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Potential of *Tithonia diversifolia* with Pirimiphos-methyl in Control of *Sitophilus zeamais* (Coleoptera: Curculionidae)

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ABSTRACT

The toxicity of *Tithonia diversifolia* leaf powder applied at 1.0 g and pirimiphos-methyl dust (PPD) at 0.025 g (recommended dose) separately and mixing 0.5 g *T. diversifolia* with half, a quarter or an eighth of the recommended dose of PPD per 50 g maize grains against *Sitophilus zeamais* (maize weevil) was studied in the laboratory. Test parameters included mortality of adults, weight loss of grains, F_1 adult emergence and persistence of the treatments. All treatments caused significant mortality compared to the untreated control. At 7 days after treatment (DAT), 90.0% mortality observed in the recommended dose of PPD was not significantly different from 83.6% mortality observed in half the recommended dose + 0.5 g *T. diversifolia* leaf powder. Grain weight loss followed the same pattern as mortality at 7 DAT. Only the recommended dose of PPD retained absolute potential after 30 days storage of maize grains. The mixtures retained some activity but their efficacy in storage was reduced over time. Our study reveals the potential of mixing botanicals with reduced rates of synthetic insecticides in management of stored product pests.

Keywords: adult emergence, maize weevil, mortality, persistence, Pirimiphos-methyl dust, wild sunflower

INTRODUCTION

This study was carried out in order to investigate the possibility of reducing the quantity of synthetic pesticide and including an organic material in pesticide formulation in order to manage maize weevil, *Sitophilus zeamais* Motschulsky.

Maize is known to be subject to depreciation by various pests which can cause severe qualitative and quantitative losses. Percentage weight losses in storage may exceed 30% in developing countries (Throne and Eubanks 2002). Losses of maize grain caused by *S. zeamais* means that resources such as time, labour, land and money spent in growing the crop are wasted. For this reason, various methods have been enacted as control measures. Chemical control involves using surface-applied insecticides. These are often ineffective for storage insects that have entered the grain at or before harvest. Cultural method includes sanitation and management of the warehouse, controlled ventilation, etc. (Odeyemi and Daramola 2000). Biological control includes the use of predators, parasites and pathogens (Cherry *et al.* 2005). The technicalities involved in the mentioned methods make their efficacy to be low, especially among the local farmers in developing world. Fumigation of stored products with a fumigant such as methyl bromide, ethylene di bromide and more commonly phosphine gas obtained from decomposing aluminum or magnesium phosphide may be more effective when properly applied in air-tight storage facilities (Compton *et al.* 1993).

Synthetic products, however, are not without their hazards to human health and the environment. In developed countries, conventional fumigation technology is currently being scrutinized for many reasons such as ozone-depletion, carcinogenic and other health concerns (Gauniyal and Johri 2002; Rajendran and Sriranjini 2008). Hazards associated with food can result in injury or harm to human health. Apart from problems of synthetic products on non-target organisms, some insect species develop resistance against them over time. Due to the demerits of synthetic chemicals (Sighamony *et al.* 1986; Ashamo 2004; Ogunleye *et al.* 2004), the search for alternative pesticides in stored product like maize becomes inevitable. Total or partial replacement of synthetic products with natural products merits investigation.

Plant products have played an important role in traditional methods of protection against crop pests and disease vectors in Africa (Stoll 2000). In recent years, research on the efficacy of the use of plant materials as stored-grain protectants against insects has been intensified (Lale and Mustapha 2000; Umeozor 2001; Behera *et al.* 2002; Adedire and Akinneye 2004; Arannilewa *et al.* 2006; Kestenholz *et al.* 2007; Negahban *et al.* 2007; Babarinde *et al.* 2008). The feasibility of reducing the quantity of synthetic pesticides and replacing them with botanicals promises both ecological and economical prospects. Don-Pedro (1989) suggested the possibility of using reduced levels of vegetable oils in combination with synthetic insecticide in simple mixtures as a means of making their use more attractive and effective. Tembo and Murfitt (1995) also showed that wheat treated with vegetable oil combined with pirimiphos-methyl at half the recommended dose was effective against *S. granarius* (L.). Recently, Obeng-Ofori and Amiteye (2005) showed that the recommended dose of pirimiphos-methyl can be reduced when mixed with vegetable oil in the management of *Sitophilus zeamais.*

