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A Review Pesticidal Activity of Essential Oils against *Sitophilus oryzae*, *Sitophilus granaries* and *Sitophilus Zeamais*

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Abstract
Infestation of cereals in storage by Sitophilus oryzae, Sitophilus granaries and Sitophilus Zeamais lead to great food loses in Sub-Saharan Africa. Some of the synthetic pesticides which are available are non-biodegradable and have adverse effect on the environment and humans. Previous studies show that plant extracts have the potential for use as pesticidal agents against the weevils. The use of plant extracts in pest management is preferred because they are readily available and chances of drug resistance are low. The aim of this study was to collate and review the fragmented information on essential oils from plants with pesticidal activity against S. zeamais, S. oryzae and S. granaries 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 196 essential oils extracted form plant species belonging to 31 plant families. Essential oils from the Lamiaceae family are the most studied, followed by Myrtaceae, Asteraceae, Apiaceae, Lauraceae and Piperaceae families. Insecticidal activity studies of the essential oils were mostly tested against S. zeamais (115 essential oils) followed by S. oryzae (58 essential oils) and S. granaries (23 essential oils) which suggests that S. zeamais is the most rampant and the most dreaded species. Future studies aimed in isolating and characterizing the active compounds from the essential oil is necessary. It is also necessary to develop effective formulations for controlling the pests.

Keywords*: Storage pest; Sitophilus; Essential oil; Toxicity*

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I. Introduction

Cereals are the most important source of food all over the world and approximately 75% of calories and 67% of protein consumed worldwide are provided by cereals. They provide 10000-15000kJ/Kg of energy, which is approximately 15-20 times more than fruits and vegetables. Cereals are also an important source of many essential vitamins, minerals and phytochemicals. The grains are easy to carry, package and transport from one place to another, and are used as an ingredient in many food products such as porridge, breakfast cereals, bread and cereal based beverages. Cereals can grow in adverse environmental and bad soil conditions, and the yield is not compromised due to harsh environmental conditions. The crops give the highest yield when compared to most other crops. However, a large proportion of cereals go to waste because of destruction by insect pest**.**

Sitophilus is a genus of weevils in the tribe Litosomini. As of 1993, there are about 14 species of *Sitophilus*[1]. Maize weevil (*Sitophilus zeamais* Motchu.), rice weevil (*Sitophilus oryzae* L.) and granary weevil *(Sitophilus granaries* L.) are among the most important pests that destroy cereals in storage. The pests affect stored grains including wheat, rice, sorghum, oats, barley, rye, buckwheat, peas and cottonseed. Both adults and larvae of the insects feed on the grains and infestation can start in the field but most damage occurs in storage. The extensive tunneling allows the pests to convert the harvest into flour within a very short time[2]. In addition, infestations of the insect result in development of *Aspergillus* which is carcinogic[3-5]. In most cases, small-scale farmers are forced to sell their produce immediately after harvest, thereby attract low prices and compromising food security. Synthetic insecticides are commercially available and the chemical method is the most effective. However, indiscriminate use of synthetic insecticides results pest resistance and undesirable effects on non-target organisms, human and environmental hazards[6, 7]. This call for a need to search for safe alternatives that is environmentally friendly.

Plants have been identified as a source of important metabolites that are used in defense against different pests and pathogenic microorganism [8-20]. Search for insecticidal compound from plants through *in-vivo* and *in-vitro* experiments has yielded important compounds including alkaloids, terpenoids, flavonoids, steroids and quinones[21-27]. Such compounds represent an important source of drugs in the process of developing new pharmacologically active compounds. The use of botanical for pests and disease control is preferred because they are environmentally friendly and non-toxic to non-targeted organisms[4, 5, 28-38]. In addition, chances of pests and pathogens developing resistance to botanical pesticides are highly unlikely. This paper provides a review on pesticidal activity of plant extracts with emphasis on plant essential oils exhibiting toxicity, repellent, antifeedant, oviposition deterrent and growth inhibition activities against *Sitophilus oryzae* (L.), *Sitophilus granaries* (L.) and *Sitophilus Zeamais* (Motsch.).

II. Essential Oils in control of *Sitophilus species*

Essential oils from plants are considered to be an alternative means of controlling many harmful insects. Recent research has demonstrated their toxicity, antifeedant, adult emergence and oviposition inhibition and repellent activity against *Sitophilus species*[23, 24, 39, 40]. Although a number of review articles have appeared in the past on the various aspects of essential oils bioactivities[27, 41, 42], the present paper emphasizes use of plant oils in control of *S. oryzae*, *S. granaries* and *S. zeamais* which are the most important storage pests in the genus *Sitophilus*.

Information access from published research in the last 15 years indicate that 196 essential oils from plants belonging to 31 different plant families were studied for their insecticidal activity against the three *Sitophilus* species weevils (Figure1). Essential oils from plants belonging to the Lamiaceae family are the most studied (50) followed by Myrtaceae (19), Asteraceae (17), Apiaceae and Lauraceae (16), Piperaceae (15), Rutaceae (13), Poaceae (8), Pinaceae, Schisandracea and Verbenaceae (4), Geraniaceae, Hypericaceae and Zingiberaceae (3), Anacardiaceae, Annonaceae, Atherospermataceae and Labiatae (2), Alliaceae, Burseraceae, Canellaceae, Cupressaceae, Ericaceae, Fabaceae, Myristicaceae, Pedaliaceae, Ranunculaceae, Santalaceae, Simmondsiaceae and Solanaceae (1). Insecticidal activity against *S. zeamais* is the most studies (115 essential oils) followed by *S. oryzae* (58 essential oils) and *S. granariu* (23 essential oils) as shown in Figure 2. This probably indicates that *S. zeamais* is the most common of the three among the *Sitophilus* species. Most of essential oils studied against *S. zeamais* belong to the following families: Lamiaceae (12), Piperaceae (14), Lauraceae and Myrtaceae (12), Rutaceae (8), Schisandracea (4), Hypericaceae, Pinaceae, Poaceae and Verbenaceae (3). Most of essential oils studied against *S. oryzae* belong to the following families: Lamiaceae (1), Myrtaceae (7), Poaceae and Rutaceae (4), and Lauraceae (3). For *S. granaries*, most essential oils studies (11) belong to Lamiaceae family.

