Original Article: Screening of Twenty Plant Powders for Potency against *SitophilusZeamais* Motschulsky (Coleoptera: Curculionidae) in Stored Maize

Olawale-Success[1], O. Oluwagbemisola[1]*, Ayeni. Ayobami Gabriel[2]

[1]*Department of Crop Protection, Federal University of Agriculture, Abeokuta, Nigeria*

[2]*Department of Applied Science, Rivers State University, Port Harcourt, Nigeria*

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ABSTRACT

The maize weevil, *Sitophilus zeamais* (Motschulsky), is a field-to-store primary pest in tropical and subtropical regions which causes up to 20-30% damage to stored maize grains. Twenty plant powders were screened for potency against *Sitophilus zeamais* arranged in completely randomized design with four replicates and control without the treatment. The results revealed that the plant powders produced no significant effect ($p > 0.05$) on mortality at the second day post treatment against *Sitophilus zeamais*. However, significant effect ($p < 0.05$) was recorded on the 7th, 14th, 21st and 28thdays post treatment. The lowest value for adult emergence was found in *Annona squamosa* (0.18), *Piper guinensis* (1.33) and *Vernonia amygdaliana* (1.67). It was found that *Annona squamosa* (10.31%), *Vernonia amygdaliana* (23.73%) and *Piper guinensis* (24.18%) recorded the lowest value for percent grain damage. The percent weight loss was found to be significantly lower in *Annona squamosa* (4.85%), *Piper guinensis* (5.43%) and *Vernonia amygdalina* (10.83%) compared with others. The percent WPI was also found to be low in *Annona squamosa* (12.86%), *Vernonia amygdalina* (28.08%) and *Piper guinensis* (32.94%). Mortality of *Sitophilus zeamais* significantly varied with the plant powders and period of exposure. The results obtained indicated that the plant powders *Annona squamosa*, *Vernonia amygdalina* and *Piper guineense* may provide effective control of *Sitophilus zeamais.*

***Corresponding Author:** *O. Oluwagbemisola, (greatconcepts2020@gmail.com)*

Introduction

Maize, *Zea mays* (L) is an important member of the Poaceae family. It ranks next to wheat and rice in cereal production worldwide [1, 2], making it very essential in terms of food security. Its cultivation occupies less land area than either wheat or rice but has a greater average yield per unit area of about 5.5 tonnes per hectare [3]. Maize is considered a cash crop contributing to per capita income especially in developing countries accounting to over 30% of the small–holder farmer earnings [4] and as a food crop. The crop is very nutritious containing about 70-72% digestible carbohydrate, 4 - 4.5% fats and oils and 9.5-11% proteins [5]. Maize kennel is also rich in vitamins and fats and makes the crop compete favourably as an energy source, with root and tuber crops per unit quantity [6]. Maize is consumed by humans as food, it is used for livestock feed and for industrial purposes [7]. However, despite these contributions, a significant loss of the crop can be experienced if good storage practices are not in place. An estimated 8-10% of total grains stored in warehouses or in silos is lost yearly as a result of inappropriate storage conditions [8]. In most developing countries, storage pests cause substantial economic losses [9]. Insects bore into the kernels and feeding on the surfaces, remove food and selectively consume nutritive components which encourage higher moisture in the grain while promoting the development of microorganisms. Maize is exposed to insect pest attack before harvest and in storage. Many pests of stored maize are coleopterans and they include: *Sitophilus oryzae* L., *Prostephanus truncates* H., *Tribolium castaneum* H., *Ephestia cautella* W. and *Sitophilus zeamais* Motsch. [10, 11]. Control of insect pests in stored food products relies heavily on the use of chemically synthesized pesticides. This however, results in serious problems of toxic residues, health and environmental hazards, destruction of non-target species, development of insect strains resistant to insecticides and increasing cost of application [12]. The need to find materials that effectively protect stored produce, that are readily available, affordable, relatively less poisonous and less detrimental to the environment has stimulated interests in the development of alternative control strategies and the re-evaluation of traditional botanical pest control agents [13]. This study therefore aimed at evaluating the potency of twenty plant powders against *Sitophilus zeamais* on stored maize.

Materials and Method

The study was carried out in the laboratory of the Department of Crop Protection Federal University of Agriculture Abeokuta, at temperature of 26.6ºC and Relative humidity of 89% respectively. Maize seeds SWAN-1 variety used for the study was obtained from the Institute of Agricultural Research and Training (IAR and T) Ibadan, Nigeria. *Sitophilus zeamais* was obtained from naturally infested maize seeds from maize sellers at Kuto market at Abeokuta, Ogun State.

