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Prospects of botanicals in the management of maize weevil, *Sitophilus zeamais* Mostch (Coleoptera: Curculionidae) in Nigeria

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Abstract
The loss of market values and problem of pests in the stored grains has contributed to the problem of food security in the tropics. Post-harvest losses due to *Sitophilus zeamais* remain an important constraint to grain storage in Africa. Infestations by maize weevil lead to severe post-harvest damage of staple food crops especially cereal and leguminous grains, on the field and in storage. Damage by the insect pest starts from the field and then the weevils are transported into store where the population multiplies rapidly. In order to reduce this loss, synthetic insecticides have been commonly used during storage of farm products. However, the use of chemical insecticides has resulted in problems such as environmental pollution, health hazards, pest resurgence and increase in costs of application arising from the development of resistance to insecticides. The emerging challenges make it necessary to search for alternative, eco-friendly methods including the use of plant materials as biopesticides for the control of insect pests of storage. This has resulted in successful evaluation of various plant materials against *S. zeamais* in stored grains. This review is aimed at discussing some of the published literatures on the management of *S. zeamais* in Nigeria using plant products in a search for alternative methods in order to minimize over usage of chemical insecticides.

Keywords: Biopesticides, insect pests, management, *Sitophilus zeamais*, stored grains

Introduction
Insect pests constitute the highest source of quantitative and qualitative depreciation to stored products due to their activities in cases of infestation, competing with man for scarce food resource by direct feeding or providing suitable conditions for micro-organisms [1]. They are a key challenge to effective production and utilization of cereal crops in sub-Saharan Africa (SSA), and post-harvest losses resulting from insect remain a huge obstacle [2]. Insect infestations to stored products are one of the major threats to storage entomology and food security in the tropics which results in substantial waste of farm produce and hence considerable loss to the economy [3, 4, 5, 6]. The damage may also results in reduction of quantity as well as quality of the stored cereal grains [7].
Considering the need for achieving food security and safety in Nigeria, there is need for effective pest management strategies for small-scale farmers who form bulk of producers in the country and Sub-Saharan Africa in general [8]. For that, a number of methods such as cultural, physical, biological and application of synthetic pesticides have been used for management of post-harvest insect pests.
Alhough synthetic insecticides provide effective pest control both on farm and storage, there is concern about the potential hazards of the chemicals to the ecosystem [8, 9, 10]. It is suggested that, to reduce the hazards associated with application of chemical insecticides in stored cereals, Integrated Pest Management (IPM) approach is required [11].

Sitophilus zeamais Motschulsky
Sitophilus zeamais is described by van Emden [12] as a weevil of about 4.0 mm long with large round punctures on the thorax. It has a head which protruds into rostrum bearing a biting-chewing mouthpart type. The antennae of *S. zeamais* are elbowed and slightly clubbed. The insect has highly sclerotized elytra coverins the hind wings [13, 14].
Mutambuki and Harbert [15] explained that *S. zeamais* female deposits its individually in small cavity in cereal grains by using its long ovipositor. The cavity is then sealed with an egg plug. The eggs hatch into larvae which are white, soft, legless, and grub-like. The larvae feed inside the grain and excavate tunnels as they develop.

This feeding habit leads to most of the damage to the grains [13, 16]. Pupation occurs within the kernel under optimum condition of 27 to 31 ºC and 40 to 75% relative humidity (R.H).

Sitophilus zeamais was observed to complete its life cycle in 26 days at 30 ºC and 75% R.H. [17]. Makate [18] reported that the mean developmental period of *S. zeamais* may range from 33 to 35 days at 24 – 28 ºC. Close to this, Parugrug and Roxas [19] recorded the total developmental period of maize weevil as 39 days at 28 ºC. Similarly, Anankware *et al.* [20] reported the total development period of *S. zeamais* ranging from 35 days under optimum conditions.

Pest Status of *Sitophilus zeamais* to Stored Grains

Sitophilus zeamais is one of the most destructing storage pests of cereal grains, causing serious losses which lead to food insecurity in developing countries [21]. The grain damage caused by *S. zeamais* to cereal grains stimulated researchers to investigate more on controlling strategies of the weevils during storage [6, 9, 22, 23, 24].