Tithonia diversifolia commonly called wild sunflower, tree marigold, Mexican tournesol, Mexican sunflower or Nitobe chrysanthemum is a member of the Asteraceae family. It is a stout shrubby, vigorously growing herb 2-3 m tall, and its leaves are mostly lobed with acute serrate lobes. It is common along major highways in southwestern Nigeria and it is a rapidly expanding exotic weed. The plant has a strong allelopathic effect on other plant species particularly *Chromolaena odorata* (Adedire and Akinneye 2004). Stoll (2000) reported its bioactivity against field insect pests. Its insecticidal properties against storage pests have been documented (Adedire and Akineye 2004; Adedire *et al.* 2006).

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Original Research Paper

Since *T. diversifolia* can be cheaply obtained by local farmers, its integration with primiphos-methyl is cheap, and several of the risks imposed by the use of pirimiphos-methyl singly can be reduced. Therefore, the objective of this study was to evaluate the efficacy of combining *T. diversifolia* with pirimphos-methyl on the management of *S. zeamais* in infested maize grains.

MATERIALS AND METHODS

Sitophilus zeamais culture

S. zeamais adults obtained from the Storage Entomology Unit of Agronomy Laboratory, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Nigeria were introduced into dry Tsolo maize variety, obtained from Sabo Market, Ogbomoso and raised as described by Babarinde *et al*. (2008) at ambient temperature (28 ± 2°C) and relative humidity (70 ± 5%). The experiments were carried out under the same conditions.

T. diversifolia leaf powder and synthetic insecticide used

Leaves (5 kg) of *T. diversifolia* were obtained from LAUTECH Farms, Ogbomoso. The leaves were air-dried under shade. They were pounded with a mortal and pestle and then sieved into a fine powder with the aid of a 0.4 mm domestic sieve. The powder was stored in an air-tight polythene bag until use. Primiphos-methyl (2%) dust locally formulated by Chemical and Allied Product PLC, Adeniyi Jones Avenue, Ikeja, Lagos, Nigeria was obtained from FITSCO (Nigeria) LTD, Jericho, Ibadan, Nigeria.

Treatments

The following treatments were used:
a) An untreated control: 50 g maize grains;
b) 0.025 g PPD (= the recommended dose);
c) *T. diversifolia* powder (1 g) corresponding to 2% w/w;
d) 0.013 g PPD (= half the recommended dose) + *T. diversifolia* (0.5 g) corresponding to 1% w/w;
e) 0.006 g PPD (= a quarter of the recommended dose) + *T. diversifolia* (0.5 g) corresponding to 1% w/w;
f) 0.003 g PPD (= an eighth of the recommended dose) + *T. diversifolia* (0.5 g) corresponding to 1% w/w.

Effect of treatments on mortality of *S. zeamais*

Fifty g of maize grains were weighed into 150 ml glass jars with a sensitive scale (Denver Measuring Instrument). Each treatment was added into the glass jar. Twenty ≤8 day old mix-sexed *S. zeamais* were introduced into each jar. The jar was covered with muslin cloth tightly held together with a cork, to prevent the escape of insects or the infestation by other pests. Each treatment was replicated four times. Mortality data were taken at 1, 3 and 7 days after treatment (DAT).

Effect of treatments on weight loss of treated maize grains and emergence of F_1 from *S. zeamais* adults

The six treatments were similarly prepared as for the mortality bioassay and 10 mix-sexed insects were introduced. Jars were covered as done for the first experiment and kept in the laboratory. Data of affected maize grains, percentage weight loss and F_1 adult emergence were taken at 42 DAT.

Persistence of treatments on stored maize

The six treatments were applied to 50 g of maize in 150 ml air-tight jars and stored for 15 days. After 15 days of storage, twenty ≤ 8 day old *S. zeamais* were introduced. There were four replicates. Mortality data was taken at 3 and 7 DAT. Similar treatments used for 15-day storage were used for 30-day storage with four replicates. After 30 days, the experimental procedures used for 15-day storage experiment were followed and mortality data was recorded at 3 and 7 DAT.