Table 1. Plant materials used for the study

S/N	Scientific name	Common/Local name	Family	Plant parts
1	*Citrus sinensis*	Sweet Orange	Rutaceae	Peel
2	*Chromolaena odorata*	Siam weed	Asteraceae	Leaf
3	*Gmelina arborea*	Ewe paper	Lamiaceae	Leaf
4	*Vernonia amygdalina*	Bitter Leaf	Asteraceae	Leaf
5	*Tithonia diversifolia*	Sunflower	Asteraceae	Leaf
6	*Piper guineense*	African Black pepper (Iyere)	Piperaceae	Seed
7	*Afromomum melengueta*	Aligator Pepper (Atare)	Zingiberaceae	Seed
8	*Carica papaya*	Pawpaw	Caricaceae	Leaf
9	*Anacardium occidentale*	Cashew	Anacardiaceae	Leaf
10	*Annona squamosa*	Custard apple	Annonaceae	Leaf
11	*Ageratum conyzoides.*	Goat weed	Asteraceae	Leaf
12	*Cymbopogon citratus*	Lemon grass	Poaceae	Leaf
13	*Ocimum gratissimum*	Efirin leaf/scent leaf	Lamiaceae	Leaf
14	*Psidium guajava*	Guava	Myrtaceae	Leaf
15	*Magnifera indica*	Mango	Anacardiaceae	Leaf
16	*Hyptis suaveolens*	Pignut	Lamiaceae	Leaf
17	*Musa paradisiaca*	Plantain leaf	Musaceae	Leaf

18	*Azadirachta indica.*	Neem	Meliaceae	Leaf
19	*Alstonia boonei*	Stool wood	Apocynaceae	Leaf
20	*Elaeis guineensis*	Palm tree	Arecaceae	Leaf

Insect Culture

One (1) kg of SWAN-1 maize seeds was put in each of 20 Kilner jars used. Thereafter, five pairs of adult *Sitophilus zeamais* were introduced into the 20 Kilner jars containing the maize seeds. The Kilner jars were covered with fine mesh cloth fastened with rubber bands to prevent the contamination and escape of insects, and the introduced insects were allowed to mate and oviposit for 7 days. After 7 days, the parent stock was sieved out while the maize seeds containing eggs were left undisturbed until the new adults emerged. The newly emerged adults of *Sitophilus zeamais* were then used for the various experiments [14]. In order to sustain the adult insects, devoured seeds were replaced continuously with fresh non-infested maize.

Twenty (20) plant materials collected fresh and identified at the Department of Forestry and Wildlife, Federal University of Agriculture, Abeokuta [15]. The plant materials were air-dried and chopped into smaller pieces in the laboratory for about two weeks. Pulverised into fine powder in a Marlex electroline 750 watts milling machine. The powder of each was kept in air tight container to retain its effectiveness and avoid loss of odour.

Screening of twenty plant powders against Sitophilus zeamais

The maize seeds were air-dried for three hours and were later packed and kept in polythene bags prior to the experiment.

Adult Mortality Test

Twenty (20) g maize seeds were weighed into a petri dish, having a hole of 2 cm in diameter and sealed with a muslin cloth. Plant powder was added to the dish at a dose rate of 2 g respectively. The petri-dish was shaken to allow for thorough mixture of the content. Ten (10) pairs of newly emerged adult *Sitophilus zeamais* from the culture were introduced into the dish, the set up was done for each plant powder including control and was arranged in complete randomized design with four replicates. Mortality was assessed at 2 days, 7 days, 14 days, 21 days and 28 days of treatment respectively. The insects were considered dead when they did not respond after probing the abdomen with a pin; the dead insects were removed after counting

Theory and Calculation

Adult Emergence

The new individuals that emerged were counted daily and recorded from 36 to 45 days, and mean adult emergence was calculated. Experiment ended when no adult emergence was recorded for four consecutive days. At the end of the experiment, the final weights of the maize were taken and recorded.

Mathematical Expressions and Symbols

Percentage seed damage

Percentage seed damage was calculated after the last experiment at 45 days by counting and recording seed with holes and without holes.

$$\text{Percentage seed damage} = \frac{\text{Total number of treated seed perforated}}{\text{Total number of seeds}} \times 100 \quad (1)$$

using the method of [16] and [17].

Percentage weight loss

Initial weight and final weight were taken and percentage weight loss was determined:

$$\%\text{Weight Loss} = \frac{\text{Initial weight of sample-final weight}}{\text{Total number of seeds}} \times 100 \quad (2)$$

Total number of seeds using the method of [18] and law [19].