Sitophilus zeamais has been reported as a primary pest that attack whole grains [24]. The developmental and feeding activities of the weevils often lead to severe powdering and contaminating the grain with their excreta [25]. The infested grains become susceptible to cracking and mould infection due to the insects' respiration that heats the grain and drives water vapour to other areas where it condenses to wet the grain thereby reducing their market value [5, 12, 19]. Ngamo *et al*. [26] observed that an attacked grain losses agronomic, nutritional and economic value, since it could not be sold or sown.

Different substantial levels of damage caused by *S. zeamais* to stored cereal grains in Nigeria have been recorded by others [27, 28, 29, 30, 31, 32, 33, 34, 35, 36].

Several investigations were conducted in order to assess the level of grain damage caused to stored cereals by *S. zeamais* at different exposure periods. For instance, Udo [36] reported that the weevil caused 16% damage on maize grains. This was supported by Ileke and Oni [32] who recorded more than 20% grain damage to wheat seeds by *S. zeamais* within three months storage. The destructive effect of maize weevil to maize grains was further reported to go beyond 30% under ambient conditions of 26 to 30 ºC and 70 to 80% R.H. [37]. Furthermore, Suleiman [38] recorded up to 65.50% grain damage in sorghum grains exposed to *S. zeamais* for a period of eight months.

Suleiman and Dandume [39] found that *S. zeamais* resulted in 8.47 to 15.71% grain damage of different sorghum varieties. Similarly, Suleiman [40] reported 53.30% grain damage of sorghum within 28 days of exposure. Also, about 30% grain damage in sorghum grains was recorded within two months exposure to the weevils [22], while less than 5% weight loss in the grains to *S. zeamais* was reported within three months [41].

Another finding showed that maize grains lost about half of their weight to maze weevils after four weeks of exposure [42]. Further, Longe [43] recorded more than 30% weight loss in a white maize variety to *S. zeamais* within 45 days. A report by Onuminya *et al*. [7] showed that *S. zeamais* caused higher grain weight loss in untreated maize than in samples treated with leaf powders of *Nicotiana tabacum*, *Eucalyptus camaldulensis*, *Carica papaya* and *Mangifera indica*. Similar results were recorded by Oloruntola *et al*. [5] when powders of rice husk and melon shell were applied. Moreover, Suleiman *et al*. [24] reported that up to 23.37 to 26.40% weight loss in sorghum was recorded due to *S. zeamais* infestations within three months of post treatment.

Control of *Sitophilus zeamais* Using Botanical Products

About 900 plant species were identified to be of insecticidal effects and could have the potentiality of serving as grain protectants [44, 45]. Therefore, the use of plant materials as bio-pesticides for the control of insect pests has been considered as an indigenous pest management for reducing damage caused by pests [46, 47, 48]. The botanicals can be used in various forms such as powders, extracts of different organic solvents, essential oils or as dried whole plants applied as layers in between grains in traditional stores [24, 35, 49, 50, 51, 52, 53, 54].

Researchers have been engaged in testing insecticidal activities of different plant species against the maize weevils infesting cereal grains in Nigerian stores. These botanicals are in various forms of formulation such as powders and extracts. For instance, powder of *P. guineense* applied at different doses was reported to cause total mortality of adults of *S. zeamais* infesting maize grains [55]. Also, *P. guineense* and *A. sativum* used at the dose of 5% inhibited progeny development and protected maize grains from losing weight to the weevils, respectively [55]. The promising effect of *Chromolaena odorata* and *Citrus limon* in the control of *S. zeamais* in stored maize was reported where significant adult mortality of the weevil, and low grain damage and high germination of maize grains were recorded [26]. Other studies using plant powders revealed that *A. melegueta*, *Jatropha curcas*, *Citrus sinensis*, *Myrcianthes fragrans* and *Psidium guajava* effectively controlled *S. zeamais* and protected maize grains against the weevils [56, 57].

Apart from powders, extracts were also tested and found effective in the management of *S. zeamais* in Nigeria. Studies conducted by Udo [36] showed that methanolic extracts of *Z. xanthoxyloides* led to significant death adults of *S. zeamais*. The study also indicated that the extracts yielded to complete inhibition of adult emergence of the insect prevented maize grains from damage. Another study showed that methanolic extract of *Vitex cymosa* (Lamiaceae) applied at 50 $mgmL^{-1}$ caused a high adult mortality of maize weevil within two weeks after treatment [58]. Similarly, *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* extracted with ethanol and methanol gave a very good result in killing *S. zeamais*, reducing adult emergence and protecting sorghum grains from damage [35, 53].

