

A Review of Insecticidal Plant Extracts and Compounds for Stored Maize Protection

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Abstract

Insect pests cause significant losses to maize grains both in the fields and 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 compounds 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 insecticidal 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 alternatives in controlling the crop storage pests.

Keywords: Post harvest pests; Maize pests; *Sitophilus zeamais*; *Prostephanus truncatus*; Plant extracts; insecticidal compounds

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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 rice¹. 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 waste because of inadequate storage structures and insect pest attack. Maize weevil (*Sitophilus zeamais* Motschulsky) 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 time³. In addition, infestation of the insects results in development of *Aspergillus* which is carcinogenic⁴. 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 environmental⁶. There is urgent need to develop safe alternatives that are readily available, convenient to use and environmentally friendly. Plants produce secondary metabolites that are used in defense against different pests and pathogenic microorganism⁷⁻¹⁸. The use of botanicals for pests and disease control is preferred because they are safe and non-toxic to humans¹⁹⁻²⁸. In addition, chances of pests and pathogens developing resistance to botanical pesticides are highly unlikely²⁹.

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 quinones³⁰⁻³². 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 inhibition activities against maize weevil (*Sitophilus zeamais* Motschulsky) 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 activity³⁵. The extracts also inhibit acetylcholine esterase (AChE), prothoracicotrophic 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 (LC₅₀) values were determined to be 11.73 and 32.34% for *A. calamus* and *A. squamosa* respectively³⁸. *Annona muricata* seed hexane extracts had LC₅₀ 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 LC₅₀ values of 3,280, 2,667 and 2,542 ppm respectively against *S. zeamais*³⁹. The LC₅₀ of the hexane extract in the topical application was 9,368 ppm at 72 hours³⁹. *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 respectively⁴⁰. 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/kg³³. 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 respectively³³. The extract prepared from *Annona mucosa* (seeds), *Annona muricata* (seeds), *Annona Montana* (seeds) *Annona montana* (leaves) and *Annona mucosa* (leaves) demonstrated LC₅₀ values of 288.33, 384.94, 621.70, 1,851.00 and 1,972.00 mg/kg respectively against maize weevil³³. *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/kg⁴¹. *Annona mucosa* seeds, leaves and branches dichloromethane extracts caused 100, 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. zeamais* respectively⁴¹. 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% mortality at a dosage of 1.5 mg/kg of grains⁴². Methanol extract of *Annona mucosa* Jacq leaf 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% respectively⁴⁵. *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 powdered *Azadirachta indica* seeds, *Cymbopogon citratus* leaves and *Dodonaea angustifolia* leaves caused 95.55, 62.22 and 31.78% mortality respectively at a dosage of 5g/100g of after 28 days⁴⁶. Application of 40% v/v *Piper guineense* caused 100% mortality of *S. zeamais* while application of *Azadirachta indica* gave 52.5% mortality after 96 hours⁴⁷. *Sclerocarya birrea* leaf and bark extracts caused 97.50 and 91.25% mortality while *Azadirachta indica* leaf extract caused 92.50% mortality at extract concentration of 0.45 ml/33 cm² after 5 days⁴⁸. The percent mortalities caused by leaf 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 flexuosus* (58.33) and *Mentha arvensis* (53.33) at 15% concentration after 6 days of exposure period³. *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 *Garcinia kola* powder caused 100% deaths after 96 hours⁴⁹. *Moringa oleifera* extract caused 59.4% deaths at a dose of 25.0% after 96 hours⁴⁹. *Murrayakoenigii*, *Eichhornia 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 assay⁵⁰. 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 grains⁵⁰. *Carica papaya* flower powder at a dose of 2.5g/30g of maize grains caused 100% mortality of weevils⁵¹.

Monodora myristica seeds, *Lantana camara* leaves and *Euphorbia lateriflora* stem hexane extracts caused 96, 73.3 and 50% mortalities of *S. zeamais* respectively after 24 hours exposure⁵². The LD₅₀ values recorded were 1.48, 6.96 and 9.62 g/100 in grains treated with *M. myristica*, *L. camara* and *E. lateriflora* extracts respectively⁵². *Lantana camara* leaves methanol extract caused 74% 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 h⁵⁴. 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 grains⁵⁵. *Delonix regia* oil caused 100% mortality at 120 hours post-treatment at all concentrations⁵⁵. *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 25 µl⁵⁶. *Anisomeles malabarica*, *Vitex negundo* and *Murraya koenigii* hexane leaf extracts caused 47.7- 96.2, 10.9-74.6 and 10.4-54.1% mortality respectively against *S. zeamais* after 24 hours⁵⁷. The extracts recorded LD₅₀ values of 1.44, 6.90 and 9.64 g/100ml for *A. malabarica*, *V. negundo* and *M. koenigii* respectively⁵⁷. *Psychotria prunifolia*, *Tithonia diversifolia*, *Senna obtusifolia* and *Adenocalymma nodosum* methanol extracts exhibited lethal times (LT₅₀) of 89.73, 111.92, 112.24 & 122.09 hours respectively when corn grains were treated with 2% of the extract⁷⁵. Garlic (*Allium sativum* L.) juice caused 87-100% mortality of *S. zeamais* 28 days after treatment⁵⁹.