Weevil perforation index (WPI)

Weevil perforation index (W.P.I) was calculated using the method of [20].

$$WPI = \frac{\%TP}{\%TP + \%CP} \times 100 \quad (3)$$

Where:

%TP= % signified Treated seed perforated

%CP=% signified Control seed perforated
WPI>50 signified Negative protectant of plant material tested (i.e. enhancement of infestation by weevil)
WPI<50 signified Positive protectant (i.e. prevention of infestation by weevil)

Data generated from the Weevil perforation index, percentage seed damage and adult emergence and weight loss were used to rank or classify the botanicals into different levels of efficacy or potency i.e. highly potent, potent, moderately potent and non-potent using the ratings of weighted average of damage parameters as described by [21].

Results and Discussion

The scientific, common name, family and plant parts of the plant materials used are shown in Table 1. The plant parts used are mainly the leaves, other parts used included the peel and the seed. The effectiveness of the twenty plant materials used to control *Sitophilus zeamais* in maize seeds was shown in Table 2. Results showed that *Annona squamosa*, *Vernonia amygdalina*, *Piper guineense*, *Tithonia diversifolia*, *Ocimum gratissimum*, *Azadirachta indica* and *Psidium guajava* were able to affect mortality on the adult beetle from 2 days after treatment of the seeds. Adult emergence was significantly lower in maize treated with *Annona squamosa* while *Musa paradisiaca* showed the highest adult emergence. Damage done on the treated seeds over the period of storage (28 days) was significantly high (on seeds treated with *Musa paradisiaca* (92 %); however, seeds treated with *Annona squamosa* recorded significantly low damage (10 %) as compared with the control seeds (94 %).

Weighted average of plant powders screened for potency against *Sitophilus zeamais* was shown in Table 3. Based on a scale of 1-5, it was shown that the highly potent botanicals were *A. squamosa*, *V. amygdalina* and *P. guineense* with weighted average between 1.00-1.99, while *T. diversifolia*, *O. gratissimum*, *P. guajava* and *A. indica* were potent with weighted average between 2.00-2.99. *Citrus sinensis*, *G. arborea*, *C. papaya*, *A. conyzoides*, *M. indica*, *A. boonei* and *E. guinensis* were moderately potent with weighted average between 3.00-3.99 while *C. odorata*, *A. melenguata*, *A. occidentale*, *C. citrates*, *H. suaveolens* and *M. paradisiaca* were non-potent with weighted average between 4.00-4.99. Also, the results obtained in this study revealed that most of the tested botanicals have positive protectant ability of maize grains against *S. zeamais* by resulting in W.P.I value of <50%. *Piper guineense*, *Annona squamosa* and *Vernonia amygdalina* are most preferred and active; they can be used for the control/management of *Sitophilus zeamais*. However, further investigations should be used on other insects other than *S. zeamais.*

Table 2. Potency of twenty plant powders against *Sitophilus zeamais*

	Plant powders	Mean mortality at 2days - 28 days Post Treatment					Adult Emer gence	Grain Damag e (%)	Weight loss (%)	WPI (%)
		2 days	7 Days	14 Days	21 Days	28 Days				
1	Citrus sinensis	0.90^{a}	0.83^{b}	0.20^{c}	0.00^{c}	0.00^{c}	4.74^{b}	45.70^{bcd}	37.30^{bcd}	17.30^{ab}
2	Chromolaena odorata	1.00^{a}	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}	6.95a^{b}	85.33^{ab}	13.20^{bcd}	56.53^{a}
3	Gmelina arborea	0.00^{a}	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}	6.29^{ab}	53.19^{ab}	12.28^{bcd}	23.81^{a}
4	Vernonia amygdaliana	3.40^{a}	2.67^{a}	2.60^{b}	2.43^{b}	2.41^{ab}	1.67^{c}	23.73^{cd}	10.83^{cd}	28.08^{bc}
5	Tithonia diversifolia	3.10^{a}	3.00^{b}	2.50^{c}	2.35^{c}	1.90^{c}	7.92^{ab}	74.73^{ab}	15.12^{a-d}	23.16^{ab}
6	Piper guineense	3.67^{a}	3.60^{b}	3.54^{a}	3.00^{a}	2.43^{a}	1.33^{c}	24.18^{d}	5.43^{d}	32.94^{c}
7	Afromomum melengueta	0.33^{a}	0.00^{b}	0.00^{b}	0.00^{c}	0.00^{c}	6.72^{ab}	77.88^{ab}	11.97^{bcd}	56.20^{a}
8	Carica papaya	2.45^{a}	2.41^{b}	0.33^{c}	0.00^{c}	0.00^{c}	6.39^{ab}	60.79^{abc}	7.73^{cd}	48.94^{ab}

