NIGERIAN AGRICULTURAL JOURNAL
ISSN: 0300-368X
Volume 50 Number 1, April 2019. Pp.37-45
Available online at: http://www.ajol.info/index.php/naj

ASSESSMENT OF PLANT POWDERS AS PROTECTANTS OF STORED MAIZE GRAINS AGAINST MAIZE WEEVIL, *Sitophilus zeamais* (MOTSCH). [COLEOPTERA: CURCULIONIDAE]

***Ehisianya, C.N., Ikpi, P.O., Okore, O.O. and Obeagu, I.A.**
[1]Department of Zoology and Environmental Biology, Michael Okpara University of Agriculture, Umudike, P.M.B. 7267, Umuahia, Abia State, Nigeria
*Corresponding Authors' email:cnehisianya@gmail.com

ABSTRACT
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 the maize weevil (*Sitophilus zeamais*) infestation and their viability was subsequently tested. The plant powders were mixed with 100g of maize and infested with 30 adults (20 females and 10 males) *S. zeamais* in 200 ml glass vials and kept under ambient conditions (25 - 30°C and 70 - 90% RH) between July and September, 2017. Treatments were arranged in a completely randomized design, and replicated four times at the Department of Zoology and Environmental Biology, Michael Okpara University of Agriculture, Abia State, Umudike, Nigeria. At 1 week after infestation, all adults were sieved out and the setup kept undisturbed for 5 weeks. Results showed that the mean progeny emergence, weight loss, and percentage grain damage by *S. zeamais* significantly ($P \leq 0.05$) decreased with increased dosage of plant powders. Cypermethrin treated grain gave significantly ($P \leq 0.05$) lower values than those treated with plant powders in all parameters tested. Significantly ($P \leq 0.05$) lower mean progeny emergence (3.0 and 3.5), and grain weight loss (1.1 and 1.30g) was recorded in *I. cylindrica* and *S. acuta*, respectively in 7.5g/100g grains compared with (9.3 and 15.0) and (2.9 and 4.3g) in *C. odorata* and *G. arborea*, respectively. However, these treatments did not significantly affect seed germination. These findings indicate that the plant powders used could serve as a safer alternative to synthetic insecticides for the control of *S. zeamai*s in stored maize grains.

Keywords: Esa'ma yewangha, Plant powders, Protectants, and Sitophilus zeamais

Introduction
Maize (*Zea mays* L.) is a major food security crop in Africa and it is usually stored to provide food reserves and also seed materials for planting (Mulungu *et al.*, 2007). In 2016, maize production for Nigeria was estimated at 10.4mt (World Data Atlas, 2016). The popularity and high acceptability of maize have been based on their low cost and versatility in food preparation (Okonkwo and Okoye, 1996). It can be boiled fresh or dry and eaten alone or with other food items such as peas, coconut and groundnut (Elegbede, 1998). It can also be processed into starch or cooked into porridge, fried into popcorn or milled into flour and used for delicacies such as *Ogi* (pap) or *Agidi* (Elegbede, 1998; Agboola and Fayemi, 1999; Iken, and Amusa, 2004). Climatic conditions in the tropics favor the cultivation of numerous food crops but also favor the development and proliferation of storage pests, which can cause considerable damage in storage and constitute an obstacle to processing (Sousa *et al.*, 2009; Jahromi *et al.*, 2012). Stored-product pests are economically important because they attack the final agricultural product. Despite high maize yields, losses in storage are high due to the maize weevil, *Sitophilus zeamais*, especially among smallholder farmers. The maize weevil is a serious pest of stored maize, causing qualitative and quantitative losses. In terms of protection of natural resources or from economic considerations, it is more reasonable to protect harvested produce against loss than to invest in further increases in agricultural production.

Insecticides of plant origin have played an important role in the traditional methods of protection against grain pests (Stancic *et al.*, 2011; Jahromi *et al.*, 2012). It has also been shown that the presence of *S. zeamais* in maize grains harvested led to a reduction in both weight and germination capacity of the grains (Ukeh *et al.,* 2008). Previously, the control of storage insects like *S. zeamais* has centered mainly on the use of chemical insecticides that are hampered by many attendant problems such as toxicity to humans that consume the product, development of insect resistant strains and the cost of procurement (Subramanyam and Hagstrum, 2000). The use of more natural and sustainable methods that can offer compatible control efficiency plus the benefit of reduced hazards to the environment is most favoured (Arabi, 2008; Abdelgaleil, 2009).

In this study, the efficacies of four plant powders as possible stored maize grain protectants against *S. zeamais* were investigated.

Materials and Methods

Study Area

The experiment was conducted to determine the toxicity and subsequent viability of selected plant powders in the Department of Zoology and Environmental Biology, Michael Okpara University of Agriculture, Umudike (MOUAU), Abia State in South Eastern Nigeria. Umudike is located on latitude 5°22′ North and longitude 7°33′E and an altitude of 122 m above sea level (NRCRI, 2010).

Insect Culture

Culture of *S. zeamais* was obtained from infested maize grains from the Department of Zoology and Environmental Biology. The food medium (healthy and whole un-infested dry landrace maize grains, *Esa'ma yewangha*) used for the bioassay was purchased from Ugep in Cross River State, and preserved in the refrigerator at -5ºC to disinfest the grains prior to the experiment. Treatments were laid out in a completely randomized design (CRD) with four replications.

Plant Materials Collection and Preparation

Fresh leaves of Siam weed (Asteraceae), Wire weed (Malvaceae), and Spear grass (Poaceae), and Gmelina (Lamiaceae) were collected from fields at Umudike and shed-dried naturally at a temperatures 25±2°C until they became crisp dry. The dried leaves were crushed into powder using pestle and mortar and kept separately in vials and stored at room temperature until needed.

Cypermethrin powder (Trade Name: Pestox, Ingredients: Cypermethrin 2.3%, Talc 97.5% and Fragrance 0.2% with manufacturing and expiry date of 04-2016 and 12-2018 was bought from an Agrochemicals Shop in Umuahia, Abia State and stored in a cool dry place in the laboratory as directed by the manufacturer to effectively maintain its shelf life.