The mortality caused by *Denntia tripetala* leaf powder ranged from 57.50 to 61.25% after 96 hours⁶⁰. *Jatropha curcas* seed acetone extract caused 90 and 100% mortality of *S. zeamais* in dipping and surface protectant methods respectively⁴⁰. *Melia azedarach* supercritical extract gave LC₅₀ value of 165.5 µl/ml after 96 hours exposure to maize weevil⁶¹. The dusts from leaves of *Laurus nobilis* at a dose of 30% w/w caused 86% mortality *S. zeamais*⁶². *Illicium verum* fruit methanol, ethyl acetate and pet-ether extracts caused 69.70-85.43, 76.46-94.50 and 74.17-91.08% mortality of *S. zeamais*⁶³. *Curcuma longa* (L.) rhizome hexane extract caused 13% mortality of maize weevils at 45 µg per insect⁶⁴. *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 treatment⁶⁵. *Ocimum basilicum* leaf hexane-methanol blend and hexane extracts caused 78.21 and 74.36% mortality respectively within 96 hours at 100% concentration⁶⁶. *Haloxylon recurvum* (Khar boti) whole plant ethanolic extract had an LD₅₀ value of 16.47 µg/insect while that of chlorantraniliprole was 0.0358 µg/ insect after 24 hours of exposure in contact toxicity assay⁶⁷. Methanol and ethyl acetate extracts from *Ocimum kilimandscharicum* Guerke leaves exhibited LC₅₀ of 22.55 and 78.05 µg/mL respectively, against *S. zeamais*²¹. The extracts from the plant also gave LC₅₀ of 31.95 and 56.29 µg/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. caused 65-100, 55-100, 67.5-100, 55-100% deaths of *S. zeamais* within 72 hours⁶⁹. *Acanthus montanus*, *Argyrea 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*, *Argyrea 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 application¹². *Tephrosia vogelii*, *Hyptissuaveolens* and *Alstonia boonei* leaf ethanol extracts caused 42.50-83.21, 25.00-64.89 and 21.50-60.52% mortality of *S. zeamais* respectively⁷¹. The lethal concentrations (LC₅₀) 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 respectively⁷¹. *Eleaodendron schweinfurthianum* extracts caused 43.43-73.2% mortality of *S. zeamais*. Ethyl acetate extract exhibited the highest toxicity followed by n-hexane extract⁷². 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 treatment⁷³. 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 weevils⁷⁵. 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 exposure⁵³. *Cupressus arizonica*, *Eucalyptus grandis*, *Ocimum gratissimum* and *Vetiveria zizanioides* repelled 68.4, 60.4, 39.6 and 86.8% of maize weevil respectively⁷⁸. *Chenopodium ambrosioides*, *Corymbia citriodora* and *Cucurbita pepo* extracts were tested for repellence activity against *S. zeamais* at doses of 5 μ l, 10 μ l, 15 μ l, 20 μ l, and 25 μ l (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 -0.23 to -0.68 and -0.23 to -0.53 respectively⁵⁶. 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 μ g/cm²⁶³. *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 μ g/cm² after 7 hours; hexane, and DCM extracts of *Kaempferia pulchra* (Ridl.) showed 77% repellence at concentration of 786 μ g/cm² after exposure duration of 4 and 5 hours respectively⁶⁴. 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 hours⁶⁶. Dichloromethane and ethyl acetate extracts from *Tithonia diversifolia* repelled 33-96 and 35-92% of *S. zeamais* respectively while *Vernonia lasioporus* dichloromethane and ethyl acetate extracts repelled 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 activity against maize weevil. Hexane extracts was the most repellent (mean repellency = 4.61 cm) followed by ethyl acetate extract (mean repellency = 3.66 cm)⁷². Repellence activity of leaf extracts from *Ocimum suave* was tested against 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, erysopine and erysovine. Erysopine and erysovine possessed antifeedant activity against *S. zeamais* adults with EC₅₀ values of 108.5 and 89.7 ppm, respectively⁸¹. 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 1000.0 μ g/mL. The MeOH extract exhibited the highest feeding deterrence activity against *S. zeamais* and *P. truncatus* with an AFI₅₀ (concentration that causes 50% feeding deterrence) values of 26.39 and 31.85 μ g/mL respectively²¹. 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 gold⁶⁵. In repellency test, the proportions of *S. zeamais* in the treated area were significantly reduced 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* respectively compared to the negative control⁸².