9	Anacardium occidentale	0.00^{a}	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}	7.51^{ab}	78.47^{ab}	14.97^{a-d}	54.46^{ab}
10	Annona squamosa	4.00^{a}	3.67^{a}	3.00^{b}	2.33^{b}	1.67^{b}	0.18^{c}	10.31^{cd}	4.85^{d}	12.86^{abc}
11	Ageratum conyzoides	0.83^{a}	1.00^{b}	0.97^{c}	1.05^{c}	0.20^{c}	7.80^{ab}	63.10^{abc}	11.00^{cd}	59.13^{a}
12	Cymbopogon citratus	0.33^{a}	0.33^{b}	0.30^{c}	0.00^{c}	0.00^{c}	6.44^{ab}	83.69^{ab}	17.53^{abc}	56.09^{a}
13	Ocimum gratissimum	3.67^{a}	3.30^{b}	2.83^{c}	2.67^{bc}	2.50^{c}	6.49^{a}	62.21^{abc}	17.00^{abc}	47.00^{a}
14	Psidium guajava	2.41^{a}	2.40^{ab}	3.33^{c}	3.00^{c}	2.60^{c}	5.46^{ab}	52.73^{abc}	7.08^{cd}	42.75^{ab}
15	Magnifera indica	2.06^{a}	2.00^{b}	2.00^{c}	1.70^{c}	0.33^{c}	8.56^{ab}	74.35^{ab}	13.28^{bcd}	39.58^{ab}
16	Hyptis suaveolens	0.90^{a}	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}	5.69^{ab}	69.01^{a}	12.27^{bcd}	59.18^{a}
17	Musa paradisiaca	0.67^{a}	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}	9.59^{ab}	92.58^{a}	23.07^{ab}	53.67^{ab}
18	Azadirachta indica	3.00^{a}	2.95^{b}	3.53^{c}	3.50^{c}	2.50^{c}	4.85^{b}	59.20^{abc}	7.47^{cd}	46.96^{ab}
19	Alstonia boonei	0.85^{a}	2.62^{b}	2.60^{c}	3.00^{c}	2.33^{c}	7.10^{ab}	82.85^{ab}	10.05^{cd}	55.39^{a}
20	Elaeis guineensis	2.80^{a}	2.15^{b}	2.03^{c}	0.23^{c}	0.06^{c}	8.41^{ab}	69.34^{ab}	13.85^{bcd}	57.18^{a}
21	Control	0.00^{a}	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{c}	10.08^{a}	94.17^{a}	25.00^{a}	50.00^{ab}

Means followed by the same letter within a column are not significantly different at the 5% level of probability (Student Newman Keuls (SNK). W.P.I = Weevil Perforation Index

Table 3. Weighted average of plant powders screened for potency against *Sitophilus zeamais*

S/N	Plant powders	Mean mortality at 2days - 28days Post Treatment					Adult Emergence	Grain Damage	Weight loss	W.P.I.	Weighted average	Potency rating
		2 days	7 Days	14 Days	21 Days	28 Days						
1	Piper guineense	1	1	1	2	2	1	2	1	3	1.5	Highly Potent
2	Annona squamosa	1	1	2	3	3	1	1	1	2	1.6	Highly Potent
3	Vernonia amygdalina	1	2	2	2	2	1	2	1	3	1.7	Highly Potent
4	Azadirachta indica	1	1	2	2	2	3	4	1	4	2.2	Potent
5	Psidium guajava	1	2	2	2	3	3	3	1	4	2.3	Potent
6	Tithonia diversifolia	2	2	2	2	3	4	5	2	2	2.6	Potent
7	Ocimum gratissimum	1	1	2	2	2	5	5	2	4	2.6	Potent
8	Alstonia boonei	2	2	2	3	4	4	5	1	5	3.1	Moderately potent
9	Carica papaya	2	2	5	5	5	4	4	1	5	3.6	Moderately potent
10	Magnifera indica	3	3	3	3	5	5	5	2	4	3.6	Moderately potent
11	Elaeis guinensis	2	3	3	5	5	5	4	2	5	3.7	Moderately potent
12	Citrus sinensis	4	4	5	5	5	3	3	4	2	3.8	Moderately potent