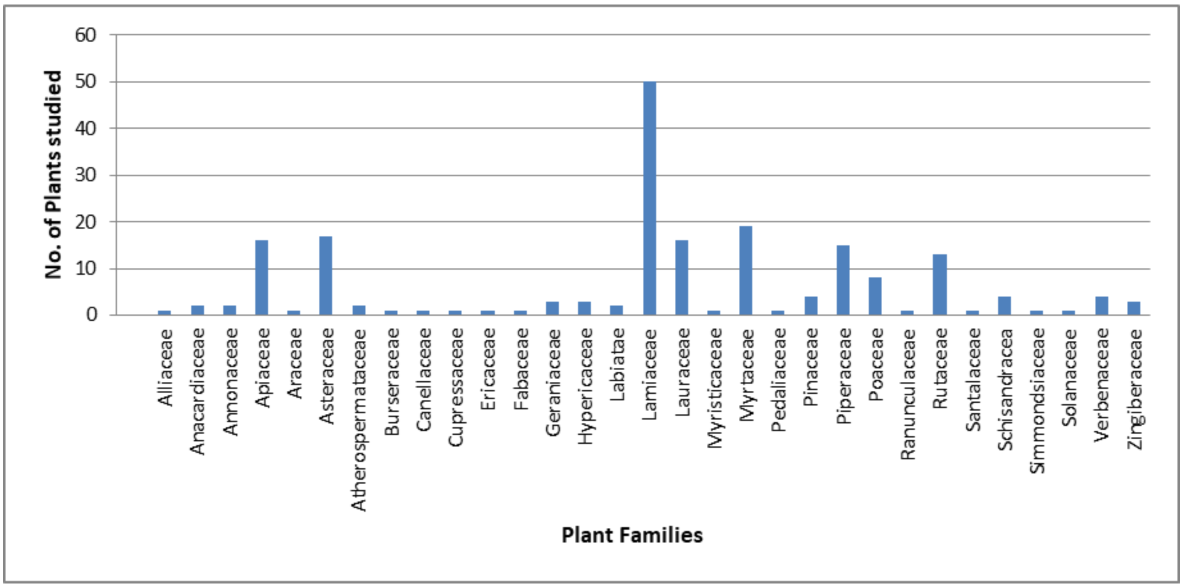

Figure no 1: Distribution of plants species studied per family

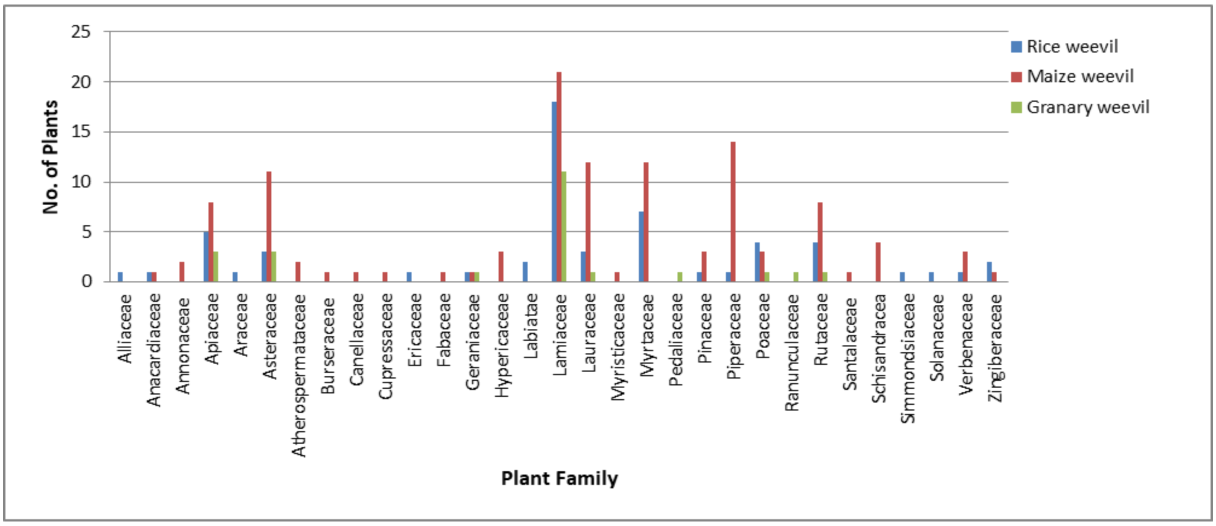

Figure no 2: Distribution of number of plant essential oils by family per insect pest

III. Activity of Essential Oils Against *Sitophilus oryzae*

From the information retrieved from published data, 58 essential oils were investigated against *Sitophilus oryzae* (Table 1). Essential oil from *C. citratus, C. nardus, C. zeylanicum and A. calcarata* gave LC_{50} values of 35, 82, 70 and 367 mg/L respectively in fumigation test and 11.5, 18.7, 3.6 and 40µg/cm^2 respectively in contact toxicity test[43]. *Carum* copticum gave LC_{50} value of 0.91µL/L[44] while *Eucalyptus spp*. had LC_{50} values between 7-8.5 µL/L [45, 46]. In the contact toxicity test, LC_{50} values of 0.14, 0.08, 0.61, 0.42, 0.01, 0.22, 0.10 and 0.11mg/cm^2 for *Achillea santolina* L., *Artemisia judaica* L., *Citrus reticulata* Balanco, *Schinus terebenthifolius* Raddi, *Mentha microphylla* C. Koch., *Lantana camara* L., *Majorana hortensis* Moench and *Eucalyptus camaldulensis* Dehnh, respectively were recorded[47]. In the fumigant toxicity assay, LC_{50} values recorded were 79.63, 100, 58.62, 56.48, 0.21, 29.47, 100 and 30.81 for *A. santolina A. judaica*, *C. reticulata*, *S. terebenthifolius*, *M. microphylla*, *L. camara*, *M. hortensis* and *E. camaldulensis*, respectively[47]. *Acorus calamus* gave LD_{50} value of 54.46µg/cm^2 against the weevil[48]. *Origanum* vulgare, *Salvia fruticosa*, *S. officinalis*, *S. pomifera*, *Thymbra capitata* and *Thymbra persicus* showed high fumigation toxicity toward *S. oryzae*, with LC_{50} values ranging between 1.5 and 9µL/L[49-51]. Application of *Mentha viridis* essential oil gave LC_{50} values of 239 and 158ppm after one and two weeks duration of exposure respectively[52]. *Syzygium aromaticum* and *Cinnamomum zeylanicum* gave 84 and 70% mortalities respectively at 4.0µl /50 ml air while *Cinnamomum zeylanicum* and *Melaleuca alternifolia* gave 90 % mortality at concentrations of 8.0 and 16.0µl /50 ml air respectively 24 hour after treatment[53]. *Syzygium aromaticum* gave LC_{50} values of 17.3 and 15.3µl after 24 and 48h exposure duration respectively[54]. At a concentration of 130µg/cm^2, *Coriandrum sativum* and *Eucalyptus obliqua* oils caused 100% mortality of the insects 24h after treatment, whereas *Pinus longifolia* oil gave 90% mortality after 72h in the fumigation test. *Coriandrum sativum Eucalyptus obliqua* and *Pinus longifolia* oils gave 100, 94 and 80% mortality 72 in the contact toxicity assay. The oils gave LD_{50} values of 36.68, 52.77 and 77.30µg/cm^2 for *C. sativum, E. obliqua and P. longifolia* respectively[55]. Essential oil from *Aegle marmelos* was toxic to the weevil with LC_{50} values of 18.488 and 16.133 µl at 24 and 48h after treatment respectively[54].

