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Particle Size Effect of *Piper guineense* in the Control of the '*Sitophilus zeamais* Motchulski' on Maize

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Authors' contributions

This work was carried out in collaboration among all authors. Author GASB conceived the idea of the research. Authors GASB and KLB performed the experiment. Author AON performed the formal analysis. Author GASB supervised the conduction of the research. Author KLB wrote the original draft. Authors OAO, AOJ and AON reviewed and editted the manuscript. All authors agreed to the final submitted version.

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ABSTRACT

Sitophilus zeamais is perhaps the most important storage insect pest of maize. The negative health implication of synthetic pesticides necessitates research into botanicals. We investigated the efficacy of ground *Piper guineense* (particles sizes 150, 300, 600, 1180, and 2360 µm) in controlling *S. zeamais*. The botanicals were compared with pirimorphos methyl and control (untreated seeds). Completely Randomized Design was used with three replications. Each

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treatment was infested with 20 adult weevils. Weevils were withdrawn after 14 days and the experiment was observed for another 38 days to count emerged adult weevils, numbers of damaged grains and exit holes on seeds, and determine loss in seed weight. Progressive efficacy and significant differences were observed among the botanicals and Pirimorphos methyl from four days after treatment application (DAT) to 14 DAT (90%, 100%, 100%, and 46.67%for Pirimorphos methyl, 150, 300, and 2360 µm of Piper respectively) as the particle size decreases. *Piper* of 150 and 300 µm particle sizes produced no new adult weevil and no seed weight loss at 52 DAW compared to others. The efficacy of piper at different particle sizes from 4 DAT showed that graduating piper particle size has significant effects on its insecticidal activity. It was concluded that ground piper of particle size 150µm is the most effective and is therefore recommended for effective control of maize weevils in storage.

Keywords: Botanical; maize; particle size; Piper guineense; Sitphilus zeamais.

1. INTRODUCTION

Maize (*Zea mays*) is a cereal belonging to the family Poaceae. It is an important staple food and feed for man and animals respectively. It is primarily an energy-giving food because of its high starch content. Maize is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. A variety of insect pests attack maize prior to harvest and in storage [1]. The storage pests include *Sitophilus zeamais* Motschulski, (Coleoptera: Curculionidae), *S. oryzae* L. (Coleoptera: Curculionidae), *Tribolium castaneum* Herbst. (Coleoptera: Tenebrionidae), and *Ephestia cautella* Walker (Pyralidae: Lepidoptera).

Among the storage insect pests of maize, *S. zeamais* is probably the most predominant and destructive [2] with infestation often starting from the field prior to harvesting. In cases of serious infestation, up to 90% of the grains may be destroyed within six months [3]. They reduce seed germination significantly and promote mold development through production of water in respiration and defecation. It also deteriorates the grain quality due to the moist odour, increased fatty acid content, and reduced starch and sugar contents [4].

Insect pest control in stored food products relies heavily on the use of gaseous fumigants and residual contact insecticides. The implications of these are serious problems of toxic residues, health and environmental hazards, development of insect strains resistant to insecticides, increased cost of application and erratic supply in developing countries due to foreign exchange constraints. It has also been observed that insects developed resistance to a number of these chemical materials. This has prompted the scientists to turn towards nature to search for safer insect control agents. Botanicals have proved to have a mild effect on produce and are effective for pest control both on the field and in the store. One of the commonly used plant materials is *P. guineense*.

Piper guineense seeds are dominated by monoterpenoids and moderate sesquiterpenoids. Like other types of pipers, *P. guineense* yield an aromatic essential oil on steam distillation. These organic compounds could be responsible for the repellent and toxic activity of *P. guineense* powder against *S. zeamais* [5]. *P. guineense* contains Piperine and Chavicine which are insecticidal to crop pests [6,7] and its mode of action was reported to be contact toxicity [8].

As postulated for insecticidal inert powders in general, application of powder on grains increases the smoothness of grain surface as seed surface tends to be glossy. This thereby reduces insect movement within the grains. The applied particles also attach to insect cuticular surface and disrupt water balance and therefore cause an ineffective spiracular control mechanism in insect [9]. Insecticidal materials in powdery form also induce easy passage of insecticidal materials into pest through insect spiracles. Insect spiracle may also be blocked.