Effect of Plant Powders on Weevil Adult Emergence

Hundred grammes of maize grains were weighed using an electronic sensitive balance (J2003 Model) and poured into 200ml glass jars with lids covered with muslin cloth. The botanical treatments were applied at rates of 0 (control), 2.5g, 5g and 7.5g. Cypermethrin powder was used as check and applied at same rate with botanicals. The grains were thoroughly mixed with the treatments before introducing *S. zeamais*. Thirty F_1 progeny of adult *S. zeamais* were introduced into each jar and left undisturbed on the laboratory bench. At 1 week after infestation, all dead and live insects were sieved out and the setup kept undisturbed for 5 weeks for F_1 progeny emergence. Weevils emerging from each treatment five weeks after the withdrawal of both live and dead adult weevils were counted and recorded to give a measure of effects of powders on weevil reproduction (adult emergence test). Emerging insects were sieved off subsequently every day to prevent mating and subsequent oviposition by F_1 as mating in *S. zeamais* does not occur before weevils are 3 days old (Walgenbach and Burkholder, 1987). The effects of treatment on reproduction of insects were determined using the reproductive potential deterrence formula:

$$\% \text{ Rd} = \{(\text{Cn} - \text{Tn})/\text{Cn}\}*100,$$

Where, Rd = Reproductive deterrence, Cn = Number of newly emerged adults in untreated (control) jar, Tn = Number of newly emerged adults in treated jar.

Damage Assessment and Weight Loss

Damage assessment was carried out on treated and untreated grains after progeny emergence was no longer noticed. The number of damaged (grains with characteristic holes) and undamaged grains from each treatment were counted and weighed. Percentage infestation was calculated using the formula:

$$\% \text{ Infestation} = \{(N_2)/ N_1\}* 100$$

Where, N_1= Total number of grains per jar; N_2= Number of infested grains per jar.

The weight of the substrate (maize grains) was taken in batches at termination of the experiment using the above mentioned electronic sensitive balance and the difference in weight was recorded. Percentage weight loss was calculated using the formula:

$$\% \text{ Weight loss} = \{(C - T)/T\}* 100$$

Where, C= Initial weight (g); T = final weight (g)

Viability Test

Viability test was carried out to assess the effect of the plant powders on post storage maize germination using 16 maize seeds randomly selected from each replicate after separation of damaged and undamaged grains from each jar. The seeds were planted in transparent labeled perforated plastic pots containing loamy soil (850g/pot to ensure all grains got equal amount of loam) at a depth of 2cm each and irrigated every 3 days and left outdoor. Germination and viability were assessed 15 days after planting (DAP) by calculating the mean number of seeds germinated out of the total mean number planted in each experimental pot. Viability was calculated using the methods of Zibokere (1994) as follows:

$$\text{Viability index (\%)} = (\text{NG}*100)/\text{TG}$$

Where NG = number of seeds that germinated, TG = total number of tested seeds

Statistical Analysis

Data on *S. zeamais* progeny emergence, weight loss and damage (%) were subjected to one-way and two-way analysis of variance, using SAS software version 8(2) (SAS, 2001). Significant means were separated using Studentized Newman Keul's (SNK) test (P=0.05).

Results and Discussion

Table 1 presents the mean progeny emergence of *S. zeamais* on maize grains treated with different plant powders and Cypermethrin at 2.5, 5.0 and 7.5g/100g grain. Treatments significantly ($P \leq 0.05$) reduced mean adult progeny at varying degrees. There were significant differences in mean progeny that emerged in Cypermethrin (0.0), *I. cylindrica* (5.0) and *G. arborea* (23.5), and 67.8 in the control. A similar trend was observed in 5.0 and 7.5g/100g treated grains.

Pooled mean progeny of *S. zeamais* in stored maize grains treated with 0, 2.5, 5 and 7.5g/100g plant powders showed no significant differences in 5.0g (6.80) and 7.5g (6.15), but were significantly ($P \leq 0.05$) lower than 2.5g (10.45), and the control (61.80) (Fig. 1).

Significantly ($P \leq 0.05$) higher damage was recorded on the control (67.8%) compared with batches of maize grains treated with *C odorata* (28.7g), *I. cylindrica* (10.8%), and Cypermethrin (0.01g) at 5.0g plant powders (Table 2).

Figure 2 presents the pooled mean progeny of *S. zeamais* in stored maize gains treated with plant powders. Significantly ($P \leq 0.05$) higher adult progeny were counted in *G. arborea* (31.56), followed by *C. odorata* (27.62), and Cypermethrin (12.75) was the least.

Analyses of variance on data from grains treated with 2.5, 5.0 and 7.5g plant powders showed significantly ($P \leq 0.05$) lower mean weight losses in grains with Cypermethrin (0.1, 0.0 and 0.0g) compared with those treated with *C. odorata* (3.9, 3.0 and 2.9g), and the most damaged was *G.arborea* (6.6, 4.8 and 4.3g) (Table 3).

Pooled mean damage (%) by *S. zeamais* to maize grains treated with 0, 2.5, 5 and 7.5 g plant powders is shown in Fig. 3. Mean percentage damage caused by *S. zeamais* on treated maize grain were not significantly different, but they were significantly ($P \leq 0.05$) lower than the control (0.0g).

Significantly ($P \leq 0.05$) lower grain damage was recorded in Cypermethrin (19.32g) treated grains than those treated with plant powders. It was followed by *I. cylindrical* (25.77g), whereas *G. arborea* (35.95g) gave the highest grain damage (Fig. 4).

Pooled mean weight loss (g) by *S. zeamais* to maize grains treated with 0, 2.5, 5 and 7.5 g plant powders is shown in Fig. 5. Mean weight loss caused by *S. zeamais* on treated maize grain was not significantly different, but they were significantly ($P \leq 0.05$) lower than the control (0.0g).

