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RESEARCH ARTICLE

UTILIZATION OF TWO LOCALLY SOURCED PLANT POWDERS AS PRESERVATIVES AGAINST *SITOPHILUS ZEAMAIS* MOTSCHULSKY (COLEOPTERA: CURCULIONIDAE) SUSCEPTIBILITY

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ABSTRACT

Due to the unfavourable and dangerous effects of conventional insecticides, protecting stored food grains against insect pest infestation has become a significant issue. Against this back drop, a laboratory experiment arranged in Complete Randomised Design was conducted to evaluate the insecticidal activity of *Bridellia micrantha* and *Chasmanthra dependens* against *S. zeamais* infestation on stored maize. Twenty grams (20g) maize seeds were admixed with 0.5, 1.0, 1.5 and 2.0g of each of the treatments in triplicates. Results showed that both plant materials caused significant adult mortality, suppressed infestation (9.45 – 21.71%), seed damage (6.88 – 21.71%) and reduced weight loss (5.79 – 34.01%) compared to control with increasing dosage rates. However, none of the plant powders was able to guarantee 100% protection against infestation, but both plant powders showed a significant promising effect in suppressing *S. zeamais* susceptibility to infestation and seed damage. The results obtained suggest that *B. micrantha* and *C. dependens* may be explored as a good potential botanical source insecticide as effective and suitable alternative to synthetic insecticides for *S. zeamais* infestation management on stored maize seeds due to their toxicity, oviposition deterrent, ovicidal activity and seed damage suppression.

KEYWORDS

Adult Mortality, Infestation, Insecticidal Activity, Oviposition Deterrent, Promising Effect, Susceptibility

1. INTRODUCTION

Maize (*Zea mays*) is an important cereal cultivated in the various agro ecological zones of Nigeria. It is gradually becoming "cash crop" with at least 30% of the arable land being put to maize cultivation under different cropping systems and amongst increasing use by food processing industries, livestock feed mills, and other agro allied industries (Ayeni, 1991; Tijani and Osotimehin, 2007). *Sitophilus zeamais* Motschulsky (*Coleoptera: Curculionidae*) infestation plays a significant role in lowering maize production below the qualities and yield required by a growing human population and rapidly increasing livestock enterprise. The insect is one of the most destructive insect pests of stored cereal food grains and has caused significant weight loss as well as impaired viability, reduced commercial worth and nutritional content of maize seeds; the extent of infestation and damages caused by *S. zeamais* called for its prompt control to enhance self-sufficiency and food security.

The control of this insect depends comprehensively on the usage of synthetic insecticides and fumigants for many years due to its quick knock down effect. Though, continuous and indiscriminate heavy usage of chemical control has led to numerous complications comprising deadly residual effects, ecological contamination, increased resistance strains, pest resurgence, secondary pest outbreak, killing of non-target species in insects and human health risk (Isman 2006; Salem et al., 2007; Ofuya et al., 2008; Shiberu and Negeri, 2016). In view of the several harms linked with the use of synthetic insecticides and fumigants for the management of stored products insect, it is therefore imperative to seek alternative sources that are freely obtainable, inexpensive, relatively less toxic and less injurious to the environment. Presently, consideration is being concentrated on the utilization of plant materials in pest management of stored products since they are found to be rich source of bioactive compounds and are commonly used as foods and in folk medicine.

Plants are considered as biological factories that produce different range of compounds collectively denoted as secondary metabolite (Kim et al., 2005). Thus, plants may offer prospective secondary metabolites such as alkaloids, terpenoids, phenolics, and flavonoids, substitute to presently used insect-control tactics since they constitute a rich source of bioactive substances (Abou-Elnaga, 2015). Plant based insecticides including essential oils are categorized by low mammalian poisonousness, minimal effect on non-target entities and short persistence in the environment, making them possibly desirable for integration in integrated pest management plans (Isman, 2006; Georges et al., 2007; Al-Alawi, 2014a). In continuation of exploration of plant materials for the management of stored products' insect pests, this study was conceived to evaluate the entomocidal potential of *Bridellia micrantha* (Hochst.) Baill. and

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Chasmanthra dependens Hochst. against *S. zeamais* infestation on stored maize.