Influence of particle size on specific particle surface area increase with decrease particle size. When a given volume of a material is made up of smaller particles, the surface area of the material increases. Therefore, as particle size decreases, greater proportions of the particle are found at the surface of the material. The objectives of the study were to determine the efficacy of various *P. guineense* texture in controlling storage insect pest (*Sitophillus zeamais*) in maize with a view identifying the appropriate particle size of *P. guineense* for effective control of *S. zeamais* in maize.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Site Location

This research work was carried out at the Entomology Laboratory of the Teaching and Research Farm of the Department of Crop Production and Horticulture, School of Agriculture, Lagos State University of Science and Technology (formerly Lagos State Polytechnic), Ikorodu, Lagos State Nigeria. The area Lies between latitude 5°10'N and longitude 3°16' E of the Greenwich meridian and is characterized by a mean average temperature between 25°C and 29°C.

2.2 Preparation of Maize Grains and Pepper Powder Treatments

Seeds of Oba Super 2; a commercial maize variety popularly grown in the area, were obtained from a reputable agro-allied store. Oven-drying of seeds was done to kill adhering pathogens that might be on the maize seeds so as not to alter results to be derived from the experiment. Ripened whole fruits of *P. guineenses* were obtained from the Teaching and Research Farm of the Department of Crop Production and Horticulture, School of Agriculture, Lagos State University of Science and Technology (formerly Lagos State Polytechnic), Ikorodu, Lagos State Nigeria, andsun-dried. The fruits were blended using Binatone electronic blender Model No: BLG-452 and pulverized to desired texture using the New Delhi – 110055 (India) Standard Test Sieve. The blended piper was poured into sieves arranged according to their mesh sizes and agitated gently. Sieving was done using five (5) sieves with different mesh sizes (150, 300, 600, 1180, and 2360 µm particle size). The agitation allowed the piper to go through the mesh hole according to their particle sizes. The particle sizes of 150, 300, 600, 1180, and 2360µmwere collected for this study. The botanical treatments were compared with two other treatments: pirimorphos methyl (a synthetic insecticide) and control (untreated).

2.3 Experimental Setup and Maintenance

25g of maize was weighed into 21 transparent cups. The treatments were introduced to the maize at 0.5g to each. Adult weevils were collected from infested maize and introduced into the transparent cups containing the sieved piper and maize and the bowls were closed. The adult weevils introduced are the parent weevils and withdrawn on the 14th day. The experiment was laid out in Completely Randomized Design (CRD) with three replications.

2.4 Data Collection and Analysis

Data were collected efficacy of the treatment at 1, 2, 3, 4, 5, 7, and 14 days after treatment while number of emerged adults, weevil mortality, numbers of damaged grains and exit holes on seeds, and loss in seed weight (g) were recorded at 45 and 52 days after withdrawal of parent weevils.

Each treatment was poured into a sieve placed on a transparent bowl and agitated gently to remove weevils and the blended piper. The removed weevils were gently prompted with a broomstick to check for mortality. The weevils were withdrawn from the treatments on the 14thday after introduction. At 45 days after the withdrawal of the parent weevils, the seeds were checked for newly emerged weevils and record taken. Weight loss in seeds was determined at 45 days after the withdrawal of the parent weevils with the use of digitalized Camry weighing scale. Grain damaged was checked on white plane paper where seeds were sorted to separate damaged and undamaged ones and holes on damaged seeds were counted and recorded. Data generated from the study were subjected to analysis of variance. Treatment means were separated using Turkey's test at 5% level of probability. Analysis of variance and mean separation were performed using 'Assistat'.

The efficacy of the treatment at 1, 2, 3, 4, 5, 7 and 14 days after treatment was calculated using the Henderson and Tilton [10] formula expressed as:

$$Corrected\ \% = 100 * 1 - \left(\frac{n\ in\ Co\ before\ treatment\ *\ n\ in\ T\ after\ treatment}{n\ in\ Co\ after\ treatment\ *\ n\ in\ T\ before\ treatment}\right)$$

Weevil mortality was calculated using the Abbot [11] formula expressed as:

$$Corrected\ \% = (1 - \frac{n\ in\ T\ after\ treatment}{n\ in\ Co\ after\ treatment}$$

Where,
n = Insect population
T = Treated
Co = Control

3. RESULTS AND DISCUSSION

3.1 Efficacy of *P. guineenses* at 1, 2, 3, 4, 5, 7, and 14 Days after Treatment (DAT)

Table 1 showed that the efficacy of *P. guineenses* at 1, 2, 3, 4, 5, 7 and 14 days after treatment. There was no mortality recorded on day of application. At 2, 3 and 4days after treatment (DAT), there were significant difference in the treatment effect on pest control although they were not potent enough to ensure effective control. Pirimorphos-methyl gave a 17.78% kill of the insect pests. At 3 DAT, the highest efficacy(23.33%) was observed in maize treated with piper of 150 µm size which is not significantly different from18.89% efficacy obtained in 300µm particle size and pirimorphos-methyl. The performance of all treatments was not good enough to effect control.