Significantly ($P \leq 0.05$) lower grain weight loss was recorded in Cypermethrin (8.68g) treated grains than those treated with plant powders. It was followed by *I. cylindrical* (8.05g), whereas *G. arborea* (13.51g) gave the highest grain damage (Fig. 6).

The mean germination (%) of maize grains treated with plant powders is presented in Table 4. Irrespective of the plant powders and dosages applied, mean germination (%) of planted maize grains were not significantly different from each other.

Irrespective of treatment dosages, there were also no significant differences in the pooled germination (%) of treated grains (Fig. 7). However, pooled germination (%) in plant powders treated grains were also not significantly different from each other, but were significantly lower than the untreated grains (23.2%) (Fig. 8) compared to treatments at 2.5g (64.5%), 5.0g (70.5%), and 7.5g (75.8%).

Plant powders from *G. arborea, C. odorata, I. cylindrica* and *S. acuta* significantly reduced adult *S. zeamais* emergence on stored maize grains. Significantly lower mean progeny emergence observed in *I. cylindrica* and *S. acuta*, at a rate of 7.5g/100g grains. These powders appear to either completely hindered oviposition or significantly reduced adult *S. zeamais* emergence indicating their potential for use in the management of this pest in stored maize grains. This result corroborate the findings of Marilei *et al.* (2010) that 40 g of corn treated with 6g of the extracts from leave and seeds extracts from neem can be considered as a viable alternative for controlling *S. zeamais* in stored corn. A similar work by Shiberu and Negeri (2017) in Ambo University, Ethiopia suggested that Pyrethrum flower, neem leaf (*Azadirachta indica*) and seed powder can replace chemical insecticides against *S. zeamais* due to their higher high mortality, lower grain damage and lower maize weight losses recorded as compared to untreated and synthetic insecticides. The results also buttress previous studies by Ivbijaro (1983) against *S. zeamais* with neem; Obeng-Ofori and Amiteye (2005) with vegetable oil and pirimiphosmethyl; Babarinde *et al.,* (2008) with *Xylopia aethopica* seed extract. In previous studies, *P. glandulosus* powder and neem seed powder greatly inhibited progeny production of *S. zeamais* (Chouka, 2007; Nukenine *et al.,* 2007).

The feeding ability of *S. zeamais* larvae is depicted by the grain weight loss. This study revealed that *I.*

cylindrica and *S. acuta* treated maize grains recorded significantly lower grain weight loss. This might be attributed to the high weevil mortality and low survival rate which controlled oviposition caused by treatments applied. The plant powders may act as fumigant, repellent, stomach poison and physical barrier (block the spiracles and impair respiration) (Law-Ogbomo and Enobakhare, 2007; Mulungu *et al*., 2007). The results of the current study confirmed the previous work of Wanyika *et al*. (2009) that *C. cinerariaefolium* affected the survival rate of adult weevils in treatments (5.0 and 7.5 g) with a mortality rate range from 76.66 to 100%.

Parwada *et al.,* (2012) reported that ground plant extracts act by dehydrating and suffocating the weevil and also by reducing weevil movements thereby resulting in reduced grain damage and weight loss. This is similar to grain weight loss in this study observed in grains treated with plant powder and Cypermethrin. Cypermethrin recorded the least grain weight loss. These findings are in agreement with Chiu (1989) who observed that synthetic dusts like Cypermethrin 1% was effective in protecting stored grains thereby reducing loss of grain weight.

Viability test revealed that botanical treatments had no inhibitory effect on the germination of maize seeds. Seed quality is the prerequisite conditions that affects the germination and hence the yield of the crops (Msuya and Stefano, 2010). Some studies have also demonstrated that oils and leaf powders of several plant species have no adverse effects on the germination of maize grain when applied as grain protectants (Manezhe *et al.,* 2004; Ogendo *et al.,* 2004). The results also agrees with an earlier work by Ogban *et al.,*(2015) in Calabar, Nigeria that there was no deleterious effect on the germination of maize seeds treated with different concentrations of *Acmella oleraceae* and *Lantana camara*. Musundire *et al.* (2015) reported that *Eucalyptus grandis* and *Tagetes minuta* leaf powders effectively protected stored maize against *S. zeamais* without affecting grain organoleptic properties. Schaafsma and Tamburic-Ilincic, (2005) and Toklu *et al*, (2015) concluded that seed treatments can significantly increase yield compared to nontreated controls. Performance in growth and yield of maize grains could be attributed to increased photosynthetic efficiency and the ability of the soil to supply the nutrient elements necessary to promote more vigorous growth, improve meristematic and physiological activities in the plants (Agba *et al.,* 2012).

Conclusion

The insecticidal properties of *I. cylindrica* and *S. acuta* are revealed in this study which could be adopted as protectants of stored maize grain against *S. zeamai*s. Results also proved that plant powders had no adverse effect on the viability of maize seeds thereby enhancing yield. These findings indicate that the plant powders used could serve as a safer alternative to synthetic insecticides for the control of *S. zeamai*s in stored maize grains.

Acknowledgements

The authors appreciate Mr. Pipi Okechukwu and Mrs Annada Hillary for keeping the laboratory optimal for this study.

References

Abdelgaleil, S. (2009). Fumigant and contact toxicity of monoterpenes to *Sitophilus oryzae* (L.) and *Tribolium castenum* Herbst and their inhibitory effects on acetylcholinesterace activity. *J. Chem. Ecol.*, 42:1-8.

Agba, O., A., Ubi, B. E., Abam, P., Ogbechi, J., Akeh, M., Odey, S. and Ogar, N. (2012). Evaluation of agronomic performance of maize (*Zea mays* L.) under different Rates of poultry manure application in an Ultisol of Obubra, Cross River State, Nigeria. *Inter. J. Agric. Forest.*, 2(4): 138-144

Agboola, A., A. and Fayem,i A. A. (1999). Preliminary trials on intercropping of maize with different tropical legumes in western Nigeria. *Nig. J. Agric. Sci.*, 71: 219-225.

