxicity	38
17.	*Annona sylvatica* A.St.-Hil.	Annonaceae	Leaves, branches, and seeds ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
18.	*Dennetia tripetala*	Annonaceae	Leaf powder	Toxicity, *emergence inhibition and weight loss prevention*	60
19.	*Duguetia furfuracea* (A.St.-Hil.) Saff.	Annonaceae	Leaf ethanol extract	Repellence	82
20.	*Duguetia lanceolata* A.St. Hil.	Annonaceae	Leaves, branches, and seeds ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
21.	*Ephedranthus dimerus* J.C.Lopes, Chatrou & Mello-Silva	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
22.	*Guatteria australis* A. St.-Hil.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
23.	*Guatteria ferruginea* A. St.-Hil.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33

24.	*Guatteria sellowiana* Schltdl.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
25.	*Guatteria villosissima* A. St.-Hil.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
26.	*Hornschuchia bryotrophe* Nees	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
27.	*Hornschuchia citriodora* D.M. Johnson	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
28.	*Hornschuchia myrtillus* Nees	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
29.	*Monodora myristica* (Gaerth)	Annonaceae	Seed hexane extract	Toxicity	52
30.	*Oxandra martiana* (Schltdl.) R E. Fr.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
31.	*Porcelia macrocarpa* (Warm.) R.E. Fries	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
32.	*Pseudoxandra spiritus-sancti* Maas	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
33.	*Unonopsis sanctae-teresae* Maas & Westra	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
34.	*Xylopia brasiliensis* Spreng.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
35.	*Xylopia decorticans* D.M. Johnson & Lobão	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
36.	*Xylopia frutescens* Aubl.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
37.	*Xylopia laevigata* (Mart.) R.E. Fr.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
38.	*Ferula assafoetida* L.	Apiaceae	Leaf water extract	Toxicity	3
39.	*Alstonia boonei*	Apocynaceae	Stem bark powder and leaf ethanol extract	Toxicity, anti-oviposition and emergence inhibition	49, 71
40.	*Nerium oleander*	Apocynaceae	Leaf powder, Leaf methanol extract	Adults emerged inhibition	62
41.	Aristolochia paulistana	Aristolochiacea e	Branches hexane, dichloromethane and ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	42
42.	*Aristolochia ringens* (Vahl)	Aristolochiacea e	Petroleum ether extract root bark	Adult mortality, adult emergence inhibition and grain damage prevention	44
43.	Acanthospermum hispidum	Asteraceae	leaf powders and extracts	Toxicity oviposition and emergence inhibition	12
44.	*Chromolaena odorata*	Asteraceae	Powdered leave	Mortality and emergence inhibition	84
45.	*Chrysanthemum cinerariaefolium*	Asteraceae	Flower powder	Toxicity and weight loss prevention	46
46.	*Tagetes erecta*	Asteraceae	Leaf powder	Toxicity, repellent, antioviposition and emergence inhibition	45
47.	*Tithonia diversifolia*	Asteraceae	Flower ethanol extract and leaf DCM and methanol extracts	Toxicity and repellency	75 ,79
48.	*Vernonia lasiopus*	Asteraceae	Leaves	Repellency	79
49.	*Vernonia scabra*	Asteraceae	Leaf ethanol extract	Repellence	82
50.	*Adenocalymma nodosum*	Bignoniaceae	Leaf ethanol extract	Toxicity and repellency	75
51.	*Warburgia ugandensis*	Canellaceae	Leaf hexane, ethyl acetate and methanol extracts	Repellency, Toxicity and emergence inhibition	15, 74, 80
52.	Carica papaya L.	Caricaceae	Leaf acetone extract and powdered leaf, stem bark, root and flower	Toxicity, anti-oviposition, emerged inhibition, grain damage prevention	50, 51
53.	*Elaeodendron schweinfurthianum*	Celastraceae	Stem bark hexane, ethyl acetate and methanol extracts	Repellency, toxicity and emergence inhibition	72

