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Sustaining rice revolution through the use of Essential Oils (EOs) of plants' extracts for postharvest protection of stored rice against *Sitophilus oryzae* in Nigeria

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Abstract

Bioassay experiments were conducted to test the efficacy of essential oils (EOs) of two spice plants in controlling *S. oryzae* in stored rice. 50g of *X. aethiopica* and *D. tripetala* seeds were separately washed, dried and pounded into powder. Essential oils were extracted from each of the spice plants through a vacuum distillation apparatus connected to high vacuum pump. The EOs were held separately for use in the laboratory bioassay to test their repellence against S. Oryzae in stored rice. The bioassay was conducted using a 4-way Olfactometer in which some rice grains were kept side by side with each of the EOs impregnated into filter paper. The rice grains and the filter paper were placed in one arm of the Olfactometer as test arm, while the other three arms were used as control. The insect pest was placed at the center of the Olfactometer and was allowed to respond to the emissions of Semiochemicals from the rice and the volatiles from the EOs. The number of entries and time spent by the insect in each arm of the Olfactometer were recorded. All data generated were subjected to analysis of variance (ANOVA) and the means separated by Tukey's simultaneous means separation. The number of entries was analyzed using t-test. The result showed a significant ($p<0.05$) repellency of the EOs to the insect pests, with EO of *X. aethiopica* more repellent than *D. tripetala*. It was therefore recommended amongst others that EOs of the two spice plants can be applied in small quantities on stored grains to serve as repellents and protectants against *S. Oryzae*.

Keywords: Bioassay; Repellency; Essential Oils; Spice Plants; Olfactometer; Semiochemicals; Volatiles

1. Introduction

Rice, *Oryza sativa* is one of the world's most important cereal crops. Amongst the cereal crops, it is only the production of wheat that is slightly higher than that of rice. The production of wheat globally in 2022 was put at 789,200.000 metric tons while that of rice was put at 517, 000,000 metric tons [1]. In 2024/2025 season, global rice production reached a record 535.8 million metric tons, a 3.0 % increase compared to the previous year. This represents a 3.1 million tons increase from the previous forecast, with India accounting for the bulk of the upward review. India produced 147 million metric tons (M/T) in the period under review, surpassing China to become the leading global rice producers. Wheat production in the same period 2024/2025 was estimated at 793 M/T, a slight increase from the previous year. [2]. Rice is an important staple for over 50 % of the world's population [3]. Its importance in the strategy for food security in sub-Saharan Africa cannot be over emphasized. It provides 20 % and 27 % needs of protein and energy respectively, in developing countries including Nigeria [3].

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Presently, Nigeria is the leading producer and consumer of rice in Africa, accounting for 64.20 % and 61.90 % of total production and consumption respectively [1]. Total rice consumption in Nigeria in recent times, stands at 54 million tons annually, while total output is about 3.8 million tons, National Bureau of Statistics [4]. Apart from its direct use as food, rice is also used in making alcohols, starch, oils, pharmaceutical products and dietetic foods.

In every cropping season, rice is produced for consumption, for sale to generate income, while some is stored, either as milled grains for future use or as rice paddy to be used as planting (sowing) materials in the next cropping season. Rice can also be stored to be sold when the price is appreciable, especially when there is a glut. However, rice undergo significant postharvest losses, ranging from the period of transportation, processing, storage and marketing. The value chain at which postharvest losses are huge, is at storage. During storage, rice grains are attacked by various order of Coleoptara in the family of Curculionidae and Bostrichidae. These include, *Trogoderma granarium, Tribolium casteneum, Rhizopertha dominica, Prostephanus truncatus, Lasioderma serricorne* etc. But the most important and primary pest of rice in storage is *Sitophilus oryzae* popularly called ‘rice weevil’.

‘Rice weevil’ is one of the most serious pests of stored rice grains in tropical and sub-tropical regions of the world. When grains are left unchecked, infestations by rice weevil can result in devastating damage to the stored grains. [5] reported that annual postharvest losses of grains as a result of infestations by *Sitophilus oryzae* have been recorded the world over. Damage by the insect to rice grains is characterized by eating up the ‘grains’ germ and converting it to dust. Even rice flour is usually attacked. The attack reduces the gain and flour quality, thereby rendering them unfit for human consumption. The rice paddy meant for planting (sowing) in the next cropping season, when attacked, will experienced loss of viability [6].

The control of this insect pest is economically very important, to ensure better storage and storage quality. Farmers have continuously been using organophosphate and organochloride insecticides such as fenitrothion, chloropyrifos-methyl, malathion, pirimiphosmethyl and dichlorvos to control insect pests in storage. These chemicals though effective, are harmful to the environment and product consumers.