Arabi, F. (2008). Chemical composition and insecticidal activity of essential oil from *Perovskia abrotanoides* (Lamiaceae) against *Sitophilus oryza* (Coleoptera: Curculionidae) and *Tribolium caestanum* (Coleoptera: Tenebrionidae). *Inter. J. Trop. Insect Sci.*, 28(3):2-8.

Chiu, S. F. (1989). Recent findings on Meliaceae and other promising botanical insecticides in China. *J. Plant Insects Dis. Prot.*, 36: 310-319.

Chouka, P. F. (2007). Powder toxicity of plants from northern Cameroon on *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) and the influence of particle size and mode of drying on their insecticidal efficacy. Postgraduate Dissertation, faculty of Science, University of Ngaoundéré, Cameroon. 58pp.

Elegbede, J. A. (1998). Legumes: Nutritional quality of plant foods. Ethiope Publishing Corporation, Benin City. Pp 205.

FAO, (2007). Food and Agriculture Organization Document. http://www.fao.org/inpho/maaize (Feb. 27, 2018)

Iken, J. E. and Amusa, N. A. (2004). Maize research and production in Nigeria. *Afr. J. Biotechnol*., 3: 302 - 307

IITA, (2003). International Institute of Tropical Agriculture Research Guide 30, IITA Training Program PMB 5320, Ibadan, Nigeria. Pp. 43.

Ivbijaro, M. F. (1983). Prevention of cowpea, *Vigna unquiculata* Walp. with the neem seed, *Azadiracta indica. Juss. Protect. Ecol.,* 5: 177 - 182.

Jahromi, M. G, Pourmirza, A. A and Safaralizadeh, M. H. (2012). Repellent effects of sirino (garlic emulsion) against *Lasioderma serricorne* (Coleoptera: Anobiidae) and *Tribolium castaneum*

(Coleoptera: Tenebrionidae) by three laboratory methods. *Afr. J. Biotechnol.* 11(2): 280-288

Law-Ogbomo, K. E., and Enobakhare, D. A. (2007). The use of leaf powders of *Ocimum gratissimum* and *Vernonia amygladina* for the management of *Sitophilus oryzae* (L.) in stored rice. *J. Entomol*. 4: 253-257

Manezhe, N. J., Potgieter, N. and Mabinya, L. V. (2004). Antimicrobial activities of volatile components of *Lippia javanica*. *Phytochem.*, 65:2333-2336.

Marilei, N. S., Alberto, C. V., Augusto, T. A. P. and Heron, O. S. L. (2010). Leaves, stems and seeds powder of neem (*Azadirachta indica* A. Juss.) used as repellent of *Sitophilus zeamais* (Coleoptera: Curculionidae) in stored corn. *Brazilian J. Food Res.*, 1(1): 21- 24.

Msuya, D. G. and Stefano, J. (2010). Responses of Maize (*Zea mays*) Seed germination capacity and vigour to seed selection based on size of cob and selective threshing. *World J. Agric. Sc.*, 6:683-688

Mulungu, L., Lupenza, G., Reuben, S. and Misangu, R. (2007). Evaluation of botanical products as stored grain protectant against maize weevil, *Sitophilus zeamais* (L.) on maize. *J. Entomol,* 4: 258-262

Musundire, R., Mazodze, F., Macheka, L., Ngadze, R. T., Mubaiwa, J. and Manditsera, F. (2015). *Eucalyptus grandis* and *Tagetes minuta* leaf powders effectively protect stored maize against *Sitophilus zeamais* without affecting grain organoleptic properties. *Afr. J. Agric. Res.*, 10(2): 49-57

NRCRI, (2010). National Root Crops Research Institute, Umudike. Annual Report 2010. Federal Ministry of Agriculture. Pp 45.

Nukenine, E. N., Adler, C. and Reichmuth, C. (2007). Efficacy evaluation of plant powders from Cameroon as postharvest grain protectants against the infestation of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). *J. Plant Dis. Prot.*, 114: 30–36.

Obeng-Ofori, D. and Amiteye, S. (2005). Efficacy of mixing vegetable oils with pirimiphos-methyl against the maize weevil, *Sitophilus zeamais* Motschulsky in stored maize. *J. Stored Prod. Res.*, 41: 57-66.

Ogban, E., Ukpong, I. Oku, E., Usua, E., Udo, S., Ogbeche, J. and Ajang, R. (2015). Potentials of two indigenous plants powder for the control of stored maize weevil, *Sitophilus zeamais* (Motschulsky). *Am. J. Exp. Agric.*, 5(1): 12-17

Ogendo, J. O., Deng, A. L., Belmain, S. R., Walker, D. J. and Musandu, A. A. O. (2004). Effect of insecticidal plant materials, *Lantana camara* L. and *Tephrosia vogelii* Hook, on the quality parameters of stored maize grains. *Afr. J. Food Technol.*, 9:29-36

Okonkwo, E. U. and Okoye, W. I. (1996). The efficacy of four seed powders and the essential oils as protectants of cowpea and maize grains infestation by *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae) and *Sitophilus zeamais* (Mots.) (Coleoptera:Curculionidae) in Nigeria. *Inter. J. Pest Manage.* 42 (3): 143-146.

Parwada, C., Gadzirayi, C., Karavina, C., Kubiku, F., Mandumbu, R. and Madumbu, B. Z. (2012). *Tagetes minuta* formulation effect *Sitophilus zeamais* (weevils) control in stored maize grain. *Inter. J. Plant Res.*, 2(3): 65-68

SAS Institute (2001). The Statistical Analytical Systems for windows. Release 8.1. Cary. North Carolina, USA

Schaafsma, A. W. and Tamburic-Ilincic, L. (2005). Effect of Seeding Rate and Seed Treatment Fungicides on Agronomic Performance, Fusarium Head Blight Symptoms, and DON Accumulation in Two Winter Wheats. *Plant Dis.*, 89 (10):1109-1113

Shiberu, T. and Negeri, M. (2017). Determination of the appropriate doses of promising botanical powders against maize weevil, *Sitophilus zeamais* Mots (Coleoptera: Curculionidae) on maize grain. *J. Stored Prod. Postharvest Res.* 8(4): 49 – 53.