2. Materials and Methods

2.1 Insect culture and experimental conditions

Sitophilus zeamais used for this study were gotten from an already standing culture in the Entomology Laboratory, Department of Crop Production Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria (7°11′N 5°35′E). They were sub-cultured in a Kilner jar, containing 250g of uninfested Oba maize cultivar. The insect culture and the experiment were kept at ambient laboratory condition of 30±2°C temperature, 75±5% Relative humidity and a 12:12 light:dark photoperiod.

2.2 Collection and preparation of plant materials

The plant parts were collected fresh from (Table 1) Araromi Obu in Irele Local Government Area of Ondo State (6° 36' 0" N, 4° 30' 0" E) and is genuineness were validated at the Forestry and Wood Technology Department, Rufus Giwa Polytechnic, Owo, Ondo State where a specimen voucher was deposited. The plant materials were immersed in clean water to eliminate dirt, thereafter air-dried for a period of 2 weeks under a room temperature to avoid likely volatilization of the bioactive constituents and ground into very fine powder using hammer mill after being pounded with pestle and mortar. The powder was sieved using 1mm^2 perforations sieve and packed in plastic container tightly covered with lids and kept in laboratory cabinet till use.

Table 1: Botanical used for the experiment

	Common Name	Botanical Name	Family Name	Parts Used
1	Coast goldleaf	*Bridellia micrantha*	Phyllanthaceae	Leaves
2	Chasmanthera	*Chasmanthera dependens*	Menispermaceae	Bark

2.3 Maize bioassay source

Maize seeds used for this study were obtained from Agricultural Input Supply Company (AISC) Akure, Ondo State, Nigeria (7° 15' North, 5° 12' East) with no history of insecticides and visible sign of insect infestation. Nevertheless, the maize seeds were positioned in a Gallenkamp oven (model 250) for 4 hours at 40°C to kill any developmental stages of insect (if any) and later air dried to prevent mouldiness in the laboratory (Adedire et al., 2011).

2.4 Toxicological effects of *Bridellia micrantha* and *Chasmanthra dependens* plant powders

Twenty grams (20g) of the maize seed were weighed into fifteen (15) 125ml plastic containers. Plant powder weighing 0.5, 1.0, 1.5 and 2.0g were put in the plastic containers and thoroughly tumble with the maize seeds to ensure proper mixing. The experiment was set up in a Completely Randomized Design (CRD) and each treatment was replicated three times. Ten (10) unsexed adult *S. zeamais* were introduced into each plastic container and covered. There was also control experiment with no addition of plant powder. The experiment was left undisturbed on the work bench in the laboratory for observation. Weevil mortality was assessed every 24 hours up to 96 hours. Knocked-down adults were considered as being alive if after a touch of "safety pin" they exhibited sustained movement of their legs under a magnifying glass for some seconds (Adesina and Mobolade-Adesina, 2016). Dead weevils were removed and discarded after every count. After 14 days, all dead and alive insects, were removed from each container leaving only the seeds in their corresponding containers. Percentage adult mortality was corrected using Abbott formula modified (Abbott, 1925; Baskar et al., 2011).

$$\%\ \text{corrected mortality} = \frac{\%\ \text{motarlity in treatment} - \%\ \text{mortality in control}}{100 - \%\ \text{mortality in control}} \times \frac{100}{1}$$

The experimental set up was left on the workbench in the laboratory for 45 days pending first filial (F1) generation emergence. Each treatment container was sifted and newly emerged adult *S. zeamais* were counted and recorded. The percentage adult emergence reduction was considered using the method of (Adesina et al., 2015).

$$\%\ \text{Adult emergence reduction} = \frac{\text{no of emerged adult from control dish} - \text{no of emerged adult from treated dish}}{\text{no of emerged adult from control dish}} \times \frac{100}{1}$$

The percentage loss in weight of the maize seeds was evaluated by re-weighing the stored maize seeds 45 days after treatments and the percentage loss in weight was determined as follows:

$$\%\ \text{weight loss} = \frac{\text{initial weight} - \text{final weight}}{\text{intial weight}} \times \frac{100}{1}$$