1.1. Statement of the problem

The physical and nutritional losses in third world countries including Nigeria are due mostly to infestations of stored food products especially the grains. The attack on the grains’ endosperm leads to a loss of weight, reduction in the nutrients and deterioration of their quality. By eating the germ, the insects cause a reduction in the seeds ability to germinate. Ultimately, the specific gravity of the grain is decreased thereby lowering the market value of the grain.

Quite often, synthetic fumigants, the organochlorine insecticides such as Lindane; organophosphorus such as malathion, fenintrothion, chlorpyrifos-methyl, dichlovos etc, have been used as protectants against insect pests activities in stored grains [7]. However, the continuous use of these chemicals has limitations such as the development of resistance by the insects, the destruction of the ecosystem with adverse effect on the target and non-target organisms, the leaving of residue on the crops and the environment which in turn lead to health hazards to all consumers [8]. It has become imperative to seek other alternative means of controlling insect pests in storage, including the control of Sitophilus oryzae in stored rice, as against the continuous use of the hazardous chemicals. This is the focus of this research work, which is intended to investigate the repellent properties and the toxicity of two spice plants (*Xylopia aethiopica and Dennittia tripetala* against *Sitophilus oryzae* in stored rice.

Objectives of the research

- The research work was envisaged with the following objectives
- to extract essential oils (EOs) from the two spice plants (*Xylopia aethiopica* and *Dennittia tripetala*),
- to test the bioactivity (repellency and toxicity) of the essential oils of the two spice plants (*X. aethiopica and D. tripetala) on Sitophilus oryzae,*
- to compare the toxicity and repellency between the two spice plants against *Sitophilus oryzae* in stored rice.

2. Materials and methods

2.1. Extraction of essential oils (EOs)

Fifty grammes (50g) of partially dried *X. aethiopica* seeds were ground in a laboratory mortar and dissolved in a 50 ml re-distilled diethyl-ether. The container was immersed in an ultrasonic wave device for 5 minutes to disperse and homogenized the contents. The vacuum distilled apparatus was then connected to a high vacuum pump (ES 50 vacuum pump, Edwards, England). The glass sections of the apparatus were strongly heated with a hot air blower to remove any less volatile contaminants from its internal surface. The U-tube and the pear shape vessel meant for collecting the distillate were sub-merged completely in nitrogen at a temperature of -196^{o} C. The residue extracted was then distilled for 24 hours at pressure of 0.05 mmHg. Seeds of *D. tripetala* were equally pounded into powder and vacuum distilled in the same manner as explained above. The ether distillates of these substances were then pipetted from the vacuum distillation apparatus through long drawn Pasteur pipette into 50 ml separation funnels to remove water. The extracts were dried using magnesium sulphate ($MgS0_4$), then filtered and concentrated in order to obtain 4 ml each of *X. aethiopica and D. tripetala* essential oils (EOs). Each of the vacuum distilled extract was sealed under nitrogen, labelled accordingly and placed in different ampoules, pending laboratory bioassay with them [9].

Laboratory Repellence and Toxicity Bioassay experiments were conducted involving the insect pest of stored rice (*Sitophilus oryyae*) using Olfactometer, modified according to Peterson (1970). An Olfactometer consists of a 6 mm thick transparent Perspex held together. A four-pointed exposure chamber shaped like a star was fixed into a circular plate measuring 12 cm x 12 cm with a hole 3 mm drilled into the walls at each point of the four cardinal glass frames. Another plate 12.2 cm x 10.2 cm x 0.6 cm was used as the floor, while the third plate also 10.2 cm x 10.2 cm x 0.6 cm with hole of 4 mm in diameter at the centre was used as a cover. In order for the insect (*S. oryzae*) to work easily in the Olfactometer, a sheet of fisher brand QL 100, filter paper (Springfield Mill, Maid stone, Kent England) was placed on the floor covering. The passing of air stream into the Olfactometer in order to keep the insect mobile was made possible with the help of an Air entrainment box (KNF Nueberger, Germany) through Telfon tubing of size 3.2 mm (Cam/ab/Ltd) [10].

2.2. Laboratory Bioassay with the Essential Oils (EOs)

Bioasays were conducted to test the repellency and toxicity of essential oil of each of the two spice plants against *S. Oryzae* with respect to time spent in each arm of the Olfactometer and the number of times the insect entered each arm.