Sousa, A., Faroni, L., Pimentel, M. and Guedes, R. (2009). Developmental and population growth rates of phosphine-resistant and susceptible populations of stored product insect pests. *J. Stored Prod. Res.*, 45:241-246.

Stancic, M. R., Coprean, D., Sava, D. Dobrinas, S. Miron, L and Schiopu, S. (2011). Use of Garlic, *Absinthium* and *Celandine* extract as natural repellents. *Env. Engineer. Manage. J.*, 10(3):445-449.

Subramanyam, B. and Hagstrum, D. W. (2000). Botanicals. In: B. Subramanyam and DW. Hagstrum (Ed,), Alternatives to Pesticides in Stored Products, IPM, Boston: Academic.

Toklu, F., Baloch, F. S. Karaköy, T. and Özkan, H. (2015). Effects of different priming applications on seed germination and some agromorphological characteristics of bread wheat (*Triticum aestivum* L.). *Turk. J. Agric. Forest.*, 39: 1005-1013

Ukeh, D., Arong, G. and Ogban, E. (2008). Toxicity and oviposition deterrence of *Piper guineense* (Piperaceae) and *Monodora myristica* (Annonaceae) against *Sitophilus zeamais* (Motsch.) on stored maize. *J. Entomol.*, 5(4):295-299.

Walgenbach, C. A. and Burkholder, W. E. (1987). Mating behavoiur of the maize weevil, *Sitophilus zeamais* (Coleoptera: Curculionidae). *Annals Entomol. Soc. Am.*, 80(5): 578-583.

Wanyika, H. N., Kareru, P. G., Keriko, J. M., Gachanja, A. N., Kenji, N. J. and Mukiira, G. M. (2009). Contact toxicity of some fixed plant oils and stabilized natural pyrethrum extracts against adult maize weevils (*Sitophilus zeamais* Motsch.). *Afr. J. Pharm. Pharmacol.* 3(2):066-069.

Zibokere, D. S. (1994). Insecticidal potency of red pepper (*Capsicum annuum*) on pulse beetle (*Callosobruchus maculatus*) infesting cowpea (*Vigna unguiculata*) seeds during storage. *Ind. J. Agric. Sci.* 64:727-728.

World Data Atlas (2016). https://knoema.com/atlas/Nigeria/topics/Agriculture/Crops-Production-Quantity-tonnes/Maize-production accessed 12/09/2018

Table 1: Progeny emergence (Mean±SE) of *Sitophilus zeamais* in stored maize grains treated with four selected plant powders and an insecticide at 5WAT

Control (0g)	Dosage (g)	*C. odorata*	*G. arborea*	*I. cylindrica*	*S. acuta*	Cypermethrin
61.8(±2.5)	**2.5**	14.0 (±3.8)[b]	23.5 (±1.9)[a]	5.0 (±0.6)[bc]	9.8 (±3.9)[b]	0.0 (±0.0)[c]
	5.0	10.3 (±3.4)[b]	15.8 (±1.2)[a]	3.5 (±0.7)[c]	4.5 (±0.7)[c]	0.0 (±0.0)[c]
	7.5	9.3 (±2.1)[b]	15.0 (±2.3)[a]	3.0 (±0.4)[c]	3.5 (±1.9)[c]	0.0 (±0.0)[c]

Each value is the mean of 4 replicates. WAT= Weeks after Treatment. Different letters within rows indicate significant differences at $p > 0.05$ (Proc. GLM, SNK)

Table 2: Percentage damage (mean ± SE) of stored maize grains treated with four selected plant powders and an insecticide by *Sitophilus zeamais*

Control (0g)	Dosage (g)	*C. odorata*	*G. arborea*	*I. cylindrica*	*S. acuta*	Cypermethrin
67.8 (±1.2)	**2.5**	25.0 (±3.7)[ab]	27.8 (±6.1)[a]	11.5 (±2.6)[bc]	22.7 (±2.1)[ab]	0.1 (±0.0)[c]
	5.0	23.1 (±1.1)[a]	28.7 (±5.1)[a]	10.8 (±1.3)[b]	19.4 (±3.1)[a]	0.1 (±0.1)[c]
	7.5	19.5 (±5.3)[a]	21.5 (±5.2)[a]	10.3 (±1.3)[ab]	14.8 (±2.3)[a]	0.0 (±0.00)[b]

Each value is the mean of 4 replicates. Different letters within rows indicate significant differences at P> 0.05 (Proc. GLM, SNK)

Table 3: Weight loss (mean ± standard error) of maize grains treated with plant powders and an insecticide

Control (g)	Dosage (g)	*C. odorata*	*G. arborea*	*I. cylindrica*	*S. acuta*	Cypermethrin
31.5(±1.0)	**2.5**	3.9 (±1.1)[b]	6.6. (±1.0)[a]	1.8 (±0.2)[bc]	2.1 (±0.1)[bc]	0.1 (±0.1)[c]
	5.0	3.0 (±0.7)[b]	4.8 (±0.4)[a]	1.4 (±0.2[bc]	1.4 (±0.6)[c]	0.0 (±0.0)[c]
	7.5	2.9 (±0.8)[b]	4.3 (±0.6)[a]	1.1 (±0.1)[c]	1.3 (±0.3)[c]	0.0 (±0.0)[c]

Each value is the mean of 4 replicates. Different letters within rows indicate significant differences at P> 0.05 (Proc GLM, SNK)

Table 4: Mean (±SE) percentage germination (seed viability) of maize grains treated with selected botanical concentrations

Control (0g)	Dosage (g)	*C. odorata*	*G. arborea*	*I. cylindrica*	*S. acuta*	Cypermethrin
23.2(±4.1)	**2.5**	63.8 (±9.4)[a]	56.2 (±3.8)[a]	67.5 (±7.5)[a]	63.8 (9.4)[a]	71.2 (±11.3)[a]
	5.0	63.8 (±3.4)[a]	67.5 (±7.5)[a]	75.0 (±8.4)[a]	71.2 (±11.3)[a]	75.0 (±8.7)[a]
	7.5	75.0 (±8.7)[a]	75.0 (±8.7)[a]	82.5 (±7.5)[a]	71.2 (±11.3)[a]	75.0 (±8.7)[a]

