Repellent and Insecticidal Efficacy of Leaf and Stem Powders of Mimosa diplotricha C. Wright ex Sauvalle (Mimosaceae) Against maize weevil, Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae)

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Abstract
Studies on the repellent and insecticidal potential of the invasive alien plant, Mimosa diplotricha C. Wright ex Sauvalle (Mimosaceae) (commonly known as the giant sensitive plant) are non-existent, hence this study evaluated the repellent and insecticidal activities of the leaf and stem powders of the against the maize weevil, Sitophilus zeamais (Motschulsky) (Coleoptera: Curculionidae) under laboratory conditions. Maize grains infested with the adults of S. zeamais were exposed to three concentrations viz. 1.5, 2.5 and 3.5 g of M. diplotricha leaf and stem powders for 3 hours after which percentage repellency was calculated. Also, adult weevils were exposed to grains treated separately with three different concentrations (1.5, 2.5 and 3.5 g) of the leaf and stem powders of M. diplotricha at different exposure periods. Percentage survival was recorded every 24 hours over a 120-hour period. The leaf and stem powders of M. diplotricha exhibited some degrees of repellency against S. zeamais, although, the repellent activity was a function of both concentration and exposure time. Following a 3-hour exposure period, the 3.5 g of the leaf (53%) and stem (58%) powders exhibited the highest repellent activity against S. zeamais. Although, the leaf and stem powders of M. diplotricha plants exhibited some degrees of mortality against S. zeamais, it was observed to be concentration and exposure time dependent. At the highest concentration (3.5 g), the leaf and stem powders of M. diplotricha accounted for only 28% mortality (72% survival) of S. zeamais after a 120-hour exposure period. This study reports the repellent and insecticidal activities of the leaf and stem powders of M. diplotricha against S. zeamais, for the first time, it however, suggests that the phytochemical constituents of the plant be analyzed first before further use.

Keywords: Invasive plant, plant powders, repellency, mortality, maize weevil.

INTRODUCTION
Man needs food for survival. To attain good health, quality food should be provided (Acero, 2014). Cereal grains are cultivated grasses. They provide humanity with more nourishment than any other food class and constitute nearly half of the total caloric requirement (Acero, 2014). Although, there are about a dozen cereal crops used as food, only maize, wheat, sorghum, millet and rice are important human food sources, accounting for 94% of all cereal consumption (FAO, 2012).

Zea mays (L.) (Poaceae) is one of the most important cereal crops in sub-Saharan Africa.
Further, the crop is an important staple food for more than 1.2 billion people in sub-Saharan Africa and Latin America (IITA, 2009). Maize is a monoecious annual grass usually consisting of a stem, one to four meters tall with long green parallel alternating leaves and prop roots. The Worldwide production of maize is estimated to be 817 million tons in 2009, more than rice (678 million tons) or wheat (682 million tons) (FAO, 2009). However, world corn production is now estimated to be 1065.11 million metric tons (World Corn Production, 2017). Africa on the other hand, produces about 6.5% with Nigeria being the largest producer followed by South Africa (IITA, 2009). Studies on the nutritional composition of *Z. mays* revealed that it is a good source of various nutrients such as proteins, crude fiber and carbohydrates (Hooda and Kawatra, 2013).

Globally, post-harvest loss of grains due to insect pests especially during storage has been estimated to be approximately 10% (Boxall *et al.*, 2002) or more. *Sitophilus zeamais* (Motschusky) (Coleoptera: Curculionidae) is one of the major pest of maize and has been reported to cause considerable losses (up to 30%) in stored maize grains through the consumption of the endosperm, consequently causing significant reduction in the quality, quantity, appearance and marketability of the grains (Holst *et al.*, 2000). Adults of *S. zeamais* are usually black in coloration with short rostrums. Infestation by these insects normally begins when the moisture content of the grains fall below 18-20% (Parugrug and Roxas, 2008), with all stages viz. eggs, larvae and pupae developing within the maize grains. Although, the use of synthetic insecticides to subdue the destructive and harmful activities of stored product pests are not uncommon (Danjumma *et al.*, 2009; Udo, 2011; Ileke and Bulus, 2012), these chemicals pose significant threats to humans partly due to their high persistence, tendency to invoke resistance, poor knowledge of application, and hazard to human health and non-target organisms (Danjumma *et al.*, 2009). These drawbacks have necessitated the need for sustainable alternatives that are of low mammalian toxicity, biodegradable and environmental friendly and safe (Lajide *et al.*, 1998; Akinneye *et al.*, 2006).