The LC_{50} of contact and residue toxicities of essential oil from *Cymbopogon nardus* were 23.2% and 1.71% respectively against *S. oryzae*[56]. *Artemisia judaica, Callistemon viminalis and Origanum vulgare* gave LD_{50} values of 0.08, 0.09, and 0.11 mg/cm^2 respectively while *Syzygium aromaticum* and *Lavandula officinalis* oils gave LD_{50} values of 0.04 and 0.07mg/cm^2 respectively[49, 57]. Fumigation of *S. oryzae* adults with *A. sativum* essential oil gave LC_{50} values of 0.30 and 0.24µl/cm^{3}air 24 and 48h after treatment respectively while LC_{50} values of 0.17 and 0.13µl/cm^2 after 24 and 48h respectively in contact toxicity tests. Fumigation with *C. tamala* oil gave LC_{50} values of 0.249 and 0.198µl/cm^{3}air after 24 and 48h respectively while in contact toxicity test, LC_{50} values of 0.241 and 0.218µL/cm^2 were observed after 24 and 48h respectively[58, 59]. In a fumigant bioassay, *H. officinalis* had the highest toxicity against *S. oryzae* adults, followed by *R. officinalis* and *M. piperita* with LC_{50} values of 78.16, 115.63 and 299.51µL/L air respectively[60]. Fumigation tests were performed to study toxicity of garlic, chili pepper, cardamom, peppermint, eucalyptus and tea tree essential oils on rice weevil at concentrations of 0.4, 0.6 and 0.8ml on 5cm diameter filter paper. Percentage mortalities were found to be in the order: peppermint (75.8%) > Tea tree (72.3%) > Garlic (65.5%) >Chili Pepper (62%) > Camphor (55.1%) > Cardamom oil (51.7%) [61]. The LD_{50} values for aniseed, camphor, citronella, eucalyptus, geranium, lavender, lemon, rosemary, vetiver and wintergreen essential oils were found to be 96.53, 49.92, 67.42, 47.42, 67.29, 154.03, 40.38, 58.34, 109.36 and 59.57 respectively while LD_{90} values were 178.38, 86.78, 110.29, 89.92, 103.47, 241.53, 83.12, 107.81, 162.11 and 115.95 respectively at 72 hours. *Laurus* nobilis oil gave LC_{50} value of 8.0µL/L against the weevil[50, 62]. Essential oils of *Coriandrum sativum* seeds gave LC_{50} value of 107.56 and 108.40µg/cm^2 against *S. oryzae* and *S. zeamais* respectively contact toxicity test while in fumigant toxicity test, LC_{50} values of 79.88 and 80.29µg/cm^2 were recorded for *S. oryzae* and *S. zeamais* respectively[63]. Essential oil from *Eucalyptus globules*, *Cymbopogon citrates* and *Citrus maxima* caused 73.33, 81.67 and 65.0% mortality of adult weevil at 1% concentration, 21 days after treatment [64]. *Contact toxicity of Origanum majorana* oil against *S. oryzae* was 80.0 and 90.0% on 3rd and 7th day respectively after treatment with 4.0%w/w oil. The oil gave LC_{50} values of 0.646 and 0.533 %w/w at 3 and 7 days after treatment respectively. In fumigant toxicity test, while the essential oil gave LC_{50} of 130.1 and 72.8µL/L air at 3 and 7 days after treatment[65]. In a contact toxicity assay *Nepeta glomerulosa* (LC_{50} = 124.318µL/L air) showed the highest toxicity against *S. oryzae* followed by *N. pogonosperma* (LC_{50} =150.49µL/L air), *N. cataria* (LC_{50} =152.630µL/L air) and *N. binaloudensis* essential oil (LC_{50} = 366.80µL/L[66]. The LC_{50} values for *T. copicum, L. camara, C. nardus and C. zeylanicum* were 07.24, 08.72, 10.63 and 06.19µL/L respectively at 72h after treatment[67]. In contact insecticidal test of *L. taraxacifolia* essential oil, LC_{50} values ranged between 54.38 -10.10µL/mL between 24-120 h after treatment [68].

Repellency of *Allium sativum* oil against *S. oryzae* was found to be 33.33, 54.16, 75.0 and 95.83% at concentrations of 0.2, 0.4, 0.8 and 1.6% respectively[58]. Repellency of *Cinnamomum tamala* essential oil was found to be 48.33, 75.83, 88.33, 97.50 and 100% at concentrations of 0.2, 0.4, 0.8, 1.6 and 3.2% oil respectively[59]. Repellency aniseed, camphor, citronella, eucalyptus, geranium, lavender, lemon, rosemary, vetiver and wintergreen essential oils were tested at concentrations of 10 and 50µL against adults of *Sitophilus oryzae*[62]. The order of repellency of the plant oils at 10µL on 6 hours of exposure with EPI was: camphor (-0.90), wintergreen (-0.88), lavender (-0.70), citronella (-0.70), rosemary (-0.67), vetiver (-0.62), lemon (-0.57), eucalyptus (-0.55), geranium (-0.44) and aniseed (-0.04). At 50µL the order of repellency was camphor (-1.0), wintergreen (-0.89), citronella (-0.89), lemon (-0.89), lavender (-0.71), vetiver (-0.69), geranium (-0.65), rosemary (-0.57), eucalyptus (-0.52) and aniseed (-0.50) [62]. *Sitophilus oryzae* was repelled by *M. piperita* (95.0 %), *R. officinalis* (91.0 %) and *H. officinalis* (86.5 %) at oil concentration of 16 µL/30 cm^2 while Repellent effect of marjoram oil ranged between 90-100% at a concentration of 4.0 %w/w within 72 hours after treatment [60, 65]. The order of repellency was of four plant oils tested against the weevil was: *N. cataria* (100%), *N. pogonosperma (*96.67%), *N. glomerulosa* (70%), and *N. binaloudensis* (100 %), at 25µL/30 cm^2 after 5h[66]. In antifeedant assay, *A. sativum* essential oil significantly decreased consumption of flour disk by *S. oryzae* adults. Consumption of flour disk was reduced to 81.72, 50.91, 33.16 and 13.73 % of control when treated with *A. sativum* essential oil at concentrations of 3, 6, 9 and 12 µl/disk respectively[58]. Consumption of flour disk was reduced to 80.27, 46.59, 20.16 and 6.64% of control when treated with 3, 6, 9 and 12 µl/disk of *C. tamala* essential oil[59]. Fumigation of *S. oryzae* adults with *A. sativum* essential oil significantly reduced oviposition potential. Reduction in oviposition was 49.45 and 15.78% of the control when the weevil was fumigated with 40 and 80% of 24-h LC_{50} respectively, 24h after treatment[58]. Application of *Mentha viridis* essential oil decreased the number of emerged *S. oryzae* adults by 58.7, 79.6 and 86.0% at concentrations of 100, 200 and 300 ppm respectively[52]. Essential oil of Origanum majorana caused 81.2% reduction of F1 progeny at 4.0 %w/w dosage [65]. Essential oil from *Eucalyptus globules*, *Cymbopogon citrates* and *Citrus maxima* gave 72.22, 77.78 and 61.11% reduction in progeny emergence at a concentration of 1% 50 days after treatment[64].