At 4 DAT, there was a significant difference (p>0.05) in the treatments effects contrary to the results obtained at 3 DAT. Pirimorphos methyl recorded an efficient control of pest killing 50% of insect population. From among the piper particle sizes, treatment with 150µm which was not significantly different from300µm consistently recorded the highest efficacy of 23.33 %and the least from piper of 2360 µm particle size (6.67% kill) not significantly different from piper of 1180µm, 2360µm and the control. At 5 DAT.

Maize treated with pirimorphos methyl gave the best performance (60.33% kill) which is not significantly different from results obtained from 150µm (60.0%) and 300µm particle size (56.67%). The same trend was observed as in 4 DAT except that there was an increase in efficacy of the botanicals relative to particle size. At 7 DAT, there were conspicuous significant differences (p>0.05) in the treatments effect on insect mortality. The different particle sizes expressed progressive efficacy as the particle size decreases. The highest efficacy was observed in maize treated with piper of 150 µm (93.33%) and 300µm particle size (80.0%) followed by 600 and 1180µm particle size and treatment with pirimorphos methyl which are not significantly different from each other. Treatment with 2360µm particle size gave the lowest result from the insecticide treatments (35.56%), which is not effective but still better than the control.

At 14DAT, there was significant difference (p>0.05) in treatments effect on insect mortality. All treatments except the control gave above 40% kill which is the least acceptable value for botanicals potency. The highest efficacy was observed in piper of 150 and 300µm particle size which is not different from piper of 600 µm particle size (94.44%), piper of 1180 µm particle size(93.33%) and actellic dust (90%) followed by piper of 2360 µm particle size (46.67%). The control gave an expected zero percent kill.

3.2 Effect of Particle size of *P. guineense* on Weevil Emergence, Mortality, Seed Damage and Loss in Seed Weight at 45 Days after Withdrawal of Parent Weevils

Effect of particle size of *P. guineense* on weevil emergence, mortality, seed damage and loss in seed weight at 45 days after withdrawal of parent weevils is presented in Table 2. Numbers of emerged adults at 45 days after withdrawal (DAW) of parent weevils was significantly (P≤ 0.05) affected by different particle sizes of *P. guineense*. The highest number of emerged adults was observed in control (32) followed by maize treated with *P*. *guineense* of 2360µm particle size (8.67). Maize treated with piper of 600 µm particle size has 1 number of insect, while those treated with piper of 300 µm particle size and maize treated with piper of 150 µm particle size have no insect.

Insect mortality at 45 days after withdrawal of parent weevils was significantly (P≤ 0.05) affected by the different particle size of *P. guineense*. The highest mortality was recorded in 150 µm and actellic dust, followed by treatments with 300 and 600µm. All other treatments have no mortality. The highest number of exit hole son maize seeds was recorded in control (37.00) while the lowest there was no exit holes observed on maize treated with *P. guineense* powder of 150 µm. The average number of damaged

Seed was highest in control (21.33) and lowest in 150 µm (0.67). Seed loss in weight was also highest in control and significantly different from other treatments.

Table 1. Efficacy of *Piper guineense* at 1, 2, 3, 4, 5, 7 and 14 days after treatment

Treatments	Efficacy of *Piper guineense* in days after treatment (DAT)						
	1	2	3	4	5	7	14
Piper of 150 µm particle size	0.00	0.00b	23.33a	23.33b	60.00a	93.33a	100.00a
Piper of 300 µm particle size	0.00	0.00b	18.89a	23.33b	56.67a	80.00a	100.00a
Piper of 600 µm particle size	0.00	0.00b	11.11b	18.89c	46.67b	70.00b	94.44a
Piper of 1180 µm particle size	0.00	0.00b	5.56b	11.11c	26.67c	63.33b	93.33a
Piper of 2360 µm particle size	0.00	0.00b	0.00c	6.67c	12.22c	35.56d	46.67b
Pirimorphos methyl	0.00	17.78a	18.89a	50.00a	60.33a	70.00b	90.00a
Control	0.00	0.00b	0.00c	0.00c	0.00c	0.00c	0.00c