Akinbuluma *et al*. [59] reported that ethanolic extracts of *Capsicum frutescens* and *Dennettia tripetala* had repellent and toxicity effects against *S. zeamais* in stored maize. It was further found that the botanicals protected maize grains stored for three months. Toxicity of oil extracts of *Olax subscorpioidea*, *Aframomum meleguata* and *Zingiber officinale* was also recorded by Oni and Ogungbite [60], where it was reported that the oils caused high mortality and reduced progeny emergence of *S. zeamais*.

There are much more botanicals in Nigeria that have been assessed for their toxic, repellent, development suppression and anti-feedant effects against *S. zeamais* infesting stored cereal grains. Their role in protecting the grains from qualitative and quantitative damage has also been investigated by others [9, 61, 62, 63, 64, 65, 66].

Several plant species have been investiagated for their insecticidal activities against *S. zeamais* attacking stored cereal grains in Nigeria and these botanicals were found to prove their efficacy, Most of these botanicals are not expensive, biodegradable, enviromental-friendly, less hazardous and locally available [67].

Repellency Potential of Botanical Products against *Sitophilus zeamais*

Lale [72] defined repellent as is any chemical that causes insects to make oriented movements away from the site of its application. Repellents are used in to an appropriate extent in the protection of stored agricultural commodities. In Nigeria, some plant species have been evaluated in the laboratory for their repellent activity against the maize weevils. For instance, Ogendo *et al.* [66] reported that leaf powders of *Lantana camara* and *Tephrosia vogelii* applied at varying doses were highly repellent against *S. zeamais* within 3 – 24 hours. However, no reasons were deduced on how mechanisms of the repellant actions of the plant powders were established.

Parugrug and Roxas [19] conducted a study and reported among leaf powder of *Azadirachta indica*, *Cymbopogon citrates*, *Lantana camara*, *Ocimum basilicum* and *Tegetes erecta*, *A. indica* and *L. camara* were highly repellant against *S. zeamais*, while *C. citrates*, *O. basilicum* and *T. erecta* showed moderate repellency. The suggested reason might be due to presence of volatile chemical compounds in the botanicals which made the insects adjusted with their odour [19].

Application of common spices to protect stored grains against insect pests has been described as a common practice in traditional Nigerian farm stores [69]. This was further proved when seed powder of *P. guineense* completely repelled adult *S. zeamais* from maize grains within 48 hours [69]. Also, repellent activity of *Hyptis spicigera* was assessed by Wekesa *et al.* [70] and recorded hight repellency of methanolic extracts of the botanical against *S. zeamais*

Another finding revealed the repellent activities of powders of *Citrus sinensis*, *Euphorbia balsamifera* and *Jatropha curcas* applied at 0.1, 0.2 and 0.3 g against *S. zeamais* after 1 to 24 hour exposure [71].

The significance of repellent materials in insect control cannot be undermined as they prevent insects from being established in a storage ecosystem through their emitted odours that drive the insects from a distance [72]. Hence, repellents reduce not only damage to stored grains, but also the oviposition, egg hatching and adult emergence of storage insect pests [34].

Toxicity Potential of Plant Products against *Sitophilus zeamais*

There have been a lot of research efforts to investigate the potentiality of plant materials on adult mortality of *S. zeamais* in stored cereal grains [33, 35, 40, 42, 43, 54, 55, 56, 57, 59, 60, 73]. It was also confirmed that some botanical extracts resulted in promising adult mortality of maize weevil in Nigeria. Suleiman *et al.* [74] investigated the insecticidal effect of leaf powders of *E. balsamifera*, *J. curcas* and *Lawsonia inermis* on *S. zeamais* infesting sorghum grains and found that all the three powders resulted in total (100%) mortality of the weevils. Similarly, the efficacy of methanolic extracts of *Z. zanthoxyloides* in the control of *S. zeamais* was reported [36]. The report showed that fresh bark extracts of the plant resulted in high adult mortality of the weevils in maize grains.

In a related development, Ashamo *et al.* [37] reported that ethanolic extracts of *Z. zanthoxyloides* and *Colocasia esculenta* resulted on almost complete mortality of maize weevil within the first post-treatment day. Agreeing with this, findings of Suleiman *et al*. [35] revealed that ethanolic leaf extracts of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* caused total mortality of adults of *S. zeamais* in sorghum grains.

