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# Toxicity and Oviposition Deterrence of *Piper guineense* (Piperaceae) and *Monodora myristica* (Annonaceae) Against *Sitophilus zeamais* (Motsch.) on Stored Maize

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**Abstract:** Plant powders from the seeds of *Piper guineense* and *Monodora myristica* were separately applied at different dosages of 1, 5 and 10% (w/w) on stored maize grains and tested against the maize weevil, *Sitophilus zeamais* in the laboratory for 12 weeks. Parameters assessed were adult mortality at 24, 48 and 72 h, adult emergence and adult weight. The results showed that 5 and 10% powders of both plants were significantly more toxic to *S. zeamais* and suppressed $F_1$ progeny emergence compared to 1% powders and the controls. However, the mean weight of the emerged adults was not significantly influenced by any of the treatments. The efficacy of the powders on the weevils was dose-dependent with higher doses providing greater protection of the maize grains. This research provides the scientific basis for the potential use of *P. guineense* and *M. myristica* powders in stored-product protection at the small-scale farmer level to reduce the application of toxic synthetic insecticides.

**Key words:** *Piper guineense*, *Monodora myristica*, repellents, *Sitophilus zeamais*

## INTRODUCTION

Maize, *Zea mays* L. (Poaceae) is the major crop cultivated in Africa for food, feed, starch and other industrial products. In Nigeria, annual production of maize is estimated at 5.4 million metric tonnes from about 3.5 million hectares (Oparaeke and Kuhiep, 2006) and in Ghana, it is about 932, 000 metric tonnes (Owusu-Akyaw, 1991). The maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) is a serious field to store pest of maize, causing considerable losses estimated at about 96 million metric tonnes all over the world (FAO, 1961). Weight losses of over 30% have been reported in West Africa after a few months of storage (Kossou and Bosque-Perez, 1998). Apart from weight losses, the feeding damages cause by the larvae and adults *S. zeamais* were responsible for the reduction in aesthetic and market value, germination and nutritive value of maize from this region (Ofuya and Lale, 2001). The economic situation in the developing world like Africa has been adversely affected mostly by the post-harvest losses of agricultural products especially during storage (Arannilewa *et al*., 2002). Although several methods have been developed as a part of an Integrated Pest Management (IPM) strategy, at present the control of *S. zeamais* in Africa relies on the fumigation of stores using methyl bromide and phosphine (Liu *et al*., 2006). The use of synthetic pesticides poses a substantial risk to the environment in the form of biomagnification and toxicity to nontarget organisms and the use of alternative structural analogues is often rendered ineffective by cross or multiple resistance (Ndungu *et al*., 1995).

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There is therefore an increasing need to search for cheap, easily biodegradable and readily available plant materials that will not contaminate food products in acting as grain protectants in small-scale storage systems. The use of locally available plant materials to protect stored products against pest damage is common practice in traditional farm storage systems in Africa and Asia (Tierto Niber, 1994; Boeke *et al*., 2004). The West African black pepper, *Piper guineense* Thonn and Schum (Piperaceae) and African nutmeg, *Monodora myristica* Dunal (Annonaceae) are used in the traditional African medicine for the treatment of headache, constipation, rheumatism, fever, diarrhoea, sores and guinea worm infections. The ripe fresh or dried fruits of these plants are sold in most markets in Nigeria as a spice use for flavouring soups and sauces (Tatsadjieu *et al*., 2003; Adewoyin *et al*., 2006). This study reports on the efficacy of *P. guineense* and *M. myristica* growing in the rain forest belt of Nigeria for the protection of stored maize against *S. zeamais*.

## MATERIALS AND METHODS

### Insect Culture

Parent stock of *S. zeamais* was obtained from stock culture maintained by Central Science Laboratory, Sand Hutton, York, England in March 2006 and reared on maize seeds in a constant temperature and humidity (CTH) room running at 25°C, 65% relative humidity on a 12:12 DL (darkness and light) photoperiod.

### Plant Material Collection and Preservation

Ripe fruits of *Piper guineense* and *Monodora myristica* were obtained from fields around Akamkpa (situated between latitude 5°00′ and 5°15′ North and longitude 8°04′ and 8°25′ East) in Southern Nigeria in December 2006 and identified at the department of Crop Science, University of Calabar, Nigeria. The matured seeds of these plants were dried in the shade for 3 days before transportation. Local yellow maize seeds purchased from Akim foodstuff market in Calabar, Nigeria were preserved in the refrigerator (-5°C) to disinfect the grains prior to the experiment.