	(Loes)				
54.	*Haloxylon recurvum* (Khar boti)	Chenopodiacea e	Ethanol extract of whole plant	Toxicity	67
55.	Argyreia nervosa	Convolvulaceae	leaf powders and extracts	Toxicity, oviposition and emergence inhibition	12
56.	*Citrullus colocynthis*	Cucurbitaceae	Leaf water extract	Toxicity	3
57.	Coccinia indica (Wight and Arn.)	Cucurbitaceae	Leaf acetone extract	Toxicity and emerged inhibition	50
58.	*Cucurbita pepo*	Cucurbitaceae	Seed ethereal, ethyl acetate, aqueous extracts and powder	Toxicity and repellence	56
59.	*Momordica charantia* L.	Cucurbitaceae	Leaf acetone and methanol extracts	Toxicity and emerged inhibition	62, 68
60.	*Cupressus arizonica*	Cupressaceae	Powdered leaves	Repellent	78
61.	Alchornea laxiflora	Euphorbiaceae	leaf powders and extracts	Toxicity, oviposition and emergence inhibition	12
61.	*Croton heliotropiifolius* Kunth	Euphorbiaceae	leaves and flowers	Repellence	82
63.	*Euphorbia balsamifera Aiton*	Euphorbiaceae	Leaf methanol extract	Toxicity, oviposition deterrence, emergence inhibition and weight loss prevention	69, 70
64.	*Euphorbia lateriflora*	Euphorbiaceae	stem hexane extract	Toxicity	52
65.	*Jatropha curcas*	Euphorbiaceae	Seed acetone extract and leaf powder	Toxicity, oviposition and emergence inhibition	40, 83
66.	*Delonix regia* (Bojer ex Hook.) Raf.	Fabaceae	Seed powder and ethanol extract	Toxicity	55
67.	Dimorphandra mollis	Fabaceae	Flower ethanol extract	Toxicity and repellency	75
68.	*Erythrina variegata*	Fabaceae	Stem bark hexane, chloroform and ethyl acetate extracts	Antifeedant	81
69.	*Lonchocarpus sericeus*	Fabaceae	Leaf powder	Emerged inhibition	62
70.	Millettia ferruginea	Fabaceae	Leaf chloroform, hexane, acetone, ethanol, methanol, and water extracts	Repellency	87
71.	*Mimosa tenuiflora* Willd. Poir.	Fabaceae	Leaf methanol extract	Mortality	68
72.	*Senna obtusifolia*	Fabaceae	Leaf ethanol and methanol extracts	Repellence, toxicity, oviposition deterrence, emergence inhibition and weight loss prevention	69, 70, 75, 82
73.	*Senna occidentalis*	Fabaceae	Leaf ethanol extract	Repellence	82
74.	*Tephrosia vogelii*	Fabaceae	Leaf ethanol extract	Toxicity oviposition and emergence inhibition	71
75.	*Garcina kola* H.	Guttiferae	Seeds pet-ether extract and powder	Toxicity and emergence inhibition and grain damage prevention	44, 49
76.	*Anisomeles malabarica*	Lamiaceae	Leaf hexane extract	Toxicity	57
77.	*Gmelina arborea* Roxb.	Lamiaceae	Powdered leave	Toxicity and emergence inhibition	84
78.	*Hyptis suaveolens*	Lamiaceae	Leaf powder, ethanol and methanol extract	Toxicity, oviposition and emergence inhibition	71, 73
79.	*Leonotis nepaetefolia* R. Br.	Lamiaceae	Leaf methanol extract	Mortality	68
80.	*Melissa officinalis* L.	Lamiaceae	Leaf methanol extract	Mortality	68
81.	*Mentha arvensis*	Lamiaceae	Leaf water extract	Toxicity	3
82.	*Ocimum basilicum* L.	Lamiaceae	Leaf powder, hexane, methanol water extracts	Toxicity, repellent, oviposition and emergence inhibition	3, 45, 66
83.	*Ocimum gratissimum* L.	Lamiaceae	Powdered leaves	Repellent	78
84.	*Ocimum kilimandscharicum* Baker ex Gürke	Lamiaceae	Leaf hexane, ethyl acetate and methanol extracts	Toxicity and antifeedant	21
85.	*Ocimum suave* Willd	Lamiaceae	Leaf hexane, ethyl acetate and methanol extracts	Repellency, toxicity and emergence inhibition	76
86.	*Vitex negundo*	Lamiaceae	Leaf hexane extract	Toxicity	57
87.	Cinnamomum camphora L.	Lauraceae	Leaf powder	Oviposition and emergence inhibition	83
88.	*Laurus nobilis*	Lauraceae	Leaf powder	Toxicity and emerged inhibition	62
89.	*Allium sativum* (L)	Liliaceae	Bulb pet-ether extract and juice	Toxicity, emergence inhibition, grain damage	44, 59