The numbers of damaged seeds were calculated by counting wholesome seeds and seeds with adult exit holes after re-weighing. This was used to determine percentage seed infestation and percentage insect tolerance as follows:

$$\%\ \text{infestation} = \frac{\text{no of seeds with adult exit hole}}{\text{total no of seeds}} \times \frac{100}{1}$$

$$\%\ \text{insect tolerance} = \frac{\text{No of seeds without adult exit hole} - \text{No of seeds with adult exit hole}}{\text{No of seeds with adult exit hole}} \times \frac{1}{}$$

2.5 Qualitative Phytochemical Screening

The plant powders were qualitatively screened for phytochemical constituents for the presence of alkaloids, saponins, tannins, glycosides and flavonoids centered on visual scrutiny of color or precipitate formation after addition of specific reagents according to a method described (Wadood et al., 2013; Yadav and Agarwala, 2011).

2.6 Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA) and treatment means were separated using the new Duncan's Multiple Range Test (DMRT). The ANOVA was performed using GenStat 14th Edition of 2011.

3. Results

Results presented in Table 2 showed the susceptibility of adult *S. zaemais* to different dosages of *B. micrantha* and *C. dependens* over a period of time. There was a significant difference (p<0.05) in death rate of *S. zaemais* owing to botanical source insecticide at 2.0 g being the best active, compared to other dosages and control treatment (Table 2). The current study exhibited that plant species, dose of powder applied, and the contact time significantly predisposed the percentage susceptibility rate of adult weevils to the plant powders. Highest mortality rate was recorded at 96 h post infestation and lowest mortality at 24h post infestation.

Table 2: Percentage death rate of adult *S. zeamais* in maize treated with *B. micrantha* and *C. dependens* powders

	Death rate hours after infestation							
	B. micrantha				*C. dependens*			
Rates	24h	48h	72h	96h	24h	48h	72h	96h
0g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5g	0.00	0.00	20.00±3.06^c	35.00± 2.06^d	0.00	10.00± 1.16^d	20.67± 2.71^d	38.50± 1.04^d
1.0g	0.00±	10.33± 0.18^c	22.67± 2.04^c	40.00± 2.41^c	0.00	20.50± 2.64^c	35.80± 1.55^c	45.00± 2.36^c
1.5g	10.33± 1.17^a	20.00± 2.62^b	30.00± 2.91^b	55.00± 1.94^b	6.00±1.57^b	25.00± 2.83^b	40.00± 2.08^b	58.00± 2.91^b
2.0g	10.33± 1.26^a	30.00± 1.02^a	45.00±3.18^a	63.00± 2.83^a	10.00± 1.15^a	40.00±2.22^a	67.00±1.92^a	70.33±3.18^a

Each value is a mean ± standard error of four replicate. Means within column followed by the same letter are not expressively different at (P> 0.05) using New Duncan's Multiple Range Test.

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Results in Table 3 showed that maize grains treated with low dosage of plant products were significantly susceptible to *S. zaemais* infestation while higher dosage rate resulted in high tolerance and lower infestation level. The results clearly indicated that stored maize susceptibility and tolerance to *S. zaemais* infestation is directly proportional to the increasing level of *B. micrantha* and *C. dependens* admixed with the stored maize.

Table 3: Percentage *S. zeamais* tolerance and infestation to *B. micrantha* and *C. dependens* powder

	% tolerance		% *S. zeamais* infestation	
Rates	*B. micrantha*	*C. dependens*	*B. micrantha*	*C. dependens*
0g	11.58±0.73^{e}	12.68± 1.65^{e}	55.40±2.01^{a}	59.51±2.50^{a}
0.5g	26.35± 2.33^{d}	36.03± 1.37^{d}	21.71± 1.34^{b}	12.32±2.39^{b}
1.0g	32.74± 1.66^{c}	40.10± 2.12^{c}	19.38± 1.25^{c}	11.07±2.04^{b}
1.5g	37.08± 2.02^{b}	46.13± 2.44^{b}	15.31± 2.89^{d}	9.67±1.25^{c}
2.0g	55.69± 2.84^{a}	51.16± 3.45^{a}	10.50± 1.43^{e}	9.45±0.76^{c}

Each value is a mean ± standard error of four replicate. Means within column followed by the same letter are not expressively different at (P> 0.05) using New Duncan's Multiple Range Test.