### Effect of Plant Powders on Weevil Mortality, Adult Emergence and Grain Damage

Two hundred grams of maize were weighed out into Kilner jars for each replicate. The dried seeds of *P. guineense* and *M. myristica* were ground into powders and applied by direct admixtures to the maize grains calculated on the weight of plant material/weight of grain (w/w) basis. Each plant powder was applied at three dosage rates of 1, 5 and 10% in Kilner jars, while the controls received no plant powders. Twenty pairs of 3 days old *S. zeamais* adults were introduced into each kilner jar containing treatments for mating and oviposition for 10 days. The jars were firmly closed with wire mesh lid covers to aid aeration and confinement of the weevils. Each treatment was replicated 4 times and laid out in a Completely Randomized Design (CRD) on the laboratory bench for 12 weeks. A mortality count was done every 24 h for 72 h after treatment by sieving out the contents into a clean white tray and counting the number of dead insects. Each time a count was done; dead individuals were discarded while live ones were returned to their respective treatments. After 10 days all live and dead weevils were removed and discarded and the seeds kept aside for $F_1$ progeny emergence. The weevils emerging from each jar were counted to give a measure of productivity and sieved off every 2 days taking into consideration that mating in *S. zeamais* does not occur before weevils are 3 days old (Walgenbach and Burkholder, 1987). The number of $F_1$ progeny from each treatment were counted, weighed, recorded and analysed using analysis of variance (ANOVA) in MINITAB 15. Data obtained from mortality count were transformed using square root transformation to normalize them before analysis and all treatment means were compared using Duncan's Multiple Range Test.

## RESULTS AND DISCUSSION

Results showed that powders of *P. guineense* and *M. myristica* applied to maize grains at different dosages showed significant ($p<0.001$) toxicity against 3 day old adult *S. zeamais* after 72 h post treatment (Table 1). *S. zeamais* mortality significantly increased with increase in concentration and days of exposure. The highest cumulative percentage insect mortality was observed in the treatment with 10% *M. myristica* and 10% *P. guineense* by the third day. There were no significant differences ($p>0.05$) in weevil mortality at 24, 48 and 72 h within plant powders treatments of the same dosages and between 1% plant powders and the control (Table 1). There were significant differences in the number of $F_1$ across dosages for *P. guineense* and *M. myristica* but not for 1% treatments and the control. The mean number of emerged adults decreased significantly ($p<0.01$) with increase in concentration of each plant powder. *P. guineense* had the least number of emerged adult (4.75) and *M. myristica* (5.25) at 10% (w/w) concentration, but at 5% (w/w) concentration the mean numbers of emerged adults were 14 and 10, respectively. However, there were no significant differences ($p>0.05$) among the treatments regarding the adult weight (Table 2).

In this study, *P. guineense* and *M. myristica* powders applied at dosages of 5 and 10% (w/w) caused significant mortality of *S. zeamais* within 24 h post treatment compared to the controls. Although the mode of action of these plant powders is not clearly understood, but the repellent and pungent odours from these plant caused the insects to climb to the walls of Kilner jars soon after introduction thereby limiting adequate feeding and oviposition. Also the physical abrasion of the insect cuticle with the resultant loss of body haemolymph or partial blockage of the spiracles (Ogunwolu *et al*., 1998; Oparaeke and Kuhiep, 2006) could result in suffocation and death.