Essential Oils (EOs) extracted from *X. aethiopica and D. tripetala* were each impregnated separately into filter paper and placed along side with shelled rice grains in one arm of an Olfactometer, while the other three arms were used as control. An air stream was passed into the Olfactometer to keep the insect mobile as it starts moving towards volatiles emitted from rice grains and the EOs of the spice plants. The number of entries and the time spent in the test arm of the Olfactometer were recorded.

2.3. Data analysis

All data generated from the experiments were subjected to analysis of variance (ANOVA) and the means were separated and compared using Tukey's simultaneous means separation according to [11] at 5 % level of probability. Data on the number of entries or visits made by the insect to the test arm and control were analyzed using t-test at (0.05) level of probability. Minitab statistical software was used for the analysis of data.

3. Results

The time spent by *S. oryzae* in the test arm of the Olfactometer containing on separated occasions rice grains plus essential oils of *X. aethiopica and D. tripetala* impregnated into filter paper was significantly ($p<0.05$) different compared to the time spent by the insect in the control arms (Table 1).

Table 1 Behavioural responses of S. oryzae to volatiles from rice grains plus 10µl essential oils (EOs) of *X. aethiopica and D. tripetala* in a 4-way Olfactometer. (mean time spent by the insect in minutes ±SE)

Treatments		
	X. aethiopica	*D. tripetala*
Test arm	1.005	2.381
Control 1	3.657	3. 684
Control 2	3.566	3.668
Control 3	3.643	2.332
$\overline{X}$ SEM ±	2.967 2.856	3.016 1.834
CV %	22.42	25.22
LSD (0.05)	0.551	0.632

Similarly, the number of entries or visits by the insect to the arms containing rice grains plus essential oils of *X. aethiopica and D. tripetala* on separate occasions, was significantly ($p<0.05$) different compared to the number of entries or visits by the insect to the control arms (Table 2).

Table 2 Behavioural responses of *S. oryzae* to volatiles from rice grains plus 10µl essential oils (EOs) of *X. aethiopica and D. tripetala* in a 4-way Olfactometer (mean number of entries into each arm of the Olfactometer)

Treatments		
	X. aethiopica	*D. tripetala*
Test arm	1.800 ± 0.05	3.500 ± 0.22
Control	3.786 ± 0.26	5.036 ± 0.35
x̄	2.793 ± 0.155	4.268 ± 0.28
t (0.05)	1.832*	2.63*

Significant at (<0.05) level of probability

The interaction level in the efficacy of the two spice plants extracts to repel the insect (*S. oryzae*) was also significantly ($p<0.05$) different in terms of the time spent in the test arm and in the control arms of the Olfactometer (Table 3).

Table 3 Interactive effect between *X. aethiopica and D. tripetala* in terms of toxicity and repellence against *S. oryzae* in stored rice (main time spent in minutes ± se)

Treatments						
	Test arm	Control 1	Control 2	Control 3	x̄	LSD (0.05)
X. aethiopica	0.64	1.22	1.34	1.26	1.12	0.52**
D. tripetala	2.22	2.32	2.63	2.56	2.43	1.62*

** = Highly significant * = Significant

4. Discussion

4.1. The repellency test with essential Oils (EOs) from both *X. aethiopica* and *D. tripetala*

D. tripetala against S. oryzae was significantly ($p<0.05$) different, in respect to the main time spent by the insect in the test arm and control arms of the Olfactometer. However, the number of entries by the insect to the test arm was equally significantly ($p<0.05$) different (Table 1). The repellency of the EOs against *S. oryzae* is in line with the views of [12] who reported the toxicity and repellency of essential oils (EOs) of *A. melegueta, X. aethiopica and D. tripetala* against *S. zeamais*, a family member and close resemblance of S. oryzae. In the experiment involving the use of Olfactometer to test the toxicity and repellency of the essential oils of the spice plants, the insect was seen spending less time of between 1.0 seconds and 2.3 seconds in the test arm containing the essential oils impregnated into filter paper and placed alongside with rice grains. As the insect enters the test arm, it was repelled by the emissions of volatile chemicals from the essential oils, after being attracted by Semiochemicals from the rice grains, to enter the test arm. Time spent in the control arms was between 2.3 seconds and 3.6 seconds for both *D. tripetala and X. aethiopica*. The time spent in the control arms was higher than the time spent in the test arm, because there were no emissions of chemical volatile compounds from them, as was the case in the test arm.