Table no 1: Plants species tested against *Sitophilus oryzae*

Family	Botanical name	Common name	Bioactivity	Reference
Alliaceae	*Allium sativum*	Garlic	Toxicity, repellency, feeding and oviposition inhibitory	58, 61
Anacardiaceae	*Schinus terebenthifolius*	Peppertree	Toxicity	47
Apiaceae	*Carum copticum*	Ajwain	Toxicity	44
Apiaceae	*Coriandrum sativum* L.	Coriander	Toxicity	55, 63, 69
Apiaceae	Cuminum cyminum	Cumin	Toxicity	70
Apiaceae	*Pimpinella anisum*	Aniseed	Toxicity and repellency	62
Apiaceae	*Trachyspermmum copicum*	Ajwain	Toxicity	67
Araceae	*Acorus calamus*	Sweet flag	Toxicity	48
Asteraceae	*Achillea santolina*	Santoline	Toxicity	47
Asteraceae	*Artemisia judaica*	Wormwood	Toxicity	47, 49
Asteraceae	*Launaea taraxacifolia* (Willd.)	Lettuce	Toxicity	68
Ericaceae	*Gaultheria fragrantissima*	Wintergreen	Toxicity and repellency	62
Geraniaceae	*Pelargonium graveolens*	Geranium	Toxicity and repellency	62
Labiatae	*Majorana hortensis*	Majorana	Toxicity	47
Labiatae	*Rosmarinus officinalis* L.	Rosemary	Toxicity and repellency	60, 62, 71
Lamiaceae	*Hyssopus officinalis* L.	Hyssop	Toxicity and repellency	60
Lamiaceae	*Lavandula officinalis*	Lavender	Toxicity and repellency	57, 62
Lamiaceae	*Mentha microphylla*	Spearmint	Toxicity	47
Lamiaceae	*Mentha piperita L.*	Peppermint	Toxicity and repellency	60

Lamiaceae	*Mentha pulegium*	Pennyroyal	Toxicity and, repellency	61
Lamiaceae	*Mentha viridis*	Pudding grass	Toxicity, growth inhibition	52
Lamiaceae	*Nepeta binaloudensis*		Toxicity and repellency	66
Lamiaceae	*Nepeta cataria*	Catnip	Toxicity and repellency	66
Lamiaceae	*Nepeta glomerulosa* Boiss.		Toxicity and repellency	66
Lamiaceae	*Nepeta pogonosperma*		Toxicity and repellency	66
Lamiaceae	*Origanum majorana*	Sweet majorana	Toxicity, growth inhibition and repellency	65
Lamiaceae	*Origanum vulgare*	Wild majorana	Toxicity	49, 50
Lamiaceae	*Salvia fruticosa*	Greek sage	Toxicity	49, 50
Lamiaceae	*Salvia officinalis* L.	Sage	Toxicity	49, 50
Lamiaceae	*Salvia pomifera*	Apple sage	Toxicity	49, 50
Lamiaceae	*Thymbra capitata*	Cone head thyme	Toxicity	49, 50
Lamiaceae	*Thymbra persicus*	Persian thyme	Toxicity	49, 50
Lamiaceae	*Thymus vulgaris*	Thyme	Toxicity	53
Lauraceae	*Cinnamomum tamala*	Cassia	Repellent, feeding and oviposition inhibition	59
Lauraceae	*Cinnamomum zeylanicum*	Cinnamon	Toxicity, repellence	42,53, 62, 67
Lauraceae	*Laurus nobilis*	Bay tree	Toxicity	50
Myrtaceae	*Callistemon viminalis*	Weeping bottle-brush	Toxicity	49
Myrtaceae	*Eucalyptus camaldulensis*	River red gum	Toxicity	47
Myrtaceae	*Eucalyptus globules*	Eucalyptus	Toxicity and emergence inhibition	53, 61,62,64
Myrtaceae	*Eucalyptus obliqua* L'Her	Stringybark	Toxicity	55
Myrtaceae	*Eucalyptus spp*		Toxicity	45,46
Myrtaceae	*Melaleuca alternifolia*	Tea tree	Toxicity	53, 61
Myrtaceae	*Syzygium aromaticum*	Cloves	Toxicity	53, 54, 57
Pinaceae	*Pinus longifolia* L.	Pine	Toxicity	55
Piperaceae	*Piper nigrum*	Black pepper	Toxicity	70
Poaceae	*Cymbopogon citratus*	Lemon grass	Toxicity and emergence inhibition	43, 64
Poaceae	*Cymbopogon flexuosus*	Cochin grass	Toxicity	53
Poaceae	*Cymbopogon nardus*	Citronella	Toxicity and repellency	43, 56, 62, 67
Poaceae	*Vetiveria zizanioides*	Vetiver	Toxicity and repellency	62
Rutaceae	*Aegle marmelos*	Golden apple	Toxicity	54
Rutaceae	*Citrus aurantium*	Lemon	Toxicity and repellency	62
Rutaceae	*Citrus maxima*	Citrus, pummelo	Toxicity, grain damage, weight loss and progeny emergence	64
Rutaceae	*Citrus reticulata*	Tangerine	Toxicity	47
Simmondsiaceae	*Simmondsia chinensis*	Jojoba	Toxicity	53
Solanaceae	*Capsicum annuum*	Chili Pepper	Toxicity and repellency	61
Verbenaceae	*Lantana camara*	Lantana	Toxicity	47, 67
Zingiberaceae	*Alpinia calcarata*	Snap ginger	Toxicity, repellence	43
Zingiberaceae	*Elettaria cardamomum*	True Cardamom	Toxicity and repellency	61

IV. Activity Of Essential Oils Against *Sitophilus Zeamais*

Information retrieved from published data indicates that 145 essential oils were investigated against *Sitophilus zeamais* (Table 2). Essential oil of *Eucalyptus saligna* gave LD_{50} value of 0.36µL/cm^2 in contact toxicity on filter paper disc and LD_{50} value of 38.05µL/40g of maize grain[72]. Toxicity effect of essential oils from *Tagetes minuta* L., *Mentha longifolia* L., *Rosmarinus officinalis* L., *Helichrysum odoratissimum* L. and *Pelargonium graveolens* L. were investigated against maize weevil, *S. zeamais*. In contact test, *T. minuta* and *M. longifolia* oils caused 100% mortality within two days after treatment at concentrations of 0.375 and 0.50µL/g of grain respectively[73]. A mortality rate of up to 100% of adult *S. zeamais* was reported when the insects were fumigated with *Tagetes patula* oil[74]. Essential oils of *Artemisia lavandulaefolia* and *A. sieversiana* gave LC_{50} values of 11.2 and 15.0mg/ respectively)[75]. LD_{50} values of 0.20, 0.21, 0.26, 0.40, 0.29 and 0.22µL/cm^2 were reported for *O. basilicum, O. americanum, O. tenuiflorum, C. hystrix, C. aurantifolia* and *E. caryophyllus* respectively, on toxicity assay on filter paper. However, the LD_{50} values were 0.43, 1.58, 2.33, 1.92, 2.29 and 1.91µL/cm^2 for *O. basilicum, O. americanum, O. tenuiflorum, C. hystrix, C. aurantifolia and E. caryophyllus* on rice grains respectively[76]. *Litsea salicifolia* gave LD_{50} value of 0.079µL/insect and LC_{50} value of 4.4µL/L air, in contact and fumigant toxicity assays respectively[77]. *Illicium fragesii* and *I. simonsii* gave LC_{50} values of 11.36 and 14.95mg/L respectively while *Ostericum sieboldii* (LC_{50} = 20.92 mg/L)[78-80]. Essential oil extract of *Ocotea odorifera* gave 86% mortality of the insects at a concentration of 0.32µLcm^{-2} 24h after treatment with LD_{50} value of 0.09µl/cm^2 (81) while *Aster ageratoides* oil gave LD_{50} value of 27.16µgcm^{-2} [81, 82]. *Blumea balsamifera* essential oil gave LC_{50} of 10.71mg/L air against *S. zeamais* adults in fumigation toxicity test. The insecticidal compound from the oil were identified to be 1,8-cineole, 4-terpeneol and α-terpeneol with LC_{50} values of 2.96,4.79 and 7.45mg/L air respectively[83]. *Ostericum grosseserratum* oil exhibited contact and fumigant toxicity against adult *S. zeamais* with LC_{50} value of 17.97 µg/adult and LC_{50} value of 13.70mg/L air [84].