The mean number of progeny produced by *S. zeamais* in the untreated control was significantly higher than the one treated with 5 and 10% (w/w) concentration of plant powders. The efficacy of the powders was dose-dependent with higher doses providing greater protection with significantly fewer emergent adults. Our observation that *P. guineense* and *M. myristica* powders caused significant adult mortality and reduction in $F_1$ progeny emergence may not only be physical. It could also be due

Table 1: Effect of *P. guineense* and *M. myristica* powders on adult *S. zeamais* mortality at 24, 48 and 72 h post treatment

| | Mean % mortality (±SE) of *S. zeamais* (h) | | |
|---|---|---|---|
| Treatments | 24 | 48 | 72 |
| Control (untreated) | 2.10±0.25b | 2.73±0.25b | 3.28±0.21c |
| *P. guineense* (1%) | 2.43±0.27b | 3.68±0.28b | 3.81±0.23c |
| *P. guineense* (5%) | 5.28±0.21a | 5.66±0.27a | 8.27±0.27b |
| *P. guineense* (10%) | 5.70±0.22a | 6.31±0.30a | 13.72±0.19a |
| *M. myristica* (1%) | 2.73±0.25b | 3.91±0.26b | 4.21±0.28c |
| *M. myristica* (5%) | 5.27±0.21a | 5.95±0.22a | 9.33±0.22b |
| *M. myristica* (10%) | 6.08±0.26a | 6.58±0.25a | 14.96±0.20a |

Means followed by the same letter(s) are not significantly different ($p>0.05$) from each other, using Duncan's Multiple Range Test

Table 2: Effect of *P. guineense* and *M. myristica* powders on adult *S. zeamais* emergence and body weight after 12 weeks

| Treatments | Mean adult emergence | Mean body weight (mg) |
|---|---|---|
| Control (untreated) | 49.50±0.98a | 3.05±0.24a |
| *P. guineense* (1%) | 47.25±0.92a | 3.02±0.21a |
| *P. guineense* (5%) | 14.00±0.80b | 3.05±0.26a |
| *P. guineense* (10%) | 4.75±0.65c | 3.05±0.24a |
| *M. myristica* (1%) | 41.25±1.13a | 3.05±0.23a |
| *M. myristica* (5%) | 10.00±0.73b | 3.02±0.27a |
| *M. myristica* (10%) | 5.25±0.69c | 3.04±0.24a |

Means followed by the same letter(s) are not significantly different ($p>0.05$) from each other, using Duncan's Multiple Range Test to feeding deterrence, oviposition deterrence or ovicidal activity resulting to reduce progeny emergence (Tapondjou *et al*., 2002, 2005; Akob and Ewete, 2007). Ukeh and Umoetok (2007) have also demonstrated the efficacies of the application of *P. guineense* and *M. myristica* volatiles in the protection of grain from insect infestation in the four-arm airflow olfactometer. The repellent activity of vacuum distilled essential oils from *Zingiber officinale* and *Aframomum melegueta* against another stored product pest, *Rhyzopertha dominica* has also been reported (Ukeh, 2008). These repellent plants may contain certain active volatile compounds that elicit antifeedant behaviour by the visiting insect. The compositions of the volatile oil from the seeds (berries) of these plants have been investigated: The major components of *P. guineense* seeds are dominated by monoterpenoids and moderate sesquiterpenoids including β-Pinene, β-Caryophyllene, Bicyclogermacrene, α-Pinene, Germacrene, δ-3-Carene, E-α-Bisabolene, α-Cubebene, Sabinene, Camphor, α-Phellandrene, β-Phellandrene, χ-Muurolene, Z-Nerolidol, Z-β-Ocimene, Myrcene, Ishwarane, Myristicin, Dillapiole, Elemicin, Limonene and Camphene (Salgueiro *et al*., 1998; Oyedeji *et al*., 2005). *M. myristica* essential oil components include α-Thuyene, α-Pinene, Myrcene, Limonene, α-Phellandrene, *p*-Cymene, Isopugegol, Aromandendrene, α-Terpineol, Carvacrol, Thymol and *cis*-Sabinol (Cimanga *et al*., 2002; Tatsadjieu *et al*., 2003). These organic compounds could be responsible for the repellent, antifeedant and toxic activity of *P. guineense* and *M. myristica* powders against *S. zeamais*. The application of plant powders may minimize insecticide usage thereby reducing health hazards to applicators and the amount of toxic residues to the environment. Treatment of grains with repellents could also have important practical applications in the parts of the world where insecticides are expensive, in short supply or where these plants are cheap and readily available. This indicates a possible scientific rationale for the traditional use of plant powders as grain protectants by resource poor farmers. The implication of this in practice is that *P. guineense* and *M. monodora* powders could constitute agents with sufficient broad spectrum of repellent activity for use as general purpose stored product insects repellent.

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