The challenge of finding a good alternative to replace these conventional insecticides has led to the bio-prospecting of plants with natural insecticidal properties. Studies on the use of invasive alien plants in the control of stored product pests and pests of medical importance are not uncommon (Kamaraj *et al.*, 2010; Uyi and Igbinoba, 2016; Uyi and Obi, 2017), only a little empirical evidence exists on the efficacy of these plants (Lawal *et al.*, 2015; Udebuani *et al.*, 2015; Uyi and Igbinoba, 2016). *Mimosa diplotricha* C. Wright ex Sauvalle (Mimosaceae) commonly known as the giant sensitive plant is a fast growing, shrubby leguminous vine native to America (Waterhouse and Noris, 1987; Simon and Proença, 2000). The plant is viewed as a major problem in many tropical and subtropical countries because of its negative impacts on agriculture, biodiversity and livelihoods (Ekhator *et al.*, 2013). Although, some invasive alien plants are reported to possess repellent and toxicological activities (Uyi and Igbinoba, 2016), there is a dearth of information on the study of *Mimosa diplotricha* for this use. Furthermore, several plant parts such as the leaves, stems, seeds and roots have been reported to possess some insecticidal activities against some stored product pests (Denloye, 2010; Ileke and Bulus, 2012; Olufumilayo, 2012). For example, the root, stem and leaf powders of *Chromolaena odorata* (L.) (Asteraceae) have been reported to possess significant repellent and toxicological activities against *Callosobruchus maculatus*, a pest of
stored cowpea (Uyi and Igbinoba, 2016; Uyi and Obi, 2017). The objective of this study was to evaluate the repellent and insecticidal activities of the leaf and stem powders of *M. diplotricha* against the greater grain weevil, *S. zeamais*.

**MATERIALS AND METHODS**

**Collection and preparation of plant powders**

Fresh leaves and stems of *M. diplotricha* plants were collected from an open farmland at Dentistry Quarters within the vicinity of the University of Benin Teaching Hospital (UBTH), Benin City (6º39’N, 5º56’ E), Nigeria. Following collection, the stems and leaves were respectively chopped into pieces, washed with water and shade-dried for 7 days and thereafter oven-dried at 60°C for 24 hours. The leaves were further dried in the oven at 60°C for 72 hours. The dried plant parts were blended into a fine powder using British Milling Machine (Braun Multiquick Immersion Hand Blender, B White Mixer MR 5550 CA Germany) and then preserved in an air-tight container for further use.

**Collection of maize weevil**

Maize grains infested with the adults of *S. zeamais* were purchased from Oba markets, Benin City, Edo State, Nigeria, after which they were transferred into a 10-litre plastic container and maintained at an ambient temperature of 25±2°C and 80±5% Relative Humidity (RH) in the laboratory, pending the time they were to be used for the trials.