Essential oil from *Laurelia sempervirens* caused 100% mortality at a concentration of 10 ml/kg grain in the contact toxicity test while it gave 72% mortality at 175 µL/L air[85]. *Warburgia ugandensis* essential oil caused 100% mortality of the weevil at 0.2 ml/ 20g of grains at 21 days after treatment[39]. Essential oil of *D. carota, C. atlantica, C. zeylanicum, C. semperbirens, L. angustifolia, P. cablin, M. pulegium* and *M. alternifolia* caused 26.67, 8.33, 10.00, 8.33, 25.0, 38.33, 96.67 and 63.33% mortality of *S. zeamais* at 24h after treatment at a concentration of 10µL/L air in fumigant toxicity test. The LD_{50} values for *M. pulegium* and *M. alternifolia* were 1.97 and 8.80µL/L respectively[86]. Essential oil of *M.* alternifolia also caused 82.22% mortality at a concentration of 11.97 mg/L air 24h after treatment. The LC_{50} values were 8.42, 7.70, and 6.78mg/L air, after 24, 48, and 72h of oil treatment respectively. The most potent compounds in the oil were terpinen-4-ol and α-terpineol with a LC_{50} value of 3.12 and 5.87mg/L air, respectively[87]. Essential oils from *Aphyllocladus decussatus* Hieron, *Aloysia polystachya* Griseb, *Minthostachys verticillata* Griseb Epling and *Tagetes minuta* L , were tested for toxicity activity. The percentage mortalities were 25, 32, 36, 82 and 66 at a concentration of 150 (µl/L air) for *A. decussates, A. polystachya* (1), *A. polystachya* (2), *M. verticillata* and *T. minuta* espectively. The LC_{50} values were 212.12, 230.74, 218.65 and 116.61µl/L air for *A. decussates, A. polystachya* (1), *A.polystachya* (2) and *M. verticillata* respectively. The toxicity of pure compounds was as follows: pulegone (LC_{50}: 11.8µl/L air), Rcarvone (LC_{50}: 17.5µl/L air), S-carvone (LC_{50}: 28.1µl/L air), ocimenone (LC_{50}: 42.3µl/L air), α-thujone (LC_{50}: 65.5µl/L air) and menthone (LC_{50}: 85.4 µl/L air) [88]. *Citrus limon* gave LC_{50} value of 9.89µL/Lair against the weevil[49].

The *M. soochowensis* essential oil displayed contact toxicity against *S. zeamais* adults (LC_{50} = 25.45µg/adult). It also showed pronounced fumigant toxicity against the insects with LC_{50} = 12.19 mg/L air[89]. Essential oil of *Coriandrum sativum* fruit gave a LD_{50} and LD_{95} of 145.49 and 10124.20µL/L air respectively at 24h and bioactive compound was found to be linalool with LC_{50} value of 172.37µL/L air. Percentage mortality of *S. oryzae* was 70% at 625µL/L air after 24h exposure to essential oil of coriander[69]. The essential oils pine (*Pinus palustris*), lemon grass (*Cymbopogon citratus*), peppermint (*Mentha piperita*), citronella grass (*Cymbopogon nardus*), sweet acacia (*Acacia farnesiana*), cinnamon (*Cinnamomum verum*), sweet orange (*Citrus sinensis*), basil (*Ocimum basilicum* L), clove (*Syzygium aromaticum*), and star anise (*Illicium verum*) were tested for toxicity activity at different concentrations. Sweet Acacia gave 100% mortality at 10µL after 24h while basil oil and star anise have 100% mortality after 36h[90]. The insecticidal effect of essential oil from leaves of *Porophyllum linaria* on maize weevil was evaluated at different doses. The mortality (%) obtained on the 10^{th} and 15th day was 43 and 82% respectively at 800 ppm, while with at ppm 30% mortality was obtained on 15^{th} day. The LC_{50} and LC_{90} values obtained after exposure for 15 days were 329.01 and 1058.86ppm respectively[91]. Essential oils from *Cymbopogon winterianus*, *Eucalyptus globulus*, *Eucalyptus staigeriana*, *Foeniculum vulgare*, *Ocimum basilicum*, *Ocimum gratissimum* and *Piper hispidinervum w*ere investigated for their toxicity to *S. zeamais* at five concentrations. The contact and ingestion toxicities of the essential oils to adult *S. zeamais* decreased in the following order: *P. hispidinervum* > *F. vulgare* > *O. basilicum* > *E. globulus* > *O. gratissimum* > *E. staigeriana* > *C. winterianus* with LC_{50} of 5.12, 26.78, 26.90, 37.88, 47.47, 61.73 and 78.89µL/40g of maize grains, respectively. In the fumigant toxicity the LC_{50} values were 2.1, 13.9, 15.8 and 19.4µL/40g of maize grains in grains treated with *P. hispidinervum, O. basilicum, F. vulgare* and *E. globulus* essential oils respectively[92]. Essential oils from *Anethum graveolens, Petroselinum crispum, Foeniculum vulgare* and *Cuminum cyminum* were tested at 25, 50, 75, 100, 156, 300, 525 and 600 mg/L air, and at 0, 30, 50, 100 and 150 µg per insect in fumigant and contact toxicity assays respectively. In the fumigant toxicity assay, LC_{50} values were found to be 157.1, 229.4, 442.8 and 535.8mg/L air for *A. graveolens, C. cyminum, F. vulgare* and *P. crispum* respectively. In the contact toxicity assay, LD_{50} values were 111.3, 120.4 and 128.2mg/L air for *A. graveolens, C. cyminum* and *P. crispum* respectively[93].