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 grains⁸³. *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 24.1 laid eggs⁵¹. *Acanthus montanus*, *Acanthospermum hispidum*, *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 eggs¹². 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 eggs¹².

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 control⁷¹. 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 control⁷³.

VIII. Growth Deterrent Plant Powders and Extracts

Petroleum-ether extracts of *Aristolochia ringens*, *Allium sativum*, *Garcinia kola* and *Ficus exasperate* at 1.5% (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 storage⁴⁴. 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 ppm³⁹. *Eichhornia 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 grains⁵⁰. Dusts from leaves of *Laurus nobilis*, *Nerium oleander* and *Lonchocarpus sericeus* at 30% w/w concentration reduced F1 progeny emergence of *S. zeamais* up to 57, 68 and 70%, respectively⁶². 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% respectively⁶².

The emergence inhibition effect of seed and stem bark powders of *Azadirachta indica*, *Alstonia boonei*, *Garcinia kola* and *Moringa oleifera* on *S. zeamais* was tested on stored wheat grains at concentrations of 0.0, 2.5, 5.0, 12.5 and 25.0% (w/w) after 42 days⁴⁹. *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 and 16 insects respectively⁴⁹. *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 control⁴¹. 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 respectively⁴².

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 of Pirimiphos-methyl which resulted in 0.75% adult emergence⁴⁷. *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 control⁶⁰. Ethanol seed extracts of *Annona montana*, *Annona mucosa*, *Annona muricata* and *Annona sylvaticac* completely inhibited the emergence of the insects³³. 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 control³³. 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 treatment⁶⁶. 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 grains⁸⁴⁻⁸⁶. *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 treatment⁸⁷. Adult emergence inhibition efficacy of leaf powders and extracts of *Acanthus montanus*, *Acanthospermum hispidum*, *Alchornea laxiflora* and *Argyrea nervosa* against *Sitophilus zeamais* were evaluated. There was no sign of progeny development in maize grains treated with *Acanthus montanus*, *Argyrea nervosa* and *Alchornea laxiflora* leaf powders and extracts. However, *Acanthospermum hispidum* powder treated grains had 15.4% adult emergence which lower 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 control¹⁵. 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 respectively⁷⁴.

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 damage⁴⁴. Methanol suspension (2% v/v) from *Momordica charantia*, *Nerium oleander* and *Ptaeroxylon obliquum* reduced the number of holes in grains by 75, 91 and 97%, respectively⁶². Grain weight loss prevention efficacy of seed and stem bark powders of *Azadirachta indica*, *Alstonia boonei*, *Garcinia 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 respectively⁴⁹.

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 grains⁴¹. 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 damage was 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 damage was 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 experiment⁴¹. 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 grains⁴². The damage was 0.3 and 1.9% in grains treated with *Annona Montana* seeds dichloromethane and hexane extracts respectively at 1500 mg/kg dosage⁴². 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 experiment³³.

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 and 3.33 % compared to the untreated control which recorded 12.67% grain damage⁴⁶. 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 damage⁴⁷. 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 application⁴⁷. *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 control⁶⁰.

Grain weight loss prevention efficacy of *Cinnamomum camphora* L., *Datura stramonium* L., *Jatropha curcas* L., *Lantana camara* L. and *Moringa oleifera* L. powders was tested on *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 grains⁸⁴. *Acanthus montanus*, *Acanthospermum hispidum*, *Argyrea 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 5 after application¹². 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 experiment⁵¹.