13	Gmelina arborea	5	5	5	5	5	3	3	2	2	3.8	Moderately potent
14	Ageratum conyzoides	4	4	4	4	5	4	4	1	5	3.8	Moderately potent
15	Hyptis suaveolens	4	5	5	5	5	3	5	1	5	4.2	Non potent
16	Chromolaena odorata	4	5	5	5	5	4	5	2	5	4.4	Non potent
17	Cymbopogon citratus	5	5	5	5	5	4	5	2	5	4.5	Non potent
18	Afromomum melengueta	5	5	5	5	5	5	5	1	5	4.5	Non potent
19	Anacardium occidentale	5	5	5	5	5	4	5	2	5	4.5	Non potent
20	Musa paradisiaca	5	5	5	5	5	4	5	2	5	4.5	Non potent
21	Control	5	5	5	5	5	5	5	3	5	4.7	Non potent

Mean Scores are: 1.00-1.99 = Highly Potent; 2.00-2.99 =Potent; 3.00-3.99 = Moderately potent; 4.00-5.00 = Non potent

Out of the twenty botanicals used in this study, three (*Vernonia amygdalina*, *Annona squamosa* and *Piper guineense*) were ranked highly potent while four (*Tithonia diversifolia*, *Ocimum gratissimum*, *Psidium guajava* and *Azadirachta indica*) were ranked potent for the control of *Sitophilus zeamais*. Previous studies have reported potency of some botanicals against different pests. It was eported the potency of *Allium sativum, Capsicum frutescens* and *Zingiber officinale* against *Sitophilus zeamais* reared on maize grains [16] while the efficiency of *Citrus sinensis* against stored products beetle *Zabrotes subfasciatus. Azadirachta indica* was reported to be efficient against pests of ornamental plants [6, 10]. Although the potent botanicals did not produce a 100 percent mortality of the weevil, the mortality was higher than the untreated control. The ability of these plants to cause mortality of adult *S. zeamais* on maize grains might be attributed to the contact toxicity of the powder on the weevil. It was reported a significant mortality of *S. zeamais* induced by *P. guineense* suggested an excellent protectant potential of the plant [20]. 79% (highest) mortality of *S. zeamais* treated with *P. guineense* on maize grains was also documented [3]. On the other hand, it was reported that black pepper (*P. guineense*) powder caused 100% mortality on *S. zeamais* in stored maize grains [12]. A study showed that *P. guineense* contains piperine and chavicine, which are insecticidal, while [8] included piperidine and alkaloids as the major active components in *P. guineense* seeds [9].

The number of adults that emerged on grains treated with *P. guineense* was very minimal compared with other botanicals. A study reported that *Piper guineense* and *Afromomum melegueta* have useful property for storage as they affected progeny development with *P. guineense* recording the lowest number of emergences [7]. It was also reported that 10.0% and 5.0% adult emergence of *S. zeamais* on maize were treated with *P. guineense* and *Capsicum frutescens,* respectively [4]. Another study reflected that powders *Azadirachta indica* and *Parthenium hysterophorus* caused more than 90% reduction in progeny emergence of *Zabrotes subfasciatus* in stored haricot beans [12]. The reduction in F_1 progeny emergence in the treated grains might have resulted from increased adult mortality, ovicidal and larvicidal properties of the tested seed powders.

Conclusions

The findings of this study revealed that the studied botanicals were effective in reducing maize grain damage caused by *S. zeamais*. Among the studied botanicals, *P. guineense* was found to be the most effective plant in reducing grain damage. *Vernonia amygdalina* and *A. squamosa* were also found promising in reducing grain damage**.** The reduction in damage caused to stored maize using *A. sativum*, *P. guineense* and *T. tetraptera* indicates the possible presence of feeding deterrence in these botanicals. In addition, the reduced damage of the maize grains treated with the botanicals is a result of the efficacy of the botanicals against maize weevil infestation in storage. This is in agreement with the previous study that showed some local plant materials protected stored maize grains from damage by *zeamais*.

The results obtained in this study also revealed that some of the tested botanicals have positive protectant ability of maize grains against *S. zeamais* by causing W.P.I. value of <50% as suggested by. WPI value <15% was also reported as the reference value for W.P.I. In this study, however, the grains treated with *P. guineense* produced a W.P.I. value less than 15%. This might be attributed to the repellent and toxicity effects of the plant powders. Similar observations were also made, reporting a WPI value of 7.69 for maize grains treated with *Jatropha curcas*. The weighted average of all the tested parameters indicated that *P. guineense*, *V. amygdalina* and *A. squamosa* were highly potent against maize weevil (*S. zeamais*).

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