Table 4: Percentage seed damage and weight loss of maize grains admixed with *B. micrantha* and *C. dependens* leaves powder

	Percentage seed damage		Percentage weight loss	
Rates	*B. micrantha*	*C. dependens*	*B. micrantha*	*C. dependens*
0g	25.40± 1.28^{a}	49.51± 2.33^{a}	58.96±3.07^{a}	57.71±2.43^{a}
0.5g	21.71± 2.05^{b}	10.67± 1.84^{b}	34.01±2.89^{b}	35.19±3.07^{b}
1.0g	19.05± 0.93^{c}	11.06± 1.82^{b}	15.59±3.12^{c}	15.88±2.44^{c}
1.5g	15.31± 1.67^{d}	7.01±0.73^{c}	9.54±2.44^{d}	8.98±1.66^{d}
2.0g	10.49± 1.02^{e}	6.88±1.18^{c}	7.06±2.02^{e}	5.79±2.82^{e}

Each value is a mean ± standard error of four replicate. Means within column followed by the same letter are not expressively different at (P> 0.05) using New Duncan's Multiple Range Test.

Maize grains treated with the different dosages of *B. micrantha* and *C. dependens* powders expressively (P<0.05) decreased damage caused by *S. zeamais* equated to the untreated grains. Grains treated with the highest dosage of powders recorded the lowest percentage weight loss of 5.79% and 7.06%, respectively while the lowest dosage of both powder (0.5g) recorded higher percentage weight loss of 35.19% and 34.01%, respectively as shown in Table 4, while the untreated grains compared to the highest dosages of both powder severed highest percentage weight loss. Similar trend was equally observed in terms of percentage seeds damage.

The effect of the two plant powders on *S. zeamais* adult emergence was presented in Table 5. The plants significantly influence *S. zeamais* adult emergence. Highest percentage adult emerged from the control dish and the minimum was recorded from dishes treated with 2.0g plant powder. However, all the dosages of *B. micrantha* and *C. dependens* powders have adult emergence inhibition effect by suppressing F1 progeny emergence in *S. zeamais* on treated maize, but none completely prevent adult *S. zeamais* from emerging from treated maize seeds.

Table 5: Mean adult emergence and adult exit hole of *S. zeamais* admixed with *B. micrantha* and *C. dependens*

Adult emergence		
Rates	***B. micrantha***	***C. dependens***
0g	11.61±2.53^{a}	13.33±2.33^{a}
0.5g	3.63±1.03^{b}	3.56±2.01^{b}
1.0g	2.71±2.02^{c}	2.71±1.94^{c}
1.5g	1.73±0.33^{d}	1.58±0.80^{c}
2.0g	1.02±	
0.15^{e}	1.00±1.82^{d}	

Each value is a mean ± standard error of four replicate. Means within column followed by the same letter are not expressively different at (P> 0.05) using New Duncan's Multiple Range Test.

Phytochemical constituents of the plants discovered the presence of tannin, saponin, flavonoid and alkaloids in both plants and absence of glycosides in *B. micrantha* (Table 6). The presence of these phytochemicals depicts their insecticidal potentials.

Table 6: Qualitative phytochemical constituents for *Bridelia micrantha* and *Chasmanthera dependens*

Phytochemical constituents	*Bridelia micrantha*	*Chasmanthera dependens*
Flavonoids	-	+
Tannins	+	+
Alkaloids	+	+
Saponins	+	+
Glycosides	+	+

4. Discussion

Emerging botanical insecticides that are effective against insect pests but safe for pollinators and other useful organisms is essential for justifiable pest management, while appraisal of insecticidal action is one of the major steps in the unearthing and development of botanical insecticides (Al-Alawi 2014a; 2014b). The result of the current study discovered that both powders of *B. micrantha* and *C. dependens* possess insecticidal properties as they evoked adult *S. zaemais* mortality higher than the control at all doses used. The significantly highest mean mortality of adult *S. zaemais* recorded in the maize seeds treated with *B. micrantha* and *C. dependens* at the various dosages and exposure periods showed that they were effective in controlling the insects. The efficacy of the powders was dependent on the dosage used and period of exposure. This was in accordance with the study of (Mulungu et al., 2007; Patole, 2009; Yankanchi and Gadache, 2010; Ziaee and Moharramipour, 2013).