				prevention	
90.	*Tapinanthus bangwensis*	Loranthaceae	Stem bark cyclohexane chloroform and methanol extracts	Toxicity and emergence inhibition	91
91.	*Lawsonia inermis* L.	Lythraceae	Leaf methanol extract	Toxicity, oviposition deterrence, emergence inhibition and weight loss prevention	69, 70
92.	*Sida acuta*	Malvaceae	Leaf powder	Toxicity and emergence inhibition	84
93.	*Azadirachta indica* (A. Juss)	Meliaceae	Seed and leaf powder and water extract	Toxicity, repellent, oviposition, emergence inhibition and grain damage prevention	3, 45, 46, 47, 48, 49
94.	*Melia azedarach*	Meliaceae	Leaf supercritical and ethanol extracts	Toxicity	38, 61
95.	*Peumus boldus* Molina	Monimiaceae	Leaf hexane and ethanol and water extracts	Mortality	54
96.	*Ficus exasperata* (L)	Moraceae	Petroleum ether extract leaves	Adult mortality, adult emergence inhibition, grain damage and weevil peforation index (WPI)	44
97.	*Moringa oleifera* L.	Moringaceae	Seed and leaf powder and methanol extract	Toxicity, oviposition and emergence inhibition	49, 73, 83
98.	*Corymbia citriodora*	Myrtaceae	Leaf ethereal, ethyl acetate, aqueous extracts and powder	toxicity and repellent	56
99.	*Eucalyptus grandis*	Myrtaceae	Powdered leaves	Repellent	78
100.	*Peganum harmala*	Nitrariaceae	Leaf water extract	Toxicity	
101.	*Passiflora cincinnata* Mast	Passifloraceae	Leaf methanol extract	Mortality	68
102.	*Phytolacca dodecandra*	Phytolaccaceae	Leaf and root ethanol extracts	Toxicity, feeding deterrence and grains weight loss	65
103.	Piper betel (L.)	Piperaceae	Leaf acetone extract	Toxicity and emerged inhibition	50
104.	*Piper guineense* (Schum and Thonn)	Piperaceae	Seeds ethanol extract	Toxicity, emergence, grain damage and weight loss	47
105.	*Cymbopogon citratus*	Poaceae	Leaf powder	Toxicity, repellent, oviposition, emergence inhibition and weight loss prevention	45, 46
106.	*Cymbopogon flexousus*	Poaceae	Leaf water extract	Toxicity	3
107.	*Imperata cylindrica*	Poaceae	Powdered leave	Toxicity and emergence inhibition	84
108.	*Vetiveria zizanioides*	Poaceae	Powdered roots	Repellency	78
109.	Eicchornia crassipes (Solmn.)	Pontedeaceae	Leaf acetone extract	Mortality and adults emerged inhibition	50
110.	*Mitracarpus hirtus (L.) DC*	Rubiaceae	Leaf methanol extract	Toxicity, oviposition deterrence, emergence inhibition and weight loss prevention	69, 70
111.	Psychotria prunifolia	Rubiaceae	Leaf ethanol extract	Toxicity and repellency	75
112.	*Citrus sinensis*	Rutaceae	Fruit peel powder and methanol extract	Toxicity and emergence inhibition	
113.	*Murraya koenigii* L.	Rutaceae	Leaf hexane and acetone extracts	Toxicity and emerged inhibition	50, 57
114.	*Ptaeroxylon obliquum*	Rutaceae	Leaf methanol extract	adults emerged inhibition (F1 progeny emergence)	62
115.	Casearia sylvestris	Salicaceae	leaves and branches hexane, dichloromethane and ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	42
116.	*Dodonaea angustifolia*	Sapindaceae	Leaf powder	Toxicity and weight loss prevention	
117.	*Magonia pubescens*	Sapindaceae	Stem ethanol extract	Repellence	82
118.	Illicium verum Hook.f.	Schisandraceae	Fruit pet-ether, ethyl acetate and methanol extracts	Toxicity and repellence	46
119.	Datura stramonium L.	Solanaceae	Leaf powder	oviposition and emergence inhibition	83
120.	*Lantana camara*	Verbenaceae	Leaf powder,ethanol, methanol and ethyl acetate	Repellency, toxicity, oviposition and emergence inhibition	45, 52, 53, 73, 83
121.	*Curcuma longa*	Zingiberaceae	Rhizome hexane, DCM and	Toxicity and repellence	64

			methanol extracts of rhizomes Leaf water extract		
122.	*Kaempferia pulchra* (Ridl.)	Zingiberaceae	Rhizome hexane, DCM and methanol extracts	Toxicity and repellence	64
123.	*Zingiber cassumunar* Roxb.	Zingiberaceae	Rhizome hexane, DCM and methanol extracts	Toxicity and repellence	64

Table no 2: Some insecticidal compounds against maize storage pests

Compound		Ref.	Compound		Ref.
quercetin 3-*O*-β-D-glucoside (**1**)	*Annona mucosa* Jacq	43	3-Oxofriedelan-28-al **(19)**	*Elaeodendron schweinfurthianum*	72
Quercetin 3-*O*-α-darabinoside (**2**)	*Annona mucosa* Jacq	43	α-Amyrin **(20)**	*Elaeodendron schweinfurthianum*	72
Kaempferol 3-*O*-β-D-galactoside (**3**)	*Annona mucosa* Jacq	43	β-Sitosterol **(21)**	*Elaeodendron schweinfurthianum Ocimum suave*	72, 76
2α-Hydroxy-3-oxodammara-20,24- diene (**4**)	*Ocimum kilimandscharicum*	21	Lanosterol **(22)**	*Elaeodendron schweinfurthianum*	72
2α,3β-Dihydroxy dammara-20, 24-diene (**5**)	*Ocimum kilimandscharicum*	21	Polygodial (**23**)	*Warburgia ugandensis*	15, 74
Apeginin7-*O*-neohespeiridoside (**6**)	*Ocimum kilimandscharicum*	21	Warbuganal (**24**)	*Warburgia ugandensis*	15, 74
Quercetin (**7**)	*Ocimum kilimandscharicum*	21	Ugandensolide (**25**)	*Warburgia ugandensis*	15, 74
Turkesterone (**8**)	*Ocimum kilimandscharicum*	21	Ugandensidial (**26**)	*Warburgia ugandensis*	15, 74
Fesitin (**9**)	*Ocimum kilimandscharicum*	21	Muzigadial (**27**)	*Warburgia ugandensis*	15, 74
Apeginin (**10**)	*Ocimum kilimandscharicum*	21	Mukaadial (**28**)	*Warburgia ugandensis*	15, 74
Chrysin (**11**)	*Ocimum kilimandscharicum*	21	Astilbin (**29**)	Dimorphandra mollis	75
Lupeol (**12**)	*Ocimum kilimandscharicum*	21	Azadirachtin (**30**)	*Azadirachta indica*	45
Stigmasterol (**13**)	*Elaeodendron schweinfurthianum*, *Ocimum kilimandscharicum* Baker ex Gürk, *Ocimum suave* Willd	21, 72. 76	Nimbolide and (**31**)	*Azadirachta indica*	45
Friedelin (**14**)	*Elaeodendron schweinfurthianum, Ocimum kilimandscharicum*	21, 72	Salannin (**32**)	*Azadirachta indica*	45
α-Amyrin acetate (**15**)	*Elaeodendron schweinfurthianum*, *Ocimum kilimandscharicum*	21, 72	β-Amyrin (**33**)	*Ocimum suave*	76
n-Octacosonoic acid (**16**)	*Ocimum kilimandscharicum*	21	Betulinic acid (**34**)	*Ocimum suave*	76
3α-Hydroxyfriedelane **(17)**	*Elaeodendron schweinfurthianum*	72	Erysopine (**35**)	*Erythrina variegata* L.	81
3-Oxo-29-hydroxyfriedelane **(18)**	*Elaeodendron schweinfurthianum*	72	Erysovine (**36**)	*Erythrina variegata* L.	81