Each value is the mean of 4 replicates. Mean Percentage germination are Arcsine values to which (Proc GLM, SNK are applicable

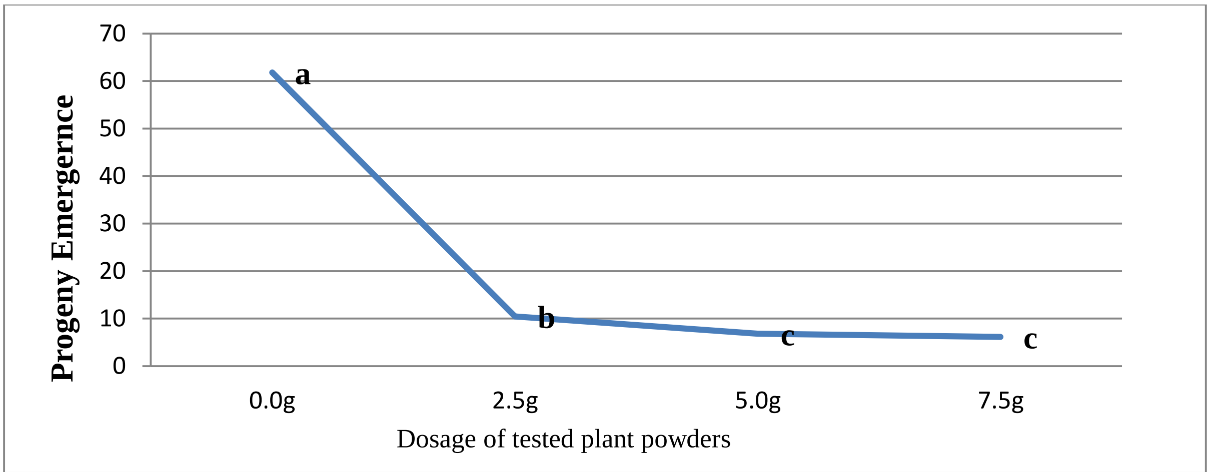

Figure 1: Pooled mean progeny of *Sitophilus zeamais* in stored maize grains treated with plant powders
Different letters indicate significant differences at P> 0.05 (Proc. GLM, SNK)

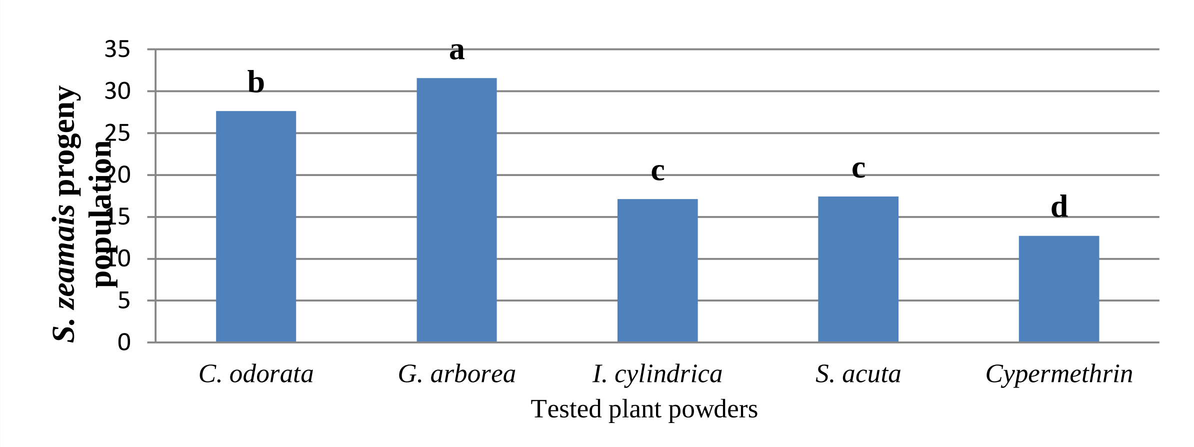

Figure 2: Pooled mean progeny of *Sitophilus zeamais* in stored maize grains treated with plant powders
Different letters above the bars indicate significant differences at P> 0.05 (Proc. GLM, SNK)

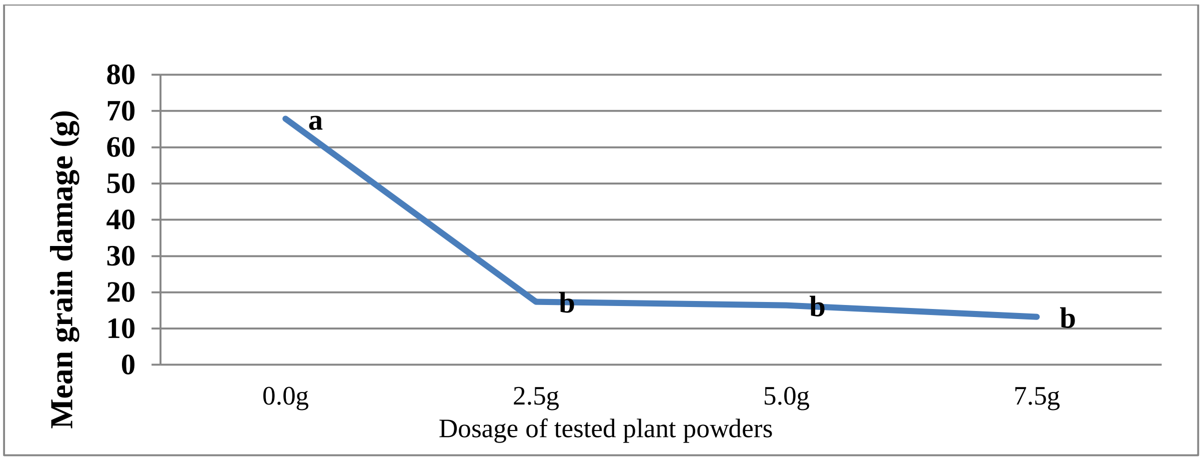

Figure 3. Pooled mean damage (%) by *Sitophilus zeamais* to maize grains treated with 0, 2.5, 5 and 7.5 g plant powders.
Different letters indicate significant differences at $P \leq 0.05$ (Proc. GLM, SNK)