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 leaf 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 AFI₅₀ values of 14.9 and 16.8 μ g/mL compared to azadirachtin (AFI₅₀ values 12.2 and 12.4 μ g/ml) against *S. zeamais* and *P. truncatus*, respectively. Quercetin 3-*O*- α -D-arabinoside (**2**) gave AFI₅₀ values of 17.3 and 20.0 μ g/ml while kaempferol 3-*O*- β -D-galactoside (**3**) gave AFI₅₀ values of 21.6 and 20.2 μ g/mL against *S. zeamais* and *P. truncatus*, respectively⁴³. Quercetin 3-*O*- β -D-glucoside (**1**) was the most toxic to *S. zeamais* and *P. truncatus* with LC₅₀ values of 20.9 and 22.2 μ g/ml, respectively. Compound **2** exhibited LC₅₀ values of 21.7 and 24.9 μ g/ml and compound **3** had LC₅₀ values of 29.3 and 24.2 μ g/ml respectively against *S. zeamais* and *P. truncatus* respectively⁴³.

Insecticidal compounds from *Ocimum kilimandscharicum* were identified as 2 α -hydroxy-3-oxodammara-20,24-diene (**4**), 2 α ,3 β -dihydroxy dammara-20, 24-diene (**5**), apeginin-7-*O*-neohesperidoside (**6**), quercetin (**7**), turkesterone (**8**), fesitin (**9**), apeginin (**10**), chrysin (**11**), lupeol (**12**), stigmaterol (**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 LC₅₀ values of 21.64 and 16.06 μ g/mL respectively. Apeginin-7-*O*-neohesperidoside (**6**) gave LC₅₀ values of 23.41 and 26.20 μ g/mL against *S. zeamais* and *P. truncatus* respectively²¹. Turkesterone (**8**) was the most antifeedant with AFI₅₀ values of 17.50 and 21.33 μ g/ml against *S. zeamais* and *P. truncatus* respectively respectively²¹. Pesticidal compounds from *E. schweinfurthianum* were identified to be 3-oxofriedelane (**14**), 3 α -hydroxyfriedelane (**17**), 3-oxo-29-hydroxyfriedelane (**18**), 3-oxofriedelan-28-al (**19**), α -amyrin (**20**), α -amyrin acetate (**15**), β -sitosterol (**21**), stigmaterol (**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 treatment⁷². The insecticidal principles from *Warburgia ugandensis* were determined to be polygodial (**23**), warbuganal (**24**), ugandensolid (**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 plant⁴⁵. *Ocimum suave* extracts were found to exhibit insecticidal properties against maize weevils and the active compounds were identified to be β -sitosterol (**21**), stigmaterol (**13**), β -amyrin (**33**), lupeol (**12**) and betulinic acid (**34**)^{76, 77}. Antifeedant principles from *Erythrina variegata* L. against *Sitophilus zeamais* were determined as erysopine (**35**) and erysovine (**36**) having EC₅₀ values of 108.5 and 89.7 ppm, respectively⁸¹.

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 on compounds responsible for the insecticidal properties of the plants is scanty despite the fact that insecticidal compounds from plants are preferred because they are considered 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.	<i>Acanthus montanus</i>	Acanthaceae	leaf powders and extracts	Toxicity, oviposition and emergence inhibition	12
2.	<i>Acorus calamus</i> L.	Acoraceae	Rhizome ethanol extract	Toxicity	38
3.	<i>Chenopodium ambrosioides</i> L.	Amaranthaceae	Aerial part ethereal, ethyl acetate, methanol, aqueous extracts and powder	Toxicity and repellent	56
4.	<i>Schinus terebinthifolius</i> Raddi	Anacardiaceae	Leaf methanol extract	Mortality	68
5.	<i>Sclerocarya birrea</i> A. Rich	Anacardiaceae	leaf and bark	Mortality	48
6.	<i>Anaxagorea dolichocarpa</i> Sprague & Sandwith	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
7.	<i>Annona acutiflora</i> Mart.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
8.	<i>Annona cacans</i> Warm.	Annonaceae	Leaves, branches, and seeds ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
9.	<i>Annona dolabripetala</i> Raddi	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
10.	<i>Annona emarginata</i> (Schltdl.) H.Rainer	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
11.	<i>Annona montana</i> Macfad.	Annonaceae	branches, leaves, and seeds hexane, dichloromethane and ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33,42
12.	<i>Annona mucosa</i>	Annonaceae	leaf, branch and seed hexane, dichloromethane and ethanol extracts	Toxicity, antifeedant, emergence inhibition and weight loss prevention	33, 41
13.	<i>Annona muricata</i> L.	Annonaceae	Leaf, branch, and seed DCM, acetone and ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33, 39, 40
14.	<i>Annona reticulata</i> L.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
15.	<i>Annona</i> sp	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
16.	<i>Annona squamosa</i> L.	Annonaceae	Seed ethanol extract	Toxicity	38
17.	<i>Annona sylvatica</i> A.St.-Hil.	Annonaceae	Leaves, branches, and seeds ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
18.	<i>Dennetia tripetala</i>	Annonaceae	Leaf powder	Toxicity, emergence inhibition and weight loss prevention	60
19.	<i>Duguetia furfuracea</i> (A.St.-Hil.) Saff.	Annonaceae	Leaf ethanol extract	Repellence	82
20.	<i>Duguetia lanceolata</i> A.St. Hil.	Annonaceae	Leaves, branches, and seeds ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
21.	<i>Ephedranthus dimerus</i> J.C.Lopes, Chatrou & Mello-Silva	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
22.	<i>Guatteria australis</i> A. St.-Hil.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33
23.	<i>Guatteria ferruginea</i> A. St.-Hil.	Annonaceae	Leaves and branches ethanol extracts	Toxicity, emergence inhibition and weight loss prevention	33