The number of entries into test arm and control was also significantly ($p<0.05$) different (Table 2). The insect could take only about 1.8 seconds to enter into the test arm containing *X. aethiopica* and 3.5 seconds to enter the text arm containing *D. tripetala* during the time of the bioassay experiment. The limited time of entries into the test arm compared to between 3.7 seconds and 5.0 seconds as seen in the control arms was not unconnected with the toxicity and repellency properties of the essential oils in the test arm. [13] also reported the toxicity and repellent properties of Citroneller essential oils against insect pests such as Cockroaches, ants and flies.

The interaction effect between the efficacy of *X. aethiopica* and *D. tripetala* essential oils was also significantly ($p<0.05$) different (Table 3). Both the time spent and the number of entries into the test arm containing essential oil of *X. aethiopica* was 0.52 % smaller than the number of entries and time spent in the test arm containing essential oil of *D. tripetala* (1.62 %) (Table 3). The lower percentage of the time spent and the number of entries into test arm containing (EOs) of *X. aethiopica*, compared to *D. tripetala* was an indication that *X. aethiopica* was more toxic and repellent to the insect *S. oryzae* than *D. tripetala*. The biochemical emissions from *D. tripetala* were less toxic and repellent to *S. oryzae* which was the reason why the insect could afford to spend more time in the test arm, after being attracted to the test arm by the Semiochemicals from the rice grains.

The repellent and toxic property of the essential oils (EOs) of the two spice plants here were also in line with the report of [14] who reported that essential oils from spice plants contain volatile compounds that are capable of interacting with the insect nervous system either by inhibiting the release of the enzymes acetyl cholinasterase or by antagonizing the function of Octopanine recepters. The essential oil *X. aethiopica* may have contain a chemical substance which is more toxic and more repellent to the *S. oryzae* than *D. tripetala*.

The EOs here could be used to mask or alter the odours coming out of stored rice thereby minimizing the ability of *S. oryzae* to detect the direction of the food source where the odours are emanating from. This observation is in line with the report of [15] who observed that the use of plant odours to repel insect pests from stored crops has been the subject of modern research. The essential oils can also be prepared and applied as protective bands around grain bulks or incorporated into packaging materials, such as sacking and paper to mask odors from stored rice or evoke non-host avoidance and repellent behaviours in the insect [16]. Moreso, the essential oils could be used to treat the structure of an empty store to flush out hidden infestation before fresh grains are introduced [17].

The essential oils (EOs) are biodegradable and environmentally friendly. They are easily available and affordable; their use can be adopted by the resource poor farmers in sub-Saharan Africa including Nigeria.

5. Conclusion

Protecting stored products from the destructive effects of pests is a practice that is common in several countries of the world. However, the need to replace the synthetic pesticides with plant extracts cannot be over emphasized. The option of using plant-based insecticides instead of the toxic synthetic pesticides is a welcome development. This is coming especially at a time when there are heightened public concerns over their hazardous effect which is now receiving great interest amongst scientist the world over. Naturally, plant extracts are more suitable for their target specificity and are available with little or no adverse effects on mammals/ecosystem [15].

In Nigeria fruits and seeds of *X. aethiopica* and *D. tripetala* are used as spice source in cooking meat and in the treatment of human health conditions such as congestion, diarrhea, bronchitis, rheumatism etc. [18]. These and many other spice plants contain antioxidants and can act as antimicrobial, molluscicide, antishistosomal, antihypertensive as well as having the ability to repel insects [19].

The two spice plants studied here have not traditionally been used in rice grain protection, but are available locally and there is evidence in literatures that their volatiles are effective against other stored product pests [17]

Recommendations

- From the findings of the research work, the following recommendations were made
- Essential oils from *X. aethiopica* and *D. tripetala* have the ability to mask the odor of stored products such as rice, thereby diverting the attention of pests from the food source,
- Essential oils (EOs) of *X. aethiopica* and *D. tripetala* can be applied in small quantities on stored grains to serve as repellents and protectants against *S. Oryzae*,
- The essential oils (EOs) can also be used in treating partially infested paddy rice, since the oils have insecticidal properties which have the potential of suppressing the reproductive capacity of such insects, thereby deterring further emergence.
- Farmers should engage in massive production *X. aethiopica* and *D. tripetala* to ensure their availability at all times and in abundance,
- Government should encourage the massive production of the spice plants, by way of giving incentives to farmers such as credit facilities, and inputs
- The government should also procure and install equipment that will help in the extraction of the essential oils from the spice plant products for use in protecting stored rice grains and other stored products.

Compliance with ethical standards

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Disclosure of conflict of interest

There was no conflict of interest

Statement of ethical approval

The conduct of the experiment was in line with all ethical standards

Statement of informed consent

Approval was secured from the HOD of Agriculture for the use of laboratory to conduct experiment

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