References

[1]. FAO. What Are the World's Most Important Staple Foods? FAO Production Year Book for 2019.

[2]. FAOSTAT. Food and Agricultural Organization of the United Nation 2014. http://faostat.fao.org/site/291/default.aspx

[3]. Islam T, Iqbal J, Abdullah K, Khan EA. Evaluation of some plant extracts against maize weevil, *Sitophilus zeamais* (coleoptera: curculionidae) under laboratory conditions. Pakistan Journal of Agricultural Sciences 2017; 54(4): 737-741.

[4]. Carrieri F, Raimo F, Pentangelo L.*Fusarium proliferatum* and *Fusarium tricinctum* as causal agents of pink root of onion bulbs and the effect of soil solarization combined with compost amendment in controlling their infections in field. Crop Prot, 2013; 43: 31-37.

[5]. White NDG, Leesch J.G. Chemical control. In: Subramanyam, B., Hagstrum, D.W. (eds) Integrated management of insects in stored products. Marcel Dekker, New York. 1995; pp 287-330.

[6]. El-Wakeil N, Gaafar N, Sallam A, Volkmar C. Side effects of insecticides on natural enemies and possibility of their integration in plant protection strategies. In: Trdan, S. (Ed.), Insecticides- Developments of Safer and More Effective Technologies. Intech press, Croatia. 2013 pp: 3-56.

[7]. Manguro LAO, Opiyo SA, Herdtweck E, Lemmen P. Triterpenes of *Commiphora holtziana* Oleogum resin. Canadian Journal of Chemistry. 2009; 87(8):1173-1179.

[8]. Manguro LOA, Opiyo SA, Asefa A, Dagne E, Muchori WP. Chemical constituents of essential oils from three *Eucalyptus* species acclimatized in Ethiopia and Kenya. Journal of Essential Oil-Bearing Plants 2010a; 13(5): 561-567. https://doi.org/10.1080/0972060X.2010.10643863

[9]. Ochung AA, Manguro LAO, Owuor PO, Jondiko IO, Nyunja RA, Akala H, Mwinzi P, Opiyo SA. Bioactive carbazole alkaloids from *Alysicarpus ovalifolius* (Schumach). Korean Society for Applied Biological Chemistry. 2015; 58(6): 839-846. https://doi.org/10.1007/s13765-015-0100-4.

[10]. Ochung AA, Owuor PO, Manguro LAO, Ishola OI, Nyunja RA, Ochieng CO, Opiyo SA. Analgesics from *Lonchocarpus eriocalyx* Harms. Trends in Phytochemical Research 2018; 2(4): 253-260.

[11]. Jeruto P, Arama P, Anyango B, Nyunja RA, Taracha C, Opiyo SA. Morphometric study of *Senna didymobotrya* (Fresen.) H. S. Irwin and Barneby in Kenya. Journal of Natural Sciences Research 2017; 7 (6):54- 69.

[12]. Ileke KD, Idoko JE, Ojo DO, Adesina BC. Evaluation of botanical powders and extracts from Nigerian plants as protectants of maize grains against maize weevil, *Sitophilus zeamais* (Motschulsky) [Coleoptera: Curculionidae]. Biocatalysis and Agricultural Biotechnology. 2020; 27: 1-10.

[13]. Opiyo SA, Manguro LOA, Okinda-Owuor P, Ateka EM, Lemmen P. 7-alpha Acetylugandensolide and antimicrobial properties of *Warburgia ugandensis* extracts and isolates against sweet potato pathogens. Phytochemistry Letters. 2011a; 4: 161-165. https://doi.org/10.1016/j.phytol.2011.02.007.

[14]. Opiyo SA, Manguro LOA, Owuor PO, Ochieng CO, Ateka EM, Lemmen P. Antimicrobial compounds from *Terminalia brownii* against sweet potato pathogens. Natural Products. 2011b; 1: 116-120. DOI: 10.2174/2210316311101020116.

[15]. Opiyo SA, Manguro LAO, Akinyi D, Ochung AA, Ochieng CO. Biopesticidal extractives and compounds from *Warburgia ugandensis* against maize weevil (*Sitophilus zeamais*). Natural Products. 2015; 5(4): 236-243. DOI: 10.2174/2210315505666150916000539.