Data analysis

Percentage data were transformed to their arcsine equivalent values, while data of F_1 adult emergence were square root transformed prior to statistical analysis. Data were then subjected to analysis of variance (ANOVA) using SAS software (SAS Institute, 1985). Means were compared using the Fischer's least significant difference statistics ($p<0.05$).

RESULTS

Mortality bioassay

The result of toxicity of different mixtures of PPD and *T. diversifolia* against *S. zeamais* reveals that at 1 DAT, 0.025g PPD (recommended dose) killed significantly higher numbers of *S. zeamais* than all other treatments. At 3 DAT, mortality observed in the recommended dose was also significantly different from mortality observed in ½-dose + 0.5 g *T. diversifolia*. A treatment of ¼-dose + 0.5 g *T. diversifolia* caused significantly higher mortality than when *T. diversifolia* was used alone. However at 7 DAT, recommended dose of PPD performed equally as ½-dose + 0.5 g *T. diversifolia* because the difference in percentage mortality was not significant (**Table 1**).

Effect of treatments on weight loss of treated maize grains

Percentage weight loss of treated maize grains with recommended dose was not significantly different from weight loss observed when grains were treated with ½-dose PPD + 0.5 g *T. diversifolia.* Weight loss in other treatments was not significantly different from the control (**Table 2**).

Effect of treatment on F_1 adult emergence

Adult emergence from maize treated with different mixtures of PPD and *T. diversifolia* powder were significantly dif-

Table 1 Toxicity of different mixtures of *T. diversifolia* powder and pirimiphos-methyl dust (PPD) against *S. zeamais*.

Treatment*	% mortality at days after treatment		
	1	3	7
Recommended dose PPD	90.0 a	90.0 a	90.0 a
½-dose PPD +0.5 g *T. diversifolia*	19.6 b	69.6 b	83.6 a
¼-dose PPD +0.5 g *T. diversifolia*	7.8 c	32.5 c	42.1 b
1/8-dose PPD +0.5 g *T. diversifolia*	0.0 c	15.6 d	26.1 c
1.0 g T. *diversifolia*	0.0 c	0.0 d	0.0 d
Control	0.0 c	0.0 d	0.0 d
LSD (0.05)	8.4	16.4	14.0

*Recommended dose PPD was 0.025 g/50 g maize. ½ -dose was 0.013 g PPD/50 g maize, ¼-dose was 0.006 g PPD/50 g maize and 1/8-dose was 0.003 g PPD/50 g maize.
Means with similar letters of the alphabet in the column are not significantly different at 5% probability.

Table 2 Percentage weight loss of maize grains protected with different mixture of *T. diversifolia* powder and pirimiphos-methyl dust (PPD) against *S. zeamais*.

Treatment*	% weight loss
Recommended dose PPD	0.0 a
½-dose PPD +0.5 g *T. diversifolia*	2.3 a
¼-dose PPD +0.5 g *T. diversifolia*	11.2 b
1/8-dose PPD +0.5 g *T. diversifolia*	12.2 b
1.0 g T. *diversifolia*	12.9 b
Control	15.2 b
LSD (0.05)	4.7

*Recommended dose PPD was 0.025 g/50 g maize. ½-dose was 0.013 g PPD/50 g maize, ¼-dose was 0.006 g PPD/50 g maize and 1/8-dose was 0.003 g PPD/50 g maize.
Means with similar letters of the alphabet in the column are not significantly different at 5% probability.

Table 3 Emergence of *S. zeamais* F_1 adult from maize grains protected with different mixture of *T. diversifolia* powder and pirimiphos-methyl dust (PPD).