Toxicity of 28 essential oils was tested against the adults of *S. zeamais*. Their LD_{50} in mg/cm^2 in contact toxicity assay were as follows cinnamon (0.04), tea tree (0.15), marjoram (0.18), peppermint (0.24), lavender, bulgarian (0.31), ylang ylang (0.32), geranium (0.36), lemongrass (0.37), patchouli (0.40), spearmint (0.40), clary sage (0.42), clove bud (0.47), *E. radiate* (0.61), rosemary (0.67), basil (0.77), *E. globulus* (0.89), citronella (1.01), cypress (1.23), orange sweet (1.40), bergamot (1.70) and sandal wood (1.87)[94]. Essential oil from *Elaeodendron schweinfurthianum* caused 89.1% mortality at 0.2ml/20g of grain[95]. The essential oils extracted from *R. officinalis*, *L. stoechas, S. viminea*, *M. septentrionalis*, *Eucalyptus* sp., and *L. alba* exhibited high mortality rates (>90%). The percentage mortality of the essential oils was as follows: *M. septentrionalis* (%M = 97), *S. viminea* (%M = 94), *L. stoechas* (%M = 93), *X. discreta* (%M = 73), *P. el-metanum* (%M = 70), *A. cumanensis* (%M = 40) and *P. nubigenum* (%M = 40). *L. stoechas* and *L. alba* gave LC_{50} values of 303.4 and 254.1µL/L air respectively[96].

Tagetes minuta and *M. longifolia* essential oils gave percentage repellency of more than 90% against maize weevil. The repellency *R. officinalis*, *H. odoratissimum* and *P. graveolens* essential oils were 51.1, 49.4 and 51.7%, respectively. Essential oil from *M. longifolia* exhibited over 70% mortality at 32µL/L air in the fumigation tests[73]. *Lippia origanoides*, *E. citriodora,* and *T. lucida* essential oils, at concentrations of 0.063 -

0.503 µL/cm^2 gave 92, 91, and 79% repellencies, respectively[74, 97]. The oils from *C. bergamia* and *L. hybrida* were effective against *S. zeamais*, with average repellencies of 56.3 and 50%, respectively, in a dilution of 0.1% of the oils in ether[98]. The repellency for *O. basilicum*, *O. americanum*, *O. tenuiflorum*, *C. hystrix*, *C. aurantifolia* and *E. caryophyllus* oils were 92.5, 75.0, 100.0, 67.5, 90.0 and 80.0% at 0.21µL/cm^2 respectively on filter paper[76]. Essential oils from *Eucalyptus benthamii*, *E. dunnii*, *E. globulus*, *E. viminalis* and *E. saligna* also exhibited repellency against *S. zeamais*[99]. Essential oil of *Daucus carota*, *Cedrus atlantica*, *Cinnamonium zeylanicum*, *Cupressus semperbirens*, *Lavendular angustifolia*, *Pogostemin cablin*, *Mentha pulegium* and *Melaleuca alternifolia* repelled 61.8, 80.0, 83.3, 81.1, 66.7, 71.0, 97.1 and 87.1% of *S. zeamais* at a concentration of 10µL /filter paper[86].

Cymbopogon winterianus, *Eucalyptus globulus*, *Eucalyptus staigeriana*, *Foeniculum vulgare*, *Ocimum basilicum.*, *Ocimum gratissimum* and *Piper hispidinervum* essential oils were investigated for their repellency to *S. zeamais* at five concentrations. The mean repellency percentages were: *E. staigeriana* (96.25%), *O. basilicum* (91.19%), *O. gratissimum* (90%), *C. winterianus* (81.82%), *E. globulus* (79.62%), *F. vulgare* (77.07%), and *P. hispidinervum* (49.37%)[92]. Essential oils from *Anethum graveolens*, *Petroselinum crispum*, *Foeniculum vulgare* and *Cuminum cyminum* were tested at concentrations of 16, 47, 78 and 156µg/cm^2. In the area preference bioassays, essential oil extracted from *F. vulgare* was the most repellent (RD_{50} = 24µg/cm^2) followed by *A. graveolens* (RD_{50} = 37.9µg/cm^2), *C. cyminum* (RD_{50} = 45.2µg/cm^2) and *P. crispum* (RD_{50} = 166.0µg/cm^2). In the two-choice bioassays, the most repellent was *P. crispum* oil followed *by C. cyminum* oil[93]. The repellency of *I. verum* ranged between 43.3 and 70% at 2h, and between 20 and 46.7% at 24h after treatment. The essential oils of *X. discreta*, *Eucalyptus* sp., *P. el-methanum*, *P. pertomentellum* and *C. citratus* exhibited the greatest repellent effect at 24h[96].

Essential oil from *aurelia sempervirens* reduced F1 emergence to 10.1% at a concentration of 5ml/kg grain at 5 weeks after treatment[85]. The number of adults that emerged from corn grains infested with eggs exposed to *P. hispidinervum* oil was lower than the control. The median lethal time to kill 50% (LT_{50}) of the eggs was 16.7h at a concentration of 1.25µL/L, and 16.52h at a concentration of 1.87µL/L[92].

Table no 2: Plants species tested against *Sitophilus zeamais*

Family	Botanical name	Common name	Bioactivity	Reference
Anacardiaceae	*Schinus molle*	False pepper	Toxicity and repellency	96
Annonaceae	*Cananga odorata*	Ylang ylang	Toxicity, repellency	94
Annonaceae	*Xilopia discreta*		Toxicity and repellency	96
Apiaceae	*Anethum graveolens*	Dill	Toxicity, repellency	93
Apiaceae	*Coriandrum sativum* L.	Coriander	Toxicity	55,63, 69
Apiaceae	*Cuminum cyminum*	Cumin	Toxicity, repellency	93
Apiaceae	*Daucus carota*	Carrot seed	Toxicity and repellency	86
Apiaceae	*Foeniculum vulgare* Mill	Fennel	Toxicity, growth inhibition and repellency	92-94, 96
Apiaceae	*Ostericum grosseserratum*		Toxicity	84
Apiaceae	*Ostericum sieboldii*		Toxicity	80
Apiaceae	*Petroselinum crispum*	Parsley	Toxicity, repellency	93
Asteraceae	*Ambrosia cumanesis Kunth*	Altamisa	Toxicity and repellency	96
Asteraceae	*Aphyllocladus decussatus* Hieron		Toxicity	88
Asteraceae	*Artemisia drancunculus*	Estragon	Toxicity and repellency	96
Asteraceae	*Artemisia lavandulaefolia*		Toxicity	75
Asteraceae	*Artemisia sieversiana*		Toxicity	75
Asteraceae	*Aster ageratoides*	Starshine	Toxicity	82
Asteraceae	*Blumea balsamifera*	Sambong	Toxicity	83
Asteraceae	*Porophyllum linaria*	Pipicha	Toxicity	91
Asteraceae	*Tagetes minuta* L.	Southern marigold	Toxicity	73, 88
Asteraceae	*Tagetes patula*	French marigold	Toxicity	74
Asteraceae	*Tagetes lucida*	Mexican marigold		97
Atherospermatacea e	*Laurelia sempervirens* (Ruiz & Pav.) Tul.	Nutmeg	Toxicity and emergence inhibition	85
Burseraceae	*Boswellia carterii*	Frankincense	Toxicity, repellency	94
Canellaceae	*Warburgia ugandensis*	Greenheart	Toxicity, repellency, growth inhibition	39
Cupressaceae	*Cupressus sempervirens*	Common cypress	Toxicity, repellence, growth inhibition	72, 86, 94, 95
Fabaceae	*Acacia farnesiana*	Sweet acacia	Toxicity	90
Geraniaceae	*Pelargonium graveolens*	Geranium	Toxicity, repellency	94
Hypericaceae	*Hypericum juniperinum* Kunth		Toxicity and repellency	96
Hypericaceae	*Hypericum mexicanum*		Toxicity and repellency	96
Hypericaceae	*Hypericum myricariifolium* Hieron		Toxicity and repellency	96
Lamiaceae	*Dracocephalum moldavica*	Dragon head	Toxicity	100