**Repellency bioassay**

Un-infested maize grains were purchased from Uselu market, Benin City, Edo State, Nigeria, and were examined for visible eggs or larvae and then freeze dried for 24hrs to ensure that the grains are free from pest infestations. The experiment was conducted at an ambient temperature of 25±2°C and 80±5% RH in the laboratory of the Department of Animal and Environmental Biology, University of Benin, Benin City, Nigeria. Two different treatment types viz. leaf and stem powder of *M. diplotricha* were used for this study. To perform the repellency bioassay, 50 g of maize grains admixed with leaf powders of *M. diplotricha* at (1.5, 2.5, 3.5 g, and stem powder at a concentration of 1.5, 2.5, 3.5 g) was placed inside a 100 ml plastic container with screw top. The grains were mixed thoroughly with the respective powders to ensure proper admixture before being transferred into a perforated 200 ml plastic cup. Five unsexed adults (less than 7 days old) of *S. zeamais* were introduced into each cup and then the top was covered with aluminum foil and tightly sealed with a rubber band to prevent the insects from escaping. The perforated cup was placed inside a completely enclosed and transparent 2 liter plastic bucket to enable an accurate count of the weevils that leaves the treated grains. The treatment was replicated eight times for each treatment type and weevils were exposed for 3 hours and observation was made after every 30 minutes. The number of insects leaving the treated grains gives a measure of repellency of the different powders. Control treatments with 50 g of maize grains mixed with zero percent (no powder added) of the powders of *M. diplotricha* inside 100 ml plastic containers with screw top were also monitored for 3 hours.

**Mortality bioassay to determine percentage survival**

To perform the mortality bioassay, 50g of maize grains was placed inside a 100 ml plastic container and powders from leaf and stem of *M. diplotricha* respectively (1.5, 2.5, 3.5 g) was added to the grains inside the container and the
mixture carefully mixed by gently shaking the container to ensure uniform coating of the plant powder with the maize grains. Five unsexed adults (less than 7 days old) of *S. zeamais* were introduced into the 100ml plastic container after which the top part was covered with a sheet of paper and held in place tightly with a rubber band to prevent the insects from escaping. The treatment was replicated eight times for each treatment type. The number of dead weevils was counted every 24 hours for 5 days (120 hours) following the commencement of the experiment. Control treatments, with 50 g of maize grains mixed with zero (0%) percent of the powders of *M. diplotricha* inside 100 ml plastic containers with screw top were also monitored as described above.

**Statistical analysis**

The percentage repellency and survival of the weevil on the different concentrations of the leaf and stem powders of *M. diplotricha* was analysed using Analysis of Variance (ANOVA). When the overall results were significant in the analyses, the difference among the treatments was compared using the Tukey’s Honest Significant Different (HSD) test. A student t test was used to compare weevil survival between the leaves and stem powder of *M. diplotricha*. All analyses were performed using Genstat 12.0 (VSN International, Hemel Hempstead, UK).

**RESULTS**

**Repellency test**

The leaf and stem powders of *M. diplotricha* exhibited some repellent activities against *S. zeamais* compared to the control treatments. Following a 3-hour exposure of *S. zeamais* to different concentrations (or treatment levels) of *M. diplotricha* leaf powder, percentage repellency significantly differed ($F_{3,31} = 10.12; P = 0.001$) among treatments with the control exhibiting the least repellent activity (12.5%) against the weevils, while the other treatments (1.5, 2.5 and 3.5g) exhibited significantly higher repellent activity (Figure 1). The highest treatment level (3.5g) exhibited the best repellent activity (53%), followed by the 2.5 and 1.5g treatments which respectively repelled 45 and 25% of the weevils (Figure 1). Similarly the percentage repellency exhibited by the different concentration of the stem powder of *M. diplotricha* against *S. zeamais* significantly differed ($F_{3,31} = 6.63; P = 0.02$) following a 3-hour exposure period (Figure 2). The 3.5g treatment of the stem powder exhibited the highest percentage repellency (57.5%) while there were no differences between the control, 1.5 and 2.5g treatments (Figure 2).