Treatment*	F_1 adult
Recommended dose PPD	2.6 a
½-dose PPD +0.5 g *T. diversifolia*	3.2 ab
¼-dose PPD +0.5 g *T. diversifolia*	3.8 ab
⅛-dose PPD +0.5 g *T. diversifolia*	4.3 ab
1.0 g *T. diversifolia*	4.4 ab
Control	5.1 bc
LSD (0.05)	2.1

*Recommended dose PPD was 0.025 g/50 g maize. ½-dose was 0.013 g PPD/50 g maize ¼-dose was 0.006 g PPD/50 g maize and ⅛-dose was 0.003 g PPD/50 g maize.

Means with similar letters of the alphabet in the column are not significantly different at 5% probability.

Table 4A Mortality of *S. zeamais* at 3 DAT in grains protected with different mixture of *T. diversifolia* powder and pirimiphos-methyl dust (PPD) after different storage periods.

Treatment*	% mortality after storage period	
	15 days	30 days
Recommended dose PPD	90.0 a	90.0 a
½-dose PPD +0.5 g *T. diversifolia*	60.9 b	32.8 d
¼-dose PPD +0.5 g *T. diversifolia*	45.8 c	31.6 d
⅛-dose PPD +0.5 g *T. diversifolia*	45.8 c	27.7 d
1.0 g *T. diversifolia*	7.8 de	4.6 e
Control	0.0 e	0.0 e
LSD treatment	8.3	
LSD storage period	5.7	
LSD treatment x storage period	ns	

*Recommended dose PPD was 0.025 g/50 g maize. ½ -dose was 0.013 g PPD/50 g maize, ¼-dose was 0.006 g PPD/50 g maize and ⅛-dose was 0.003 g PPD/50 g maize.

Means with similar letters of the alphabet in columns and rows are not significantly different at 5% probability.

Table 4B Mortality of *S. zeamais* at 7 DAT in grains protected with different mixture of *T. diversifolia* powder and pirimiphos-methyl dust (PPD) after different storage periods.

Treatment*	% mortality after storage period	
	15 days	30 days
Recommended dose PPD	90.0 a	90.0 a
½-dose PPD +0.5 g *T. diversifolia*	90.0 a	56.9 b
¼-dose PPD +0.5 g *T. diversifolia*	80.1 b	49.4 c
⅛-dose PPD +0.5 g *T. diversifolia*	60.4 c	40.6 d
1.0 g *T. diversifolia*	27.7 d	4.6 e
Control	3.3 e	0.0 e
LSD treatment	6.8	
LSD storage period	5.1	
LSD treatment x storage period	ns	

*Recommended dose PPD was 0.025 g/50 g maize. ½-dose was 0.013 g PPD/50 g maize, ¼-dose was 0.006 g PPD/50 g maize and ⅛-dose was 0.003 g PPD/50 g maize.

Means with similar letters of the alphabet in columns and rows are not significantly different at 5% probability.

ferent. A treatment of recommended dose of PPD gave 2.6 F_1 adults which was significantly lower than 5.1 adults observed in the control. The number (3.2) of F_1 adults observed in ½-dose + 0.5 g *T. diversifolia* was not significantly different from the number (2.6) of F_1 adults observed in the recommended dose (**Table 3**).

Persistence in grain

Data on the effectiveness of different treatments after different storage periods are presented in **Tables 4A** and **4B**. It was noticed that storage period affected the efficiency of all treatments that had *T. diversifolia* mixture. When the treatment was stored for 15 days and 30 days, cumulative mortality observed at 3 days post infestation of *S. zeamais* was highest in recommended dose of PPD and was followed by ½-dose + 0.5 g T. *diversifolia.* Storage period significantly affected mortality with higher mortality observed in 15 days storage than in 30 days storage. The mixtures performed significantly better than *T. diversifolia* alone and the control (**Table 4A**). At 7 days post infestation of *S. zeamais*, treatments stored for 15 days had an equal percentage (90%) of mortality in recommended dose of PPD and ½-dose + 0.5 g *T. diversifolia.* This, however, declined when treatment was stored for 30 days. Throughout the experiential periods *T. diversifolia* alone preformed lesser than other treatments (**Table 4B**).