A group researcher stated that time is a factor to be considered in the use of plant powders as grain protectants (Akunne et al., 2014a; 2014b). Toxic action of the plant powders increased with increasing exposure period and the rise in death rate according to increasing contact period and dosage was due to the escalation of the quantity of bioactive constituents in the plant materials. The contact time is decisive for the efficacy of *B. micrantha* and *C. dependens* powders, as insects' movement increases the interaction of the insect cuticle with dust particles (Athanassiou et al., 2005).

The lower percentage survival recorded against *S. zaemais* caused by *B. micrantha* and *C. dependens* could be linked to (i) the chemical constituents present in the plants which are inimical to the insects and (ii) the desiccation occasioned by the harshness of the small particles of the plant powders, as inert dust and sand works on same principle which breakdowns the layer of wax on the epicuticle, aggravating the deadly loss of water as reported or dehydrates the insect cuticle and aggravates asphyxia in insect (Korunic 1998; Fields and Korunic 2000; Kavallieratos et al., 2005; Subramanyam and Roesli, 2000; Akunne et al., 2014b).

The decrease in the rate of emerged adults detected from the study could be as a consequence of the admixture of maize seeds with plant powders which fill the insect intergranular air spaces and prevent adult free movement for mating and oviposition. This assertion confirms the positions of who stated that percentage adult emergence is directly proportional to the insect oviposition rate (Adesina and Ofuya, 2015; Adesina et al., 2011). The failure of these insects to develop may be due to the death of the insect's larvae, which may arise due to incapability of the larvae to completely cast off their exoskeleton. The secondary metabolites found in these plants could be liable for the failure of the adult insects to emerge as discoursed by who stated that secondary metabolites in botanicals are found to interrupt growth and reduce larva existence as well as interfere with the life cycle of insects (Mordue-Luntz and Nisbet, 2000; Yang et al., 2006). A group researcher detected that plant products lowered the emergence of progeny by increasing adult death rate, inhibiting oviposition, ovicidal and larvicidal activities (Suleiman and Yusuf, 2011; Ibrahim et al., 2012; Mofunanya and Nta, 2016; Obembe et al., 2020). While, many researchers disclosed that adult *S. zeamais*, are exterminated by contact with diatomaceous earths, Triplex powders Nigerian raw diatomite correspondingly (Arthur and Throne, 2003; Tadesse and Subramanyam, 2018; Medugu et al., 2020). Nonetheless, some oviposition could still take place and offspring destruction may not be effective. That may explain the lowest emergence of progeny at the lowest treatment doseage.

Mean proportion of seed damage and loss in weight were much more in the control dish compared to the maximum protection offered maize grains treated with plant powders. The reduced damage and loss in weight may be due to the oviposition deterrent and/ or ovicidal properties which suppressed or inhibited egg laying and hatching resulted into low emerged adult to devour the stored maize. The reduced damaged seed and loss in weight in the seeds treated with plant powders might also be as a result of the antifeedant properties of the plants evaluated. From this study, it can be observed that percentage damaged seed and loss in weight is directly proportional to number or percentage adult emergence from treated seeds.

Some chemical substances available in the plants include alkaloids, tannins, saponins, flavonoids, and are bioactive constituents found in the evaluated plants; which could be responsible for the insecticidal action demonstrated by the plants, that resulted in low adult *S. zaemais* survival and progeny emergence thus leading to the prevention of the treated maize grains from damages (Trease and Evans 1989; Okwu et al., 2006). The observation from this study aligned with the assertion Adesina et al. (2016) of who conveyed the insecticidal efficacy of *B. micrantha* in subduing *Podagrica uniforma* and *Nisotra dilecta* infestation on *Abelmoschus esculentus*.

5. Conclusion

The observed adult insect mortality, reduced F_1adult emergence, seed damage and percentage weight loss after the application of the plant powders may be due to the bioactive components of the plant species that were responsible for insecticidal activities against *S. zeamais* infestation. The results obtained suggest that *B. micrantha* and *C. dependens* may be explored as a good potential botanical source insecticide as effective and suitable alternative to synthetic insecticides for *S. zeamais* infestation management on stored maize seeds due to their toxicity, oviposition deterrent, ovicidal activity and seed damage suppression. Further study is recommended for the isolation and characterization of the plant bioactive molecules to determine its mode of action.

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