Apart from mortality effect, biochemical and physiological parameters could be assessed to upraise the toxicity of insecticides against insect pests. These parameters may include but not limited to vetillogenin body protein and activity of acetycholinesterase (AChE) [75]. It was observed that reproductive capacity of many insects is disrupted when there is failure in the production of oocytes during vetillogenesis due to a lack of protein [14, 16, 53, 76]. Additionally AChE acts as a neurotransmitter by breaking down acetylcholine at the synaptic cleft so that next nerve impulse can pass across the synaptic gap [77]. When this activity is interfered, loss of coordination may likely occur, which could lead to knock-down and eventually death of the insect [97]. Halliru and Suleiman [54] reported that chloroform leaf extracts of *E. balsamifera*, *L. inermis* and *M. hirtus* significantly reduced the concentration of total body protein of *S. zeamais* and inhibited the activity of AChE in the insect body. This finding has uncovered that some botanicals have the potential of interfering with the role of total body protein and AChE in reproduction and neurotransmission in *S. zeamais*, respectively.

It could be concluded that different parts of many plant species have the ability of being toxic against *S. zeamais* infesting stored cereal grains. Application of botanicals could therefore be adopted in order to improve the storage condition of Nigerian cereal grains.

Oviposition Deterrence of Botanicals against *Sitophilus zeamais*

Effects of some botanicals on oviposition against *S. zeamais* have been reported by several researchers [79, 80, 81, 82]. For example, Edelduok *et al.* [79] reported that testa powder of melon reduced oviposition of *S. zeamais* at all dosages when compared with the control which signifies the insecticidal potentials of the plant species against the weevil. Also, Ileke [81] found that aqueous extracts of *Alstonia boonie* were effective in reducing the number of eggs laid by *S. zeamais*. It was further reported that cotyledon powder of *C. vulgaris* reduced the number of eggs deposited by *S. zeamais* in maize grains from 25.25 in the control to 1.25 in the treated grains [83].

Effects of Botanicals on Adult Emergence of *Sitophilus zeamais*

Powders and extracts of various botanicals have been evaluated to assess their effect in inhibiting emergence of F_1 progenies of *S. zeamais*. An example is seen in the findings of Udo [55] who reported a reduction in progeny production of *S. zeamais* in maize grains treated with different spicy powders at the dose of 5% (w/w). Agreeing with this, another finding revealed that root-bark powders of *Piptadeniastrum africanum* and *Aristolochia repens* completely inhibited the emergence of *S. zeamais* [83].

Another finding by Ileke and Oni [32] showed that extracts of *A. indica* and *A. boonei* greatly inhibited adult emergence of *S. zeamais* in wheat seeds to zero within six weeks post-treatment. This is strongly supported by Suleiman *et al*. [35] that ethanolic extracts of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* exhibited total inhibition in adult emergence of *S. zeamais* in treated sorghum grains.

Potential of Botanicals as Grain Potectants against *Sitophilus zeamais*

There have been efforts to investigate grain protectant ability of a number of plant products from *S. zeamais* infestations and/or damages in Nigeria [32, 55, 84]. One of the reports revealed that some spices protected maize from the weevil where grains treated with *A. sativum* lost less than 0.5% of their weight to *S. zeamais* [55]. Similarly, Arannilewa *et al.* [28] Observed a very good protectant ability of petroleum ether extracts of some medicinal plants on maize grains against the maize weevil.

Another instance happened when leaf powder of *C. papaya* was evaluated and found that it reduced grain damage in maize infested by *S. zeamais* [85]. This is in line with Mbah and Okoronkwo [34] who reported that leaf powder of *C. odorata* and fruit peels of *C. Limon* offered a drastic reduction in grain damage caused by the weevils. Also, Findings of Ileke and Oni [32] demonstrated the ability of powders of *A. indica* and *A. boonei* in protecting stored wheat from damage where less than 1% weight loss was recorded in the treated grains. This was advanced that no grain weight loss was recorded in maize grains treated with *Gossypium hirsutum* and *Brassica carinata* seed oils [86].

It could also be noted that findings of Suleiman [40] indicated that some spicy powders of *A. sativum*, *Capsicum frutescens* and *Z. officinale* were effective in reducing grain damage to less than 5% in stored sorghum infested by *S. zeamais*. To concur this, Akinbuluma *et al.* [59] reported that maize grains treated with ethanolic extracts of *C. frutescens* and *Dennetia tripetala* had better protection and lower weight loss than the untreated grains.