DISCUSSION

The bioactivity of *T. diversifolia* leaf powder and extracts against stored product insects have been reported (Adedire and Akineye 2004; Adedire *et al.* 2006). In this study, *T. diversifolia* applied singly at 1.0 and 0.5 g mixed with ½-, ¼- and ⅛-dose PPD per 50 g maize grains were investigated for their efficacy in controlling *S. zeamais.* The mixture of ½-dose and 0.5 g of *T. diversifolia* caused significant mortality of *S. zeamais* within 1–7 days compared to untreated controls. *T. diversifolia* powder used alone doses not have significant effect on the mortality of *S. zeamais.* The fact that mortality recorded when maize was treated with ½-dose + 0.5 g *T. diversifolia* was not significantly different from mortality of recommended dose of PPD reveals the potentials of incorporating *T. diversifolia* into PPD for control of *S. zeamais.* Although acute toxicity was not prominent when PPD level was reduced, chronic toxicity was very significant. This is evident because mortality progressively increased with days after treatment. The increase in mortality post-treatment period was due to the fact that the insect had no escape route and was confined in the treatment to pick up lethal dosage as time of exposure increased. Adedire *et al.* (2006) had reported that toxicity of T. *diversifolia* powder to *S. zeamais* increased with days post treatment. Weight loss was significantly prevented in all treatments compared with the control. Similar result was obtained by Ewete *et al.* (2007) who reported that maize grain weight loss was prevented by botanical treatment of grains.

Interestingly, the performance of recommended dose of PPD (0.025 g/50 g maize) was not significantly different from the performance of ½-dose + 0.5 g *T. diversifolia*. This is a potential of reducing the dosage of PPD in its usage as protectant of maize at post-harvest level. The result of emergence of F1 adults followed the same pattern as that of weight loss. Suppression of F_1 progeny development as observed in this study could be due to reduced egg-laying and increased mortality of eggs (Maina and Lale 2005). As well, it was possible that the female died before they could lay eggs. Persistence of the treatment was dose-dependent and storage period-dependent. This result confirms Wawrzyniak and Blazejewska (2001) who reported that *Foeniculum capillaceum* powdered fruit decreased the fecundity of *S. oryzae.* Storage of the treatment for a longer period before infestation of *S. zeamais* affects its efficacy. Besides the recommended dose of PPD, all other formulations with *T. diversifolia* reduced efficacy with storage period. Lale (1994) had reported that plant powder have tendency of loss of potency in storage after some time. From this study, it is revealed that the mixing of *T. diversifolia* with PPD enhanced chemical toxicity and persistence, hence the higher mortality of adult weevils in maize grains treated with the mixtures compared with values obtained in sole application of *T. diversifolia*. This confirms Obeng-Ofori and Amiteye (2005) who reported that vegetable oils can be incorporated into pirimiphos-methyl for the management of *S. zeamais*.

Since weight loss and F_1 adults observed in mixtures of PPD and *T. diversifolia* were lower than what was observed when *T. diversifolia* was applied as a sole treatment, the potential of the mixtures is further established. The use of ½-dose + 0.5 g *T. diversifolia* appears promising. Chander *et al.* (1991) also reported that a combination of 4 ml/kg of mustard oil and turmeric powder at 20 g/kg gave the best protection of rice, completely suppressing progeny emergency of *S. oryzea* (L.). Tembo and Murfitt (1995) also showed that wheat with vegetable oils combined with pirimiphos-methyl at half the recommended dose was as effective as pirimiphos-methyl at the recommended dose against *S. granarius* (L.). The application of plant powder-insecticide mixtures may minimize insecticide usage hence reduce health hazards and reduce financial input of protecting stored products. Furthermore, the use of reduced rate (0.5 g *T. diversifolia* which is 1% of the produce) of powder will make its utilization more attractive.

Protecting grains with plant powder or insecticide mixtures could be prospective in parts of the world where insecticides are expensive or in short supply or where plant powders are really available. However, an aspect that worth further research is the persistence of the mixtures after a fairly long storage period. This deserves further works before large–scale practical application of the study can be initiated. This is because storage period tends to have depletive imparts on the efficacy of *T. diversifolia*-PPD mixtures.

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