**Mortality bioassay**

Although the leaf and stem powder of *M. diplotricha* exhibited some levels of mortality against *S. zeamais*, overall they exhibited poor insecticidal activities against the weevils. Following a 120-hour exposure of *S. zeamais* to different levels of *M. diplotricha* leaf powder, the percentage of weevil survival significantly differed ($F_{3,31} = 17.19; P = 0.001$) with the 3.5g exhibiting the least survival (72.5%) or highest mortality (27.5%) while the control treatment exhibited 100% survival or (0.0%) (Figure 3). Percentage weevil survival did not differ between the 1.5 and 2.5g treatments (Figure 3). Following a 120-hour exposure of *S. zeamais* to the different concentrations of the stem powder of *M. diplotricha*, percentage survival significantly differed ($F_{3,31} = 18.98; P = 0.001$) with the 3.5g treatment exhibiting the least survival (73.5%) or highest mortality (26.5%) while the control treatment exhibited 100% survival or (0.0%) (Figure 4). Percentage weevil survival did not significantly differ between the 1.5 and 2.5g treatments (Figure 4). Finally, survival did not significantly differ between the leaf and stem powder (Table 1).
Fig. 1: Percentage (mean ± SE) repellency of different concentrations of *Mimosa diplopticha* leaf powder against *Sitophilus zeamais* following a 3-hour exposure period. Means capped with different letters are significantly different [after Tukey’s Honest Significant Difference test (HSD): P<0.05]. Sample sizes are given in parenthesis.

Fig. 2: Percentage (mean ± se) repellency of different concentrations of *Mimosa diplopticha* stem powder against *Sitophilus zeamais* following a 3-hour exposure period. Means capped with different letters are significantly different [after Tukey’s Honest Significant Difference test (HSD): P<0.05]. Sample sizes are given in parenthesis.

Fig. 3: Percentage (mean ± se) survival of *Sitophilus zeamais* exposed for 120 hours to different concentrations of *Mimosa diplopticha* leaf powder. Means capped with the same letters are not significantly different [after Tukey’s Honest Significant Difference test (HSD): P>0.05]. Sample sizes are given in parenthesis.

Fig. 4: Percentage (mean ± se) survival of *Sitophilus zeamais* exposed for 120 hours to different concentrations of *Mimosa diplopticha* stem powder. Means capped with the same letters are not significantly different [after Tukey’s Honest Significant Difference test (HSD): P>0.05]. Sample sizes are given in parenthesis.
Table 1: Percentage (mean ± se) survival of *Sitophilus zeamais* exposed for 120 hours to powders from leaf and stem of *Mimosa diplotricha* at different concentrations.

<table>
<thead>
<tr>
<th>Concentration (g)</th>
<th>Leaf powder (%)</th>
<th>Stem powder (%)</th>
<th>Test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>80.00 ± 3.78 (8)</td>
<td>85.10 ± 3.17</td>
<td>t = 1.01</td>
<td>0.334</td>
</tr>
<tr>
<td>2.5</td>
<td>77.50 ± 2.50 (8)</td>
<td>77.48 ± 2.48</td>
<td>t = 0.01</td>
<td>0.999</td>
</tr>
<tr>
<td>3.5</td>
<td>72.50 ± 3.66 (8)</td>
<td>72.45 ± 3.63</td>
<td>t = 0.01</td>
<td>0.998</td>
</tr>
</tbody>
</table>

The numbers in brackets represent the sample size.

**DISCUSSION**

This study evaluated the repellent and insecticidal activities of the leaf and stems powders of *M. diplotricha* plants against the maize weevil, *S. zeamais*. The study revealed that the leaf and stem powders of *M. diplotricha* exhibits a variable degree of repellency and insecticidal activities against *S. zeamais*.