Lamiaceae	*Lavandula* angustifolia	Lavender	Toxicity and repellency	86, 94
Lamiaceae	*Lavandula hybrida*	Lavender		98
Lamiaceae	*Lavandula stoechas*	French Lavender	Toxicity and repellency	96
Lamiaceae	*Mentha piperita*	Peppermint	Toxicity, repellency	90, 94
Lamiaceae	*Mentha pulegium*	Pennyroyal	Toxicity and repellency	86
Lamiaceae	*Mentha spicata*	Spearmint	Toxicity, repellency	94
Lamiaceae	*Minthostachys septentrionalis*		Toxicity and repellency	96
Lamiaceae	*Minthostachys verticillata*	Peperina	Toxicity	88
Lamiaceae	*Mosla soochowensis* Matsuda		Toxicity	89
Lamiaceae	*Ocimum americanum*	Holy basil	Toxicity and repellency	76
Lamiaceae	*Ocimum basilicum* L.	Sweet basil,	Toxicity, growth inhibition and repellency	76, 90, 92, 94, 96
Lamiaceae	*Ocimum gratissimum* L	Clove basil	Toxicity, growth inhibition and repellency	92
Lamiaceae	*Ocimum suave*		Toxicity, repellency, growth inhibition	95
Lamiaceae	*Ocimum tenuiflorum*	Hairy basil	Toxicity and repellency	76
Lamiaceae	*Origanum majorana*	Sweet marjoram	Toxicity, repellency	94
Lamiaceae	*Pogostemin cablin*	Patchouli	Toxicity and repellency	86
Lamiaceae	*Pogostemon cablin*	Patchouli	Toxicity, repellency	94
Lamiaceae	*Rosmarinus officinalis*	Rosemary	Toxicity, repellency	94, 96
Lamiaceae	*Salvia sclarea*	Clary Sage	Toxicity, repellency	94
Lamiaceae	*Satureja viminea*	Tree mint	Toxicity and repellency	94
Lauraceae	*Aniba* robusta		Toxicity and repellency	96
Lauraceae	*Aniba puchury-minor*		Toxicity and repellency	96
Lauraceae	*Beilschmiedia costaricensis*		Toxicity and repellency	96
Lauraceae	Cinnamomum cassia	Cinnamon	Toxicity, repellency	94
Lauraceae	*Cinnamomum triplinerve*		Toxicity and repellency	96
Lauraceae	*Cinnamomum verum* J.S. Presl	Cinnamon	Toxicity	90
Lauraceae	*Cinnamonium zeylanicum*	Cinnamon	Toxicity and repellency	86
Lauraceae	*Litsea salicifolia*		Toxicity	77
Lauraceae	*Nectandra acutifolia*		Toxicity and repellency	96
Lauraceae	*Ocotea longifolia*		Toxicity and repellency	96
Lauraceae	*Ocotea odorifera*	Cinnamon	Toxicity and repellency	81
Lauraceae	*Ocotea sp.*		Toxicity and repellency	96
Myristicaceae	*Virola carinata*		Toxicity and repellency	96
Myrtaceae	*Eucalyptus benthamii*	Bentham's gum	Repellency	99
Myrtaceae	*Eucalyptus citriodora*	Lemon-scented gum		97
Myrtaceae	*Eucalyptus dunnii* Maiden	Eucalyptus	Repellency	99
Myrtaceae	*Eucalyptus globulus* Labill	Dunn's white gum	Toxicity, growth inhibition and repellency	92, 94, 99
Myrtaceae	*Eucalyptus radiata*	Eucalyptus	Toxicity, repellency	94
Myrtaceae	*Eucalyptus saligna* Smith	Blue gum	Toxicity, repellency, emergence inhibition	72, 99
Myrtaceae	*Eucalyptus sp*		Toxicity and repellency	96
Myrtaceae	*Eucalyptus staigeriana* F. Muell. ex F.M. Bailey	Lemon-scented iron bark	Toxicity, growth inhibition and repellency	92
Myrtaceae	*Eucalyptus viminalis* Labill	Manna gum	Repellency	99
Myrtaceae	*Eugenia caryophyllus*	Clove	Toxicity and repellency	76
Myrtaceae	*Melaleuca alternifolia*	Tea tree	Toxicity and repellency	86,87, 94
Myrtaceae	*Syzygium aromaticum*	Clove	Toxicity and repellency	90, 94, 96
Pinaceae	*Cedrus atlantica*	Cedarwood	Toxicity and repellency	86
Pinaceae	*Pinus Palustris*	Longleaf pine	Toxicity	90
Pinaceae	*Pinus spp*.	Pine	Toxicity, repellency	94
Piperaceae	*Peperomia sp.*		Toxicity and repellency	96
Piperaceae	*Piper aequale*		Toxicity and repellency	96
Piperaceae	*Piper aduncum*	Spiked pepper	Toxicity and repellency	96
Piperaceae	*Piper bogotense*		Toxicity and repellency	96
Piperaceae	*Piper asperiusculum*		Toxicity and repellency	96
Piperaceae	*Piper el-metanum*		Toxicity and repellency	96
Piperaceae	*Piper eriopodon*		Toxicity and repellency	96
Piperaceae	*Piper hispidinervum* C. DC	Long pepper	Toxicity, growth inhibition and repellency	92
Piperaceae	*Piper holtonii*		Toxicity and repellency	96
Piperaceae	*Piper imperiale*		Toxicity and repellency	96
Piperaceae	*Piper marginatum*	Marigold pepper	Toxicity and repellency	96
Piperaceae	*Piper nubigenum*		Toxicity and repellency	96
Piperaceae	*Piper pertomentellum*		Toxicity and repellency	96
Piperaceae	*Piper pesaresanum*		Toxicity and repellency	96
Poaceae	*Cymbopogon* citratus	Lemon grass	Toxicity and repellency	90, 94, 96
Poaceae	*Cymbopogon nardus* Linn	Citronella grass	Toxicity	90, 94, 96