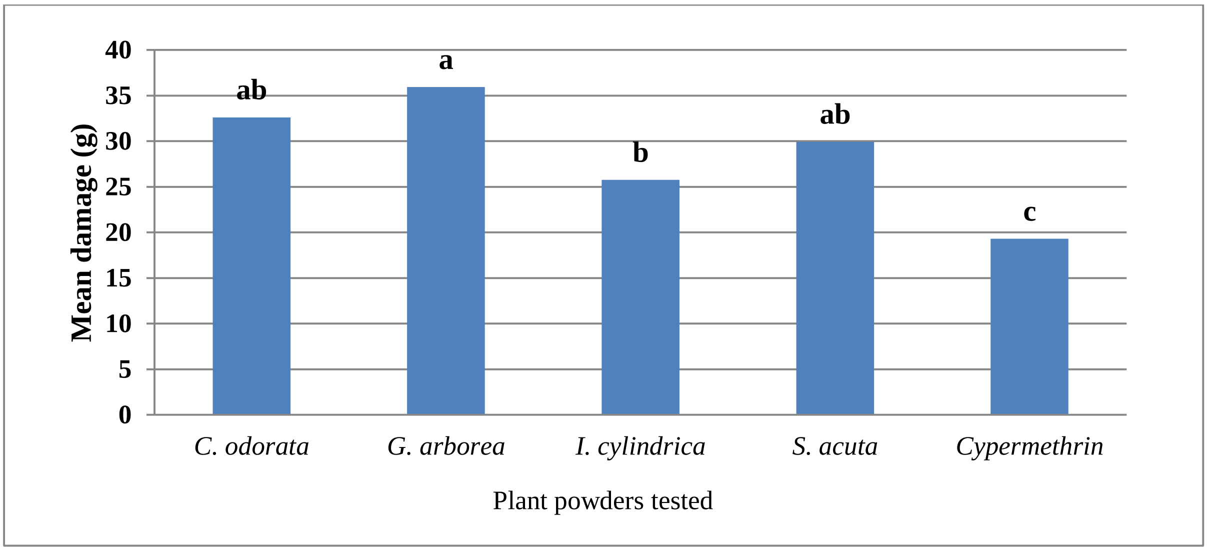

Figure 4: Pooled mean damage (%) to *plant powder* treated maize grains by *Sitophilus zeamais*
Different letters above bars indicate significant differences at $P \leq 0.05$ (Proc. GLM, SNK)

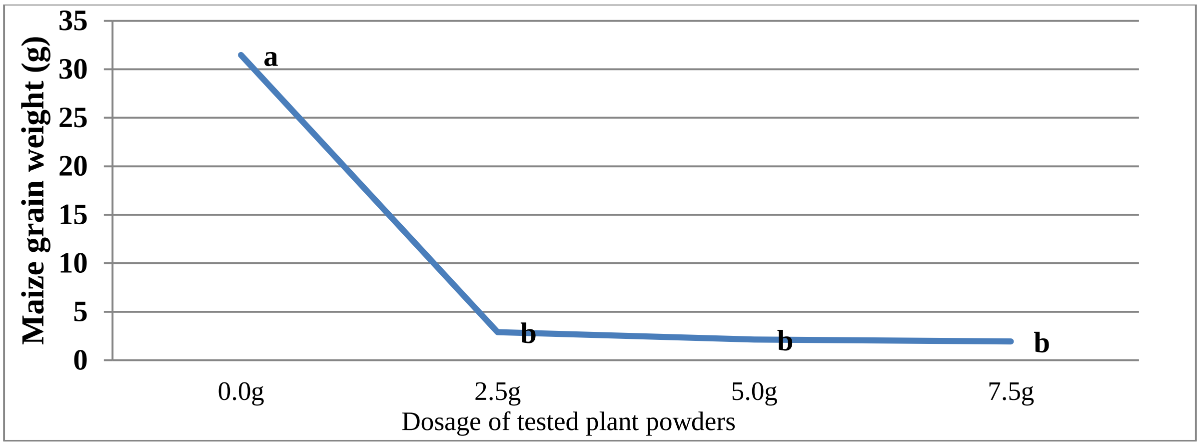

Figure 5: Pooled mean weight loss by *Sitophilus zeamais* to maize grains treated with 0, 2.5, 5 and 7.5 g plant powders. Different letters indicate significant differences at $P \leq 0.05$ (Proc. GLM, SNK)