Reports by Olorunmota *et al.* [5] further revealed that powers and ashes of rice husk and melon shell were effective in the protection of maize grains against *S. zeamais*. The botanicals reduced grain weight loss to as low as zero to 0.33% within six weeks after treatment. It was further reported that botanical powders and ethanolic extracts of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* serving as natural grain protectants were effective in reducing grain damage of stored sorghum caused by *S. zeamais* [24].

Sitophilus zeamais infestations have been observed by Giga *et al.* [87] to deteriorate grain quality in addition to quantitative loss. It is noted that presence of *S. zeamais* in stored cereal grains may lead to both quantitative and qualitative damage [22]. The deterioration of grain quality might be as a result of changes in proximate and mineral components of the grain]88]. This is further explained that loss in grain quality sets in primarily from those changes that occur in the physical and chemical properties of the grains [89]. This is one of the major challenges facing food security in developing countries including Nigeria.

Despite the fact that several plant species have been tested to assess their grain protectant ability against *S. zeamais*, information on effects of botanicals on nutritional quality of grains infested by *S. zeamais* is scanty. However, Danjumma *et al.* [88] reported that powders of *A. indica*, *A. sativum*, *N. tabacum*, *O. basilicum*, *Z. officinale* applied at 1 and 2 g/50 g (w/w) decreased loss of organic compounds in treated maize grains. Also, reports of Suleiman and Abdullahi [90] reveal that leaf powders of *E. balsamifera*, *L. inermis*, *M. hirtus* and *S. obtusifolia* preserved the proximate content of sorghum grains infested by *S. zeamais* after 6 months of storage. It could therefore be inferred that botanicals could be utilized to prevent stored grains from both quantitative and qualitative losses caused by *S. zeamais*.

Challenges and their Strategic Solutions to Utilization of Bio-Pesticides in Nigeria

The challenges to utilization of bio-pesticides in Nigeria have been outlined by others [10, 91, 92]. Also, in order to enhance sustainable use of bio-pesticides under the framework of integrated pest management in Nigeria, strategic solutions to the problems have been recommended. One of the challenges of the application of plant products as bio-pesticides in Nigeria is that most of the data are obtained from laboratory experiments with little from field trials. Abubakar *et al.* [93] observed that most of the laboratory evaluations did not address the aspect of lethal concentrations of botanicals against insect pests. It is important that researchers need to look into this aspect to investigate on lethal doses/concentrations of various botanicals with insecticidal potentials. Rajashekar *et al.* [94] further observed that not much is documented on the toxicity of some botanicals on non-target animals, while tolerances for some have not been established. In view of this, it is recommended to conduct more field trials to upraise the insecticidal activities of those botanicals found effective in the laboratories. Additionally, since most of the grains commodities are stored for future use, further studies are neede to assess the effect of bio-pesticides against mammals in order to understand any potential vertebrate toxicity and ensure their safety for consumption as suggested by Golob *et al.* [97].

The quantity of botanicals to be applied to stored commodities is another challenge facing the utilization of bio-pesticides in Nigeria. Suleiman and Rugumamu [10] observed that it would be difficult to collect enough plant material for treatment of medium to large scale grains [97]. To overcome this challenge, large-scale production of botanicals with insecticidal properties is required. Also, plant products with repellent properties could help in this regard.

Another constraint is that most farmers have the perception that the use of bio-pesticides is a traditional method and considered not efficient to protect stored products against insect pests [91]. To overcome this, there is need for sensitization on the availability and promising effects of bio-pesticides so that farmers and other grain processors would understand the benefits of the utilization of botanicals in the management of *S. zeamais*.

Table 1: List of some plants species tested for insecticidal activities against *Sitophilus zeamais* in Nigeria and reported during the period of 2011 to 2021