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

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

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

			methanol extracts of rhizomes Leaf water extract		
122.	<i>Kaempferia pulchra</i> (Ridl.)	Zingiberaceae	Rhizome hexane, DCM and methanol extracts	Toxicity and repellence	64
123.	<i>Zingiber cassumunar</i> 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)	<i>Annona mucosa</i> Jacq	43	3-Oxofriedelan-28-al (19)	<i>Elaeodendron schweinfurthianum</i>	72
Quercetin 3-O-α-darabinoside (2)	<i>Annona mucosa</i> Jacq	43	α-Amyrin (20)	<i>Elaeodendron schweinfurthianum</i>	72
Kaempferol 3-O-β-D-galactoside (3)	<i>Annona mucosa</i> Jacq	43	β-Sitosterol (21)	<i>Elaeodendron schweinfurthianum</i> <i>Ocimum suave</i>	72, 76
2α-Hydroxy-3-oxodammara-20,24-diene (4)	<i>Ocimum kilimandscharicum</i>	21	Lanosterol (22)	<i>Elaeodendron schweinfurthianum</i>	72
2α,3β-Dihydroxy dammara-20, 24-diene (5)	<i>Ocimum kilimandscharicum</i>	21	Polygodial (23)	<i>Warburgia ugandensis</i>	15, 74
Apeginin 7-O-neohesperidoside (6)	<i>Ocimum kilimandscharicum</i>	21	Warbuganal (24)	<i>Warburgia ugandensis</i>	15, 74
Quercetin (7)	<i>Ocimum kilimandscharicum</i>	21	Ugandensolide (25)	<i>Warburgia ugandensis</i>	15, 74
Turkesterone (8)	<i>Ocimum kilimandscharicum</i>	21	Ugandensidial (26)	<i>Warburgia ugandensis</i>	15, 74
Fesitin (9)	<i>Ocimum kilimandscharicum</i>	21	Muzigadial (27)	<i>Warburgia ugandensis</i>	15, 74
Apeginin (10)	<i>Ocimum kilimandscharicum</i>	21	Mukaadial (28)	<i>Warburgia ugandensis</i>	15, 74
Chrysin (11)	<i>Ocimum kilimandscharicum</i>	21	Astilbin (29)	<i>Dimorphandra mollis</i>	75
Lupeol (12)	<i>Ocimum kilimandscharicum</i>	21	Azadirachtin (30)	<i>Azadirachta indica</i>	45
Stigmasterol (13)	<i>Elaeodendron schweinfurthianum</i> , <i>Ocimum kilimandscharicum</i> Baker ex Gürk, <i>Ocimum suave</i> Willd	21, 72, 76	Nimbolide and (31)	<i>Azadirachta indica</i>	45
Friedelin (14)	<i>Elaeodendron schweinfurthianum</i> , <i>Ocimum kilimandscharicum</i>	21, 72	Salannin (32)	<i>Azadirachta indica</i>	45
α-Amyrin acetate (15)	<i>Elaeodendron schweinfurthianum</i> , <i>Ocimum kilimandscharicum</i>	21, 72	β-Amyrin (33)	<i>Ocimum suave</i>	76
n-Octacosonoic acid (16)	<i>Ocimum kilimandscharicum</i>	21	Betulinic acid (34)	<i>Ocimum suave</i>	76
3α-Hydroxyfriedelane (17)	<i>Elaeodendron schweinfurthianum</i>	72	Erysopine (35)	<i>Erythrina variegata</i> L.	81
3-Oxo-29-hydroxyfriedelane (18)	<i>Elaeodendron schweinfurthianum</i>	72	Erysovine (36)	<i>Erythrina variegata</i> L.	81

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