[16]. Opiyo SA, Manguro LAO, Owuor PO, Ateka EM. Triterpenes from *Elaeodendron schweinfurthianum* and their antimicrobial activities against crop pathogens. American Journal of Chemistry. 2017; 7(3): 97-104. DOI: 10.5923/j.chemistry.20170703.03.

[17]. Opiyo SA, Njoroge PW, Ndirangu GE, Kuria KM. A review of biological activities and phytochemistry of *Rhus species*. American Journal of Chemistry. 2021a; 11(2): 28-36. DOI: 10.5923/j.chemistry.20211102.02.

[18]. Opiyo SA, Muna KK, Njoroge PW, Ndirangu GE. Analgesic Activity of *Conyza floribunda* Extracts in Swiss Albino Mice. Journal of Natural Sciences Research. 2021b; 12(12): 1-6.

[19]. Ochieng CO, Ishola I, Opiyo SA, Manguro LOA, Owuor PO, Wong KC. Phytoecdysteroids from the stem bark of *Vitex doniana* and their anti-inflammatory effects. Planta Medica. 2013 79, 52-59. DOI: 10.1055/s-0032-1327880.

[20]. Ochieng CO, Opiyo SA, Mureka EW, Ishola IO. Cyclooxygenase inhibitory compounds from *Gymnosporia heterophylla* aerial parts. Fitoterapia. 2017; 119: 168-174. DOI: 10.1016/j.fitote.2017.04.015.

[21]. Makenzi AM, Manguro LAO, Owuor PO, Opiyo SA. Chemical constituents of *Ocimum Kilimandscharicum* Guerke acclimatized in Kakamega Forest, Kenya. Bulletin of the Chemical Society of Ethiopia. 2019a; 33(3): 527-539. DOI: https://dx.doi.org/10.4314/bcse.v33i3.13.

[22]. Njoroge PW, Opiyo SA. Antimicrobial activity of root bark extracts of *Rhus natalensis* and *Rhus ruspolii*. Basic Sciences of Medicine. 2019a; 8(2): 23-28. Doi: 10.5923/j.medicine.20190802.01.

[23]. Njoroge PW, Opiyo SA. Some antibacterial and antifungal compounds from root bark of *Rhus natalensis.* American Journal of Chemistry. 2019b; 9(5): 150-158. Doi: 10.5923/j.chemistry.20190905.03.

[24]. Kuria KM,Opiyo SA. Characterization of immunogenic soluble crude proteins from *Biomphalaria Pfeifferi* against *Schistosoma mansoni*. Journal of Natural Sciences Research.2020;10(12): 28-34. DOI:10.7176/JNSR/10-12-03.

[25]. Opiyo SA, Ogur JA, Manguro LOA, Itietze LF, Schuster H. A new sterol diglycoside from *Conyza floribunda*. South African Journal of Chemistry. 2009; 62: 163-167.

[26]. Opiyo SA, Manguro LOA, Ogur JA, Wagai SO. Bioactive constituents of *Conyza floribunda*. Research Journal of Pharmacology. 2010; 4(3): 55-59.

[27]. Ndirangu EG, Opiyo SA, Ng'ang'a MW. Chemical composition and repellency of *Nigella sativa* L. seed essential oil against *Anopheles gambiae* sensu stricto. Trends in Phytochemical Research. 2020a; 4(2): 77- 84.

[28]. Ndirangu EG, Opiyo SA, Ng'ang'a MW. Repellent Properties of Compounds and Blends from Nigella sativa Seeds against Anopheles gambiae. Basic Sciences of Medicine. 2020b; 9(1): 1-7.

[29]. Siegwart M, Graillot B, Lopez CB, Besse S, Bardin M, Nicot PC, Lopez-Ferber M. Resistance to bioinsecticides or how to enhance their sustainability: A review. Front. Plant Sci. 2015; 6: 381-388.

[30]. Manguro LAO, Ogur J, Opiyo S. Antimicrobial constituents of *Conyza floribunda*. Webmed Central Pharmacology. 2010b; 1(9): WMC00842.

[31]. Opiyo SA. Evaluation of efficacy of selected plant extracts in the management of fungal and bacterial diseases which affect sweet potato. Unpublished PhD thesis, Maseno University, Kenya 2011.

[32]. Opiyo SA. A review of ^{13}C NMR spectra of drimane sesquiterpenes, Trends in Phytochemical Research. 2019; 3(3): 147-180.

[33]. Ribeiro LP, Vendramim JD, Gonçalves GLP, Ansante TF, Gloria EM, Lopes JC, Mello-Silva R, Fernandes JB. Searching for promising sources of grain protectors in extracts from Neotropical Annonaceae. Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas. 2016; 15(4): 215-232.

[34]. Soujanya PL, Sekhar JC, Kumar P, Sunil N, Prasad CV, Mallavadhani UV.Potentiality of botanical agents for the management of postharvest insects of maize: a review. J Food Sci Technol. 2016; 53(5): 2169-2184.

[35]. Banken JAO, Stark JD. Stage and age influence on the susceptibility of *Coccinella septempunctata* L. (Coleoptera: Cocinellidae) after direct exposure to the neem insecticide, Neemix. Journal of Economic Entomology. 1997; 90: 1102-1105.

[36]. Rajashekar Y, Raghavendra A, Bakthavatsalam N. Acetylcholinesterase inhibition by biofumigant (Coumaran) from leaves of *Lantana camara* in stored grain and household insect pests. Bio Med Research International. 2014; Article ID 187019:6.