Poaceae	*Cymbopogon winterianus* Jowitt	Java citronella	Toxicity, growth inhibition and repellency	92
Rutaceae	*Citrus aurantifolia*	Lime	Toxicity and repellency	76
Rutaceae	*Citrus bergamia*			98
Rutaceae	*Citrus bigaradia*	Bergamot	Toxicity, repellency	94
Rutaceae	*Citrus hystrix*	Kaffir lime	Toxicity and repellency	76
Rutaceae	*Citrus limon*	Lemon	Toxicity, repellency	49, 94
Rutaceae	*Citrus reticulata*	Mandarin	Toxicity, repellency	94
Rutaceae	*Citrus sinensis*	Orange sweet	Toxicity and repellency	90, 94, 96
Rutaceae	*Coleonema* album	Confetti Bush	Toxicity and repellency	96
Santalaceae	*Santalum album*	Sandal wood	Toxicity, repellency	94
Schisandracea	*Illicium simonsii*		Toxicity	78
Schisandracea	*Illicium verum* Hook	Star anise	Toxicity and repellency	90, 96
Schisandracea	*Illicium fragesii*		Toxicity	79
Schisandracea	*Kadsura heteroclita*		Toxicity	101
Verbenaceae	*Aloysia polystachya* Griseb	Donkey tea	Toxicity	88
Verbenaceae	*Lippia alba*	Mat grass	Toxicity and repellency	96
Verbenaceae	*Lippia javanica*	Fever tree	Toxicity and repellency	102
Verbenaceae	*Lippia origanoides* Kunth		Toxicity and repellency	96, 97
Zingiberaceae	*Curcuma* longa	Turmeric	Toxicity and repellency	96

V. Activity of Essential Oils Against *Sitophilus granaries*

Information retrieved from published data indicates that 23 essential oils were investigated against *Sitophilus granaries* (Table 3). *Origanum acutidens* and *Mentha pulegium* oils were reported to exhibit insecticidal activity against S. granaries[103, 104]. *Azilia eryngioides* essential oil gave LT_{50} values of 21.04, 17.44, 14.80 and 10.38h at concentrations of 37.03, 74.07, 111.11 and 148.14µL/L air respectively. The oil gave LC_{50} value of 20.05 µL/L air against the insect[105]. In the fumigant toxicity test, essential oil from flower of *L. angustifolia* gave LC_{50} and LC_{90} values of 1.5 and 4.mg/L respectively in the absence of wheat grains while the oil gave LC_{50} and LC_{90} values of 10.9 and 47.6mg/L respectively in the presence of the substrate. In the contact toxicity test, LC_{50} and LC_{90} values were recorded as 83.8 and 379.7µg/adult respectively at 24h after treatment, while LC_{50} and LC_{90} values were 58.3 and 208.3µg/adult respectively at 48h[106]. Essential oil extracts from Coriander, Mint and Sesame gave 90.0, 89.0 and 87.3% cumulative mortality of the insects 7 days after treatment[107]. Fumigant effect of essential oil of *Mentha piperita*, *Citrus cienensis* and *Nigella sativa* were investigated against *S. granarius.* All the three essential oils caused 100% mortality of the weevil at 24h after treatment at a concentration of 7%[108]. Essential oil from *Thymus pallescens* gave LC_{50} and LC_{90} values of 9.3 and 34.6µL/mL respectively in the contact test while in the fumigation assy *T. pallescens* oil gave LC_{50} and LC_{90} values of 8.2 and 25.3µL/mL respectively. Essential oil from *Cymbopogon citratus* gave LC_{50} of 12.6 and 9.7µL/mL in contact and fumigation toxicity assays respectively[109]. Rosemary oil exhibited 58.41% fumigant toxicity against *S. granarius* 24h after treatment[110].

Essential oil from flower of *Lavandula angustifolia* were evaluated for repellence activity against *S. granaries* at concentrations of 0.74, 1.49, 2.97, 5.94, 11.88, 23.76 and 47.52mg/L. Mean repellence values were higher than 80% (V repellent class) starting from the 0.441mg/cm^2 dose[106]. Essential oil from *T. pallescens* showed a strong repellent effect (83.4-100%) against the weevil[109]. *Rosmarinus officinalis, Laurus nobilis, Echinacea purpurea, Origanum majorana, Ocimum basilicum and Foeniculum vulgare* essential oil showed repellent effect under laboratory conditions. The essential oils caused 84.27-98.88% decrease in the progeny production of F1 generation[110].

Table no 3: Plants species tested against *Sitophilus granarius*

Family	**Botanical name**	***Common name***	**Bioactivity**	**Reference**
Apiaceae	*Azilia eryngioides*		Toxicity	105
Apiaceae	*Coriandrum sativum* L.	Coriander	Toxicity, oviposition and growth inhibition	107
Apiaceae	*Foeniculum vulgare*	Fennel	Toxicity, reduction in F1 progeny development, repellency	110
Asteraceae	*Echinacea purpurea*	Echinacea	Toxicity, reduction in F1 progeny development, repellency	110
Asteraceae	*Helichrysum odoratissimum*	Kooigoed	Toxicity, repellency	73
Asteraceae	*Tagetes minuta* L.	Marigold	Toxicity, repellency	73
Geraniaceae	*Pelargonium graveolens*	Geranium	Toxicity, repellency	73
Lauraceae	*Laurus nobilis*	Daphne	Toxicity, emergence inhibition, repellency	110
Lamiaceae	*Lavandula angustifolia* Miller	Lavender	Toxicity, repellency, anti-feedant	106, 111
Lamiaceae	*Mentha balsamea* Willd.	Peppermint	Toxicity	111
Lamiaceae	*Mentha longifolia*	Horse mint	Toxicity, repellency	73
Lamiaceae	*Mentha piperita L.*	Peppermint	Toxicity	108
Lamiaceae	*Mentha pulegium*	Pennyroyal	Toxicity	103
Lamiaceae	*Ocimum basilicum*	Basil	Toxicity, emergence inhibition, repellency	110

Lamiaceae	*Origanum acutidens*		Toxicity	103
Lamiaceae	*Origanum majorana*	Marjoram	Toxicity, emergence inhibition, repellency	110
Lamiaceae	*Rosmarinus officinalis*	Rosemary	Toxicity, emergence inhibition, repellency	73, 110, 111
Lamiaceae	*Satureja viminea*	Mint	Toxicity, oviposition and growth inhibition	107
Lamiaceae	*Thymus pallescens* Noe.		Toxicity, repellency	109
Pedaliaceae	*Sesamum indicum*	Sesame	Toxicity, oviposition and growth inhibition	107
Poaceae	*Cymbopogon citratus* Stapf	Lemon grass	Toxicity, repellency	109
Ranunculacea e	*Nigella sativa L.*	Black cumin,	Toxicity	108
Rutaceae	*Citrus cienensis (L.)*	Sweet orange	Toxicity	108

VI. Conclusion

This study shows that essential oils from plants have a potential in managing insect pests belonging to genus *Sitophilus*. The information retrieved has also indicated that most studies carried out were mostly geared towards identification of biopesticidal agent against *S. zeamais* more than *S. oryzae* and *S. granaries*. This could be an indication that *S. zeamais* is the most rampant and the most dreaded species. It is also evident that most studies ended with testing of the crude essential oils. The information about compounds responsible for the insecticidal activity of the oils is scanty despite the fact that insecticidal compounds from nature have preferred because they are environmentally safe. Future studies aimed in isolating and characterizing the active compounds from the essential oil is necessary. It is also necessary to develop effective formulations for controlling the pests.

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