Plant Species	Common Name	Family	Part(s) Used	Formulation(s)	Reference(s)
Allium sativum L	Garlic	Amaryllidaceae	Bulbs	Powder	Suleiman [40]
Alstonia boonei De Wild	Cheesewood	Apocynaceae	Stembark	Powder	Ojo and Ogunleye [83]
Anacardium occidentale L.	Cashew	Anacardiaceae	Nuts	Extracts	Adedire *et al.* [95]
Aristolochia repens Miller	Dutchman's pipe	Aristolochiaceae	Stem	Powder	Ojo and Ogunleye [83]
Azadirachta indica A. Juss	Neem	Meliaceae	Leaves	Extracts	Babarinde *et al.* [96]
Capsicum frutescens L	Chilli pepper	Solanaceae	Fruits	Powder, Extracts	Suleiman [40], Akinbulama *et al.* [59]
Carica papaya (L.)	Pawpaw	Caricaceae	Leaves	Powder	Onimunya *et al.* [7]
Citrus sinensis L.	Orange	Rutaceae	Peels	Powder	Suleiman *et al.* [71]
Cucumis melo L.	Melon	Curcubitaceae	Melon shell	Ash, Powder	Olorunmota *et al.* [5]
Delonix regia (Bojer ex Hook.) Raf.	Flamboyant	Fabaceae	Seeds	Powder, Extracts	Ajayi [73]
Dennettia tripetala Bak F.	Pepperfruit	Annonaceae	Fruits	Extracts	Akinbulama *et al.* [59]
Eucalyptus camaldulensis (Dehnh.)	River red gum	Myrtaceae	Leaves	Powder	Onimunya *et al.* [7]
Euphorbia balsamifera Aiton	Balsam spurge	Euphorbiaceae	Leaves	Powder, Extracts	Suleiman *et al.* [74], [53]
Garcinia kola (Heckel)	Bitter kola	Guttiferae	Seed	Powder	Ojo and Ogunleye [83]
Jatropha curcs L.	Physic nut	Euphorbiaceae	Leaves	Powder	Suleiman *et al.* [74]
Lawsonia inermis L.	Henna	Lythraceae	Leaves	Powder, Extracts	Suleiman *et al.* [74]
Leptadenia hastata L.	Decne	Asclepiadaceae	Leaves	Powder	Suleiman *et al.* [71]
Mangifera indica (L.)	Mango	Anacardiaceae	Leaves	Powder	Onimunya *et al.* [7]
Mitracarpus hirtus (L.) DC	Button grass	Rubiaceae	Leaves	Extracts	Suleiman [65]
Nicotiana tabacum (L.)	Tobacco	Solanaceae	Leaves	Powder	Onimunya *et al.* [7]
Oryza sativa L.	Rice	Poaceae	Rice husk	Ash, Powder	Olorunmota *et al.* [5]
Picralima nitida Stapf Th. & H. Dur.	Picralima	Apocynaceae	Seeds	Powder	Ojo and Ogunleye [83]
Piper guineense Schum. & Thonn.	Black pepper	Piperaceae	Seeds	Powder	Ojo and Ogunleye [83]
Piptadeniastrum africanum (Hook. F.) Brenan	Dahoma	Fabaceae	Leaves, Rootbark	Powder	Ojo and Ogunleye [83]
Sclerocarya birrea A. Rich	Marula	Anacardiaceae	Leaves, Bark	Extracts	Babarinde *et al.* [96]
Senna obtusifolia L.	Coffee weed	Fabaceae	Leaves	Extracts	Suleiman [65]
Xylopia aethiopica (Dunal) A. Rich.	Ethiopian pepper	Annonaceae	Fruit	Powder	Ojo and Ogunleye [83]
Zingiber officinale Rosc	Ginger	Zingiberaceae	Rhizomes	Powder	Suleiman [40]

Conclusion

Findings of this paper have revealed that *S. zeamais* is destructive insect pests infesting stored grains which results in serious post-harvest losses, economic constraint and hence general food insecurity in Nigeria. Considering the significance of achieving food security and safety, it is necessary to search for effective pest management strategies for small-scale farmers. To achieve this, a variety of approaches such as physical, cultural, biological and application of synthetic insecticides are employed for the control of post-harvest insect pests. In order to reduce the usage of chemical insecticides, several botanicals in various formulations could be applied to manage *S. zeamais* infesting stored grains (Table 1). Insecticidal activities of various plant materials in terms of repellent actions, adult mortality, oviposition deterrence, adult emergence inhibition and reduction in grain damages against *S. zeamais* have been assessed with recorded success. Also, some botanicals have been reported to be effective in reducing concentration of body protein and inhibit the activity of AChE in *S. zeamais* body. In order to search for environmental-friendly and alternative methods to chemical insecticides, more research activities on the application of plant products to control *S. zeamais* and other insect pests of stored grains in Nigerian storage structures is recommended.

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