[37]. Owokotomo IA, Ekundayo OE, Abayomi TG, Chukwuka AV. Invitro anti- cholinesterase activity of essential oil from four tropical medicinal plants. Toxicol Rep. 2015; 2: 850-857.

[38]. Wongtong S, Nawanich S. Some Insecticidal Plant Extracts for controlling maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). Kasetsart Journal Natural Science. 2001; 35: 259-270.

[39]. Hincapié LCA, Lopera AD,Ceballos GM. Actividad insecticida de extractos de semilla de *Annonamuricata* (Anonaceae) sobre *Sitophilus zeamais* (Coleoptera: Curculionidae). Revista Colombiana de Entomología. 2008; 34: 76-82.

[40]. Asmanizar AD, Idris AB. Evaluation of *Jatropha curcas* and *Annona muricata* seed crude extracts against *Sitophilus zeamais* infesting stored rice. J. Entomol. 2012; 9(1): 13-22.

[41]. Ribeiro LP, Vendramim JD, Bicalho KU, Santos Andrade M, Fernandes JB, Moral RA, Demétrio CGB. *Annona mucosa* Jacq. (Annonaceae): a promising source of bioactive compounds against *Sitophiluszeamais* Mots. (Coleoptera: Curculionidae). Journal of Stored Products Research. 2013; 55: 6-14.

[42]. Ribeiro LP, Vendramim JD, Andrade MS, Bicalho KU, Silva MFGF, Vieira PC, Fernandes JB. Tropical Plant Extracts as Sources of Grain-Protectant Compounds against *Sitophilus* zeamais Motschulsky (Coleoptera: Curculionidae). Neotrop Entomol. 2014; DOI: 10.1007/s13744-014-0233-x.

[43]. Makenzi AM, Manguro LOA, Owuor PO, Opiyo SA. Flavonol glycosides with insecticidal activity from methanol extract of *Annona mucosa* Jacq. leave. Trends in Phytochemical Research. 2019b; 3(4): 287-296.

[44]. Arannilewa ST, Ekrakene T,Akinneye JO. Laboratory evaluation of fourmedicinal plants as protectants against the maize weevil, *Sitophilus zeamais* (Mots). African Journal of Biotechnology. 2006; 5(21): 2032-2036.