This study demonstrated that the stem and leaf powders of *M. diplotricha* somewhat repelled *S. zeamais* and the repellency was a function of both concentration (grams) and exposure time. Although there is paucity of literature on the effect of *M. diplotricha* on any stored grain insect pest including *S. zeamais*, studies on other plants and their parts, oil and extract against *S. zeamais* have been documented. For example, Asawalam et al. (2008) and Udo (2005) reported moderate to high repellency of *Ocimum gratissimum* (L.) (Lamiaceae) and *Piper guineense* (Schumach) (Piperaceae) leaf powder against *S. zeamais*. Essential oils from fruit of *Litsea cubeba* (Lour.) pers. (Lauraceae) showed strong repellence activity against *S. zeamais* and *Tribolium castaneum* (Herbst.) (Tenebrionidae) even at low concentrations (Ko et al., 2009). Also, essential oil from *Etinglera elatior* (Jack) (Zingiberaceae), *Etinglera pyramidosphaera* (K. Schum) (Zingiberaceae), *Zingiber officinale* (Roscoe) (Zingiberaceae) strongly repelled *S. zeamais* at all tested exposure times (Ishii et al., 2010).

Although, the leaf and stem powders of *M. diplotricha* plants exhibited some degree of mortality against *S. zeamais*, it was observed to be concentration and exposure time dependent. Overall, the percentage mortality caused by the leaf and stem powders of *M. diplotricha* was less than 28% (more than 72% survival), thus suggesting that the leaf and stem powders possess low insecticidal activities. The lack of a significant difference between the leaf and stem powders in percentage mortality or survival of the weevil powders suggest that both plant parts may contain similar amounts of chemical compounds. Although studies on the insecticidal activities of *M. diplotricha* are relatively scarce (or non-existence), some other plants are known to exhibit insecticidal properties (Longe, 2016) against the weevil. For example, Longe (2016) showed that *Corymbia citrodora* (Hook) (Myrtaceae) leaf dust (powder) is highly effective against *S. zeamais* of stored maize grains with 100% efficiency. Also, Yeshaneh (2015) reported that *Tagetes minuta* (Gimi) (L.) (Asteraceae) 5% and *Carissa schimperi* (merez) (A.DC.) Schweinf. (Apocynaceae) 5% can be used in the control of *S. zeamais*. Cotton seed oil showed 100% mortality against *S. zeamais* with a duration time of less than a day (Gemechu et al., 2012). *Chenopodium* leaf powder mixed with maize grains at the rate of 2 and 4% w/w caused a significant reduction in maize weevils (Mekuria, 1995; Dejen, 2002). Adedire and
Ajayi (1996) recorded 100% mortality of *S. zeamais* treated with *Capsicum frutescens* (L.) (Solanaceae) after 28 days. In addition, it was also reported that 2.0g of *Nicotiana tabacum* (L.) (Solanaceae) applied in 50g of maize grains resulted to 100% mortality of *S. zeamais* (Danjumma et al., 2009).

One plausible explanation for the poor repellency and low mortality of the leaf and stem powders of *M. diplotricha* against *S. zeamais* is that the weevil might have developed strategies to cope with unknown secondary chemicals possessed by the plant or the chemical composition of the plant is not toxic enough to kill the insect. It may not be out of place to speculate that the concentrations of the plant powders were not high enough to cause death. This speculations might be validated by the results of an earlier study (Nwala, 2016) where the leaf, stem and root powders of an invasive alien plant, *C. odorata* were not very effective for the control of *S. zeamais*. The author found that the powders repelled less than 26% of weevils and caused below 11% mortality. In spite of the low mortality and poor repellency of the plant powders of *M. diplotricha*, the powders or plant cannot be completely excluded - as they exerted some degree of repellency and mortality against *S. zeamais* suggesting that a much higher dosage or extracts of the plant might exhibit greater potency against the weevil.

**CONCLUSION**

This study demonstrated the potential for the use of *M. diplotricha* leaf and stem powders in the control of the maize weevil (*S. zeamais*) for the first time, albeit poorly. *Mimosa diplotricha* leaf and stem powders exhibited minimal toxicity and repellency activities against the maize weevil at all treatment rates. In sum, this study demonstrated that the leaf and stem powders of *M. diplotricha* are less toxic to *S. zeamais* irrespective of the exposure time.

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