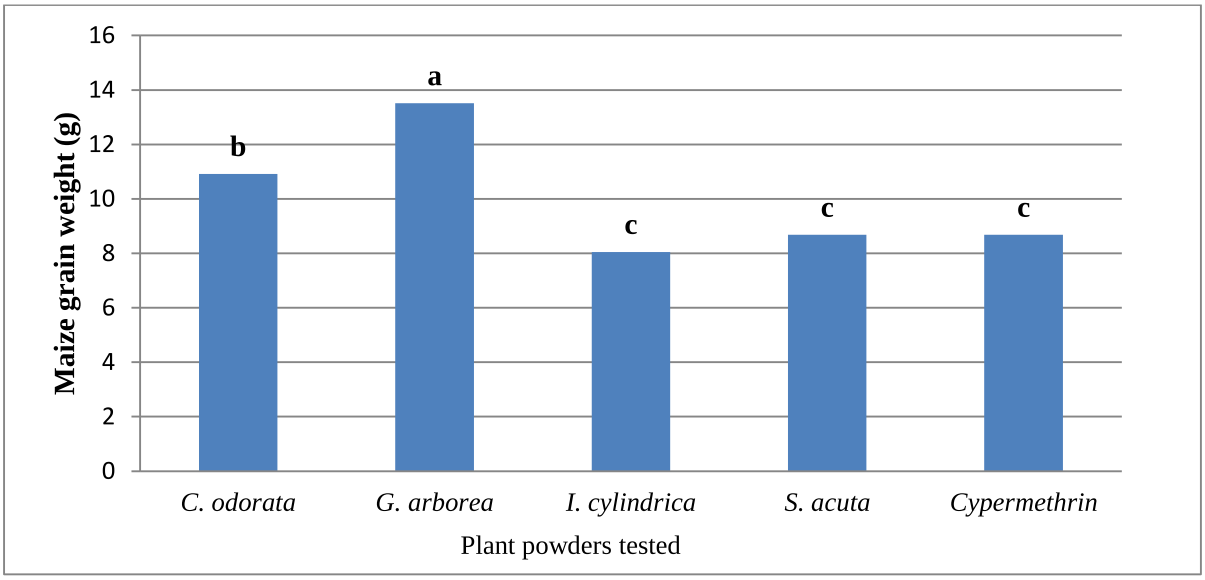

Figure 6: Pooled mean weight loss (g) to maize grains treated with *plant powder* by *Sitophilus zeamais*
Different letters above bars indicate significant differences at $P \leq 0.05$ (Proc. GLM, SNK)

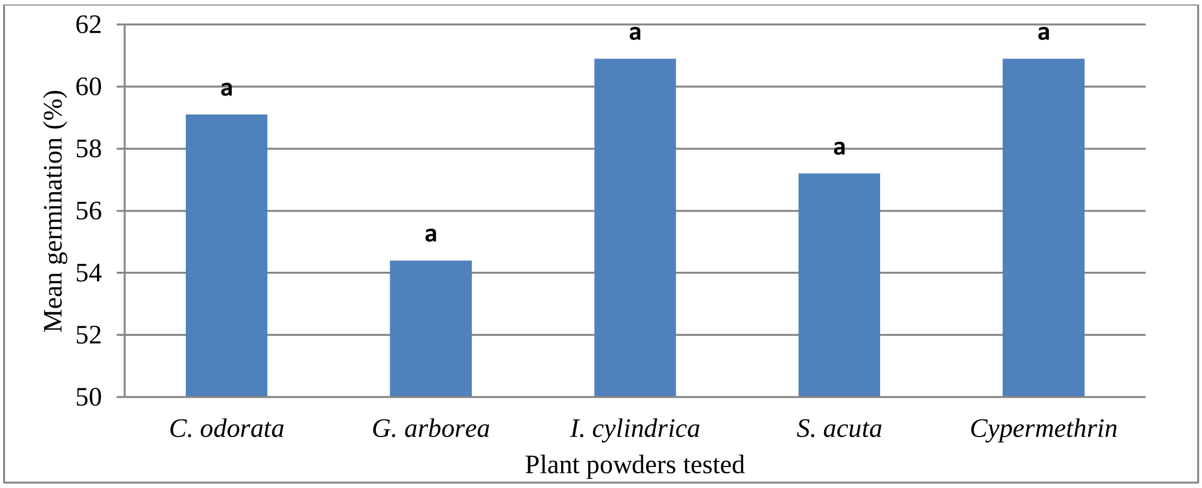

Figure 7: Pooled mean germination of maize grains treated with *plant powders*
Different letters above bars indicate significant differences at $P \leq 0.05$ (Proc. GLM, SNK)

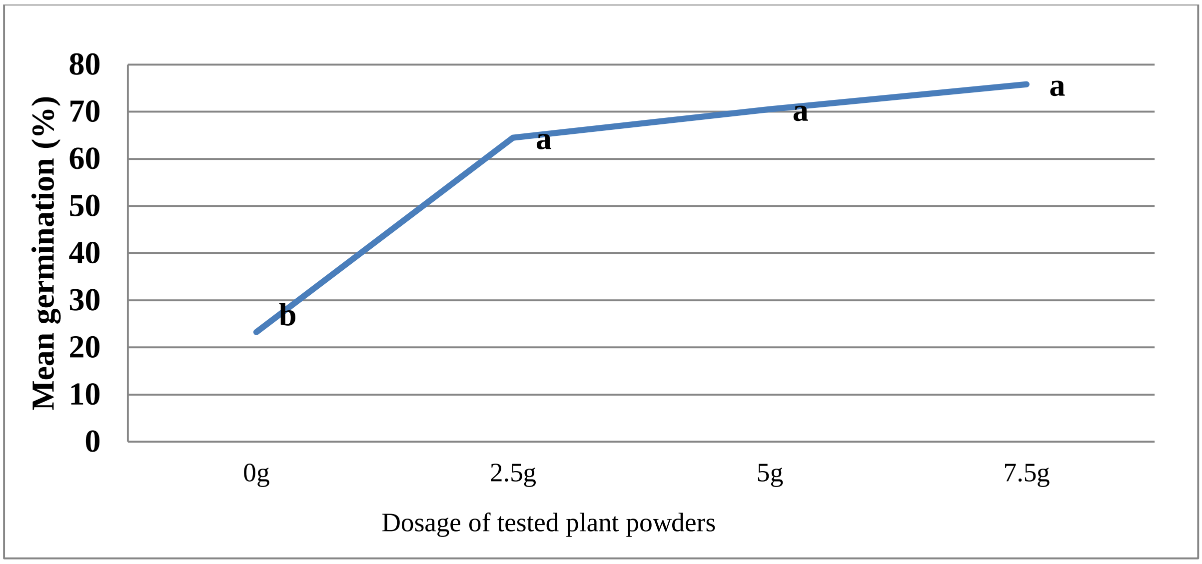

Figure 8: Pooled mean germination of maize grains treated with *plant powders*
Different letters indicate significant differences at $P \leq 0.05$ (Proc. GLM, SNK)