[45]. Parugrug ML, Roxas AC. Insecticidal action of five plants against maize weevil, *Sitophiluszeamais* Motsch (Coleoptera:Curculionidae). KMITL Sci. Tech. 2008; 8: 24-38.
[46]. Shiberu T, Negeri M. Determination of the appropriate doses of promising botanical powders against maize weevil, *Sitophilus zeamais* Mots (Coleoptera: Curculionidae) on maize grain. Journal of Stored Products and Postharvest Research. 2014;8(4): 49-53.
[47]. Akinbuluma MD, Ewete FK. Comparative efficacy of extracts from *Azadirachta indica*, *Piper guineense* and pirimiphos-methyl against *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) in stored maize.Journal of Biology, Agriculture and Healthcare. 2014; 4(27): 327-334.
[48]. Babarinde SA, Petinrin MO, Adeleye AD, Ajani BS. Toxicity of *Sclerocarya birrea* and *Azadirachta indica* extracts against maize weevil *Sitophilus zeamais* Motchulsky (Coleoptera: Curculionidae) in storage. Bangladesh J. Sci. Ind. Res.2017; 52(4): 337-342.
[49]. Ileke KD, Oni MO. Toxicity of some plant powders to maize weevil, *Sitophilus zeamais* (motschulsky) [Coleoptera: Curculiondae] on stored wheat grains (*Triticum aestivum*). Afr. J. Agric. Res. 2011; 6: 3043-3048.
[50]. Chakradhar D, Ajay N, Nagaraju K. Laboratory evaluation of grain protectant efficacy of different foliar extracts against maize weevil - *Sitophiluszeamais* (Motschulsky), Archives of Phytopathology and Plant Protection. 2010; 43: 18.
[51]. Adenekan MO, Adejumo AOD, Akande OK. Evaluation of pawpaw plant extracts against*Sitophilus zeamais* (Mots) (Coleoptera: Curculionidae) on maize seeds.Journal of Multidisciplinary Engineering Science Studies. 2020; 6(5): 3186-3192.
[52]. Ogunsina OO, Oladimeji MO, Lajide L. Insecticidal action of hexane extracts of three plantsagainst bean weevil, *Callosobruchus maculatus* (F.) and maize weevil, *Sitophilus zeamais* motsch. Journal of Ecology and the Natural Environment. 2011; 3(1): 23-28.
[53]. Ayalew AA. Insecticidal activity of *Lantana camara* extracts oil on controlling maize grain weevils. Toxicology Research and Application. 2020; 4: 1-10.
[54]. Ortiz UMG, Silva AM, Tapia VJC, Rodriguez MA, Lagunes TC, Santillán-Ortega A, BermúdezR, Aguilar-Medel S. Toxicity of Boldo *Peumus boldus* Molina for *Sitophilus zeamais* Motschulsky and *Tribolium castaneum* Herbst. *Chilean* J. Agric. Res.2012;72: 345-349
[55]. Ajayi OE.Insecticidal activity of powder and extracts of *Delonix regia* seed against maize weevil, *Sitophilus zeamais* (Coleoptera: Curculionidae). FUTA Journal of Research in Sciences. 2013; 2013(1) 54-62.
[56]. Mazzonetto F, Corbani RZ, Dalri AB. Biofumigation of plant species on *Sitophilus zeamais* in stored maize. Appl Res Agrotecnol. 2013; 6: 53-61.
[57]. Radha R. Toxicity of three plant extracts against bean weevil, *Callosobruchus maculatus* (F.) and maize weevil, *Sitophilus zeamais* motsch. International Journal of Current Research. 2014;6(4): 6105-6109.
[58]. Tavares WS, Grazziotti GH, Souza Junior AA, Freitas SS, Consolaro HN, Ribeiro PEA, Zanuncio JC. Screening of extracts of leaves and stems of Psychotria spp. (Rubiaceae) against Sitophilus zeamais (Coleoptera: Curculionidae) and Spodoptera frugiperda (Lepidoptera: Noctuidae) for maize protection. J. Food Prot. 2013; 76(11):1892-19.
[59]. Nwachukwu ID, AsawalamEF. Laboratory evaluation of freshly prepared juice fromgarlic (*Allium sativum L.*) Liliaceae as protectantsagainst the maize weevil, *Sitophilus zeamais* (Motsch.)[Coleoptera: Curculionidae]. African Journal of Biotechnology. 2014;13(10): 1123-1130.
[60]. Udo IO. Laboratory evaluation of pepper fruit (*Dennetia tripetala*) against maize weevil (*Sitophilus zeamais*) on stored maize grains. Swift Journal of Agricultural Research. 2015; 1(6): 67-69.
[61]. Teixeira CM, Scapinello J, Magro JD, Garcia FRM. Effects of supercritical extract of *Melia azedarach (Meliaceae)* on the control of *Sitophilus zeamais Motschulsky*, 1855 (Coleoptera, Curculionidae).Revista de Ciências Agroveterinárias. 2019; 18(2): 275-280.
[62]. Conceição C, Barbosa A, Matos O, Mexia A. Potential of plant products as protectants of stored maize against *Sitophilus zeamais* Motschulsky (Coleoptera:Curculionidae). 10th International Working Conference on Stored Product Protection. Julius-Kühn-Archiv. 2010; 425: 615-621.
[63]. Wei LL, Hua RM, Li MY, Huang YZ, Li SG, He YJ, Shen ZH. Chemical composition and biological activity of star anise *Illicium verum* extracts against maize weevil, *Sitophilus zeamais* adults. Journal of Insect Science. 2014; 14(80): 1-13.
[64]. Aryani DS, Auamcharoen E. Repellency and contact toxicity of crude extracts from three Thai plants (Zingiberaceae) against maize grain weevil, *Sitophilus zeamais* (Motschlusky) (Coleoptera: Curculionidae). Journal of Biopesticides. 2016; 9(1): 52-62.
[65]. Qwarse M, Mihale MJ, Henry L, SempombeJ, Mugoyela V, Sung'hwa F. Pesticidal activity of *Phytolacca dodecandra* extracts against *Sitophilus zeamais* (*Motschulsky) (Curculionidae*) and *Tribolium castaneum* (Tenebrionidae) Storage Pests in Maize. Journal of Food Security. 2016; 4(6): 147-155.
[66]. Ouko RO, Koech SC, Arika WM, Njagi SM, Oduor RO, Ngugi MP. Bioefficacy of organic extracts of *Ocimum basilicum* against *Sitophilus zeamais*. Entomol Ornithol Herpetol. 2017; 6: 1-7.
[67]. Ahmed Z, Khan MF, Rana H. Toxicological effects of *Haloxylon recurvum* Bunge ex Boiss (Khar Boti) whole plant extract and novel insecticide chlorantraniliprole against maize weevil, *Sitophilus zeamais* Motschulsky. Punjab Univ. J. Zool.2017;32(2): 159-166.
[68]. Dias GG, Oliveira VLF, Soares TNA, Lorenzo VP, Lima MAG,Santos CAB. Insecticide activity of plant extracts of the northeastern Brazilian flora for the control of *Sitophilus zeamais* [Mots, 1885] and *Sitotrogacerealela* [Olivier, 1819]. International Journal for Innovation Education and Research. 2019;7(8): 47-62.
[69]. Suleiman M, Sani I. Insecticidal activity of ethanolic leaf extracts against the maize weevil, *Sitophilus zeamais* Motsch (Coleoptera: Curculionidae). Archiv Zool Stud. 2018; 1: 004.
[70]. Suleiman M. Biological Activity of Organic Leaf Extracts against the Maize Weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae). Journal of Zoological Research. 2019;3(3): 18-24.
[71]. Negbenebor HE, Nura S. Bioefficacy of some plants ethanolic extracts against maize weevil (*Sitophilus zeamais*) infestation of stored maize grains.Ife Journal of Science. 2020;22(2): 125-133.
[72]. Opiyo SA. Evaluation of Warburgia ugandensis extracts and compounds for crop protection against Prostephanus truncates. Advances in Analytical Chemistry. 2020b; 10(2): 15-19. DOI: 10.5923/j.aac.20201002.01.
[73]. GaribaSY, Dzidzienyo DK, Eziah VY. Assessment of four plant extracts as maize seed protectants against *Sitophilus zeamais* and *Prostephanustruncatus* in Ghana, Cogent Food & Agriculture. 2021; 7: 1-16.
[74]. Opiyo SA. Insecticidal activity of *Ocimum Suave* Willd extracts and compounds against *Sitophilus Zeamais* Motschulsky. Basic Sciences of Medicine, 2020a; 9(2): 32-37. DOI: 10.5923/j.medicine.20200902.03.
[75]. Tavares WS, Faroni LRD, Ribeiro RC, Fouad HA, Freitas SS, Zanuncio JC. Effects of astilbin from *Dimorphandra mollis* (Fabaceae) flowers and Brazilian plant extracts on *Sitophilus zeamais* (Coleoptera: Curculionidae). Fla Entomol. 2014; 97(3): 892-901.
[76]. Opiyo SA. Insecticidal activity of *Elaeodendron schweinfurthianum* extracts and compounds against *Sitophilus zeamais* Motschulsky. American Journal of Chemistry 2020c; 10(3): 39-44. Doi: 10.5923/j.chemistry.20201003.01.

[77]. Opiyo SA. Insecticidal Drimane Sesquiterpenes from *Warburgia ugandensis* against Maize Pests American Journal of Chemistry. 2021b; 11(4): 59-65.

[78]. Akob CA, Ewete FK. Control of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) with local plant materials in the western highlands of Cameroon. Journal ofThe Cameroon Academy Of Sciences. 2010;9 (1): 3-10.

[79]. Gitahi SM, Piero MN, Mburu DN,Machocho AK. Repellent Effects of Selected Organic Leaf Extracts of *Tithonia diversifolia* (Hemsl.) A. Gray and *Vernonia lasiopus* (O. Hoffman) against *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). Scientific World Journal. 2021; 2021: 1-13.

[80]. Opiyo SA. Repellent effects of *Ocimum suave* extracts and compounds against *Prostephanus truncatus* horn. American Journal of Chemistry. 2021a; 11(2): 23-27, DOI: 10.5923/j.chemistry.20211102.01.

[81]. Liu ZL, Chu SS, Jiang GH, Liu SL. Antifeedants from Chinese medicinal herb, Erythrina variegata var. orientalis, against maize weevil Sitophilus zeamais. Nat Prod Commun. 2012; 7:171–172.

[82]. Silva LB, Silva JC, Pavan BE, Pereira FF, Maggioni K, Andrade LH, Candido ACS,Peres MTLP. Insecticide irritability of plant extracts against *Sitophilus zeamais* African Journal of Agricultural Research. 2013; 8: 978-983.

[83]. Mahmoud MA, Zedan AA. Essaying some plant powders against maize weevil, *Sitophilus zeamais* (Motsch.), for protecting maize grains from damage. J. Plant Prot. and Path., Mansoura Univ. 2018; 9(11): 729-734.

[84]. Ehisianya CN, Ikpi PO, Okore OO, Obeagu IA. Assessment of plant powders as protectants of stored maize grains against maize weevil, Sitophilus zeamais (motsch). [coleoptera: curculionidae]. Nigerian Agricultural Journal. 2019; 50(1): 38-45.

[85]. Opiyo SA, Owuor PO, Manguro LOA, Ateka E, Miano DW. Development of a PCR technique for simultaneous detection of sweet potato chlorotic stunt virus and sweet potato feathery mottle. Journal ofPlant Pathology. 2010b;92(2): 353-356.

[86]. Opiyo SA, Owuor PO, Manguro LOA, Ateka EM, Karuri HW. Survey of sweet potato viruses and detection of cucumber mosaic virus in western Kenya. Journal of Plant Pathology. 2010c;92(3): 795-799.

[87]. Hiruy B, Getu E. Militia feruginaea solvent extracts on maize weevils and red flour beetles repellency; an implication to use them in storage pest management in Ethiopia, Cogent Food & Agriculture. 2020; 6:1, 1860562, DOI: 10.1080/23311932.2020.1860562.

[88]. Sae-Yun A, Ovatlarnporn C, Itharat A, Wiwattanapatapee R. Extraction of rotenone from *Derris elliptica* and *Derris malaccensis* by pressurized liquid extraction compared with maceration. J Chromatogr. 2006; 1125: 172-176.

[89]. Barceloux DG. Medical toxicology of natural substances: foods, fungi, medicinal herbs, plants and venomous animals. Wiley. 2008; ISBN: 978-0-471-72761-3.

[90]. Shawkat MS, Khazaal AQ, Majeed MR. Extraction of pyrethrins from *Chrysanthemum cinerariaefolium* petals and study on its activity against flour beetle *Tribolium castaneum*. Iraqi J Sci. 2011; 52: 456-463.

[91]. Diouf EHG, Diop M, Sène A,Samb A. Phytochemical Screening and Insecticidal Activity of Three Extracts of *Tapinanthus bangwensis* (Engl. & Krause) on *Sitophilus zeamais* (Maize Weevil). *Open Access Library Journal*. 2016 3: e2962.

Sylvia A. Opiyo. "A Review of Insecticidal Plant Extractsand Compoundsfor Stored Maize Protection."*IOSR Journal of Applied Chemistry (IOSR-JAC)*, 14(10), (2021): pp 23-37.