Means with different alphabets in each column are significantly different from each other (P<0.05)

Table 2. Effects of *Piper guineense* on adult emergence and mortality, number of exit holes, number of damaged seeds and seed loss in weight at 45 days after withdrawal of parent weevil

Treatments	Adult emergence	Insect mortality	Number of Exit holes	Number of damaged seeds	Seed loss in weight (g)
Piper of 150 µm particle size	3.00c	3.00a	0.00d	0.67c	1.00b
Piper of 300 µm particle size	2.00c	2.00b	0.67c	1.00b	1.00b
Piper of 600 µm particle size	1.00c	2.00b	3.00c	3.00b	1.00b
Piper of 1180 µm particle size	1.00c	0.00c	4.67c	3.00b	1.00b
Piper of 2360 µm particle size	8.67b	0.00c	11.33b	8.33b	1.00b
Pirimorphos methyl	1.00c	3.00a	1.00c	1.00b	0.33b
Control	32.00a	0.00c	37.00a	21.33a	2.00a

Means with different alphabets in each column are significantly different from one another (P<0.05)

Table 3. Effects of *Piper guineense* on adult emergence and mortality, number of exit holes, number of damaged seeds and seed loss in weight at 52 days after withdrawal of parent weevil

Treatments	Adult emergence	Insect mortality	Number of Exit holes	Number of damaged seeds	Seed loss in weight (g)
Piper of 150 µm particle size	0.00c	0.00c	0.00d	0.67c	0.00c
Piper of 300 µm particle size	0.00c	0,00c	0.67c	1.00b	0.00c
Piper of 600 µm particle size	1.00c	1.00b	3.67c	3.00b	1.00b
Piper of 1180 µm particle size	1.33c	0.67c	4.67c	4.00b	1.33b
Piper of 2360 µm particle size	12.00b	0.33c	14.00b	9.00b	1.66b
Pirimorphos methyl	3.00c	3.00a	3.33c	6.00b	0.33c
Control	40.00a	0.00c	40.00a	24.00a	3.50a

Means with different alphabets in each column are significantly different from one another (P<0.05)

Table 4. Simple correlation and regression between increasing piper texture size and adult emergence, insect mortality, number of exit holes on seeds, number of damaged seeds and seed loss in weight at 45 and 52DAW

Parameters	Correlation coefficient (r)	Regression equation	Level of significance	Correlation coefficient (r)	Regression equation	Level of significance
	45 DAW			52 DAW		
Adult emergence	0.62	Y = 5.3146x - 11.489	*	0.64	Y = 6.7523x - 14.578	*
Insect mortality	0.86	Y = -0.6571x + 3.467	***	0.92	Y = -0.5811x + 3.201	***
Number of exit holes	0.69	Y = 6.2471x - 12.420	*	0.70	Y = 6.8383x - 13.377	*
Number of damaged seeds	0.72	Y = 3.5797x - 6.307	*	0.73	Y = 4.0471x - 7.220	*
Loss in seed weight	0.43	Y = 0.1429x + 0.667	*	0.66	Y = 0.4231x + 0.101	*

, P ≤ 0.1;*, P ≤ 0.0*

3.3 Effect of Particle Size of *P. guineense* on Weevil Emergence, Mortality, Seed Damage and Loss in Seed Weight at 52 days after Withdrawal of Parent Weevils

The effect of particle size of *P. guineense* on weevil emergence, mortality, seed damage and loss in seed weight at 52 days after withdrawal of parent weevils is as shown in Table 3. Application of piper at varying particle size significantly reduced emergence of weevils while the control (untreated maize) maintained its high weevil emergence. Treatments with piper of 150 and 300 µm particle size maintained high potency and produced no new adult weevil and no seed weight loss.

Regressing increasing piper texture and adult emergence, insect mortality, number of exit holes on seeds, number of damaged seeds and seed loss in weight at 45 and 52DAW showed positive relationship (Table 4). Decreasing particle size of *P. guineense* increased its efficiency in the control of maize storage weevil through increased adult mortality and decreased damage to seeds and seed weight loss.

Wood ash has been commonly used by peasants for pest control in poultry house and homesteads. In Nigeria, wood ash from kola tree (*Cola sp*.) and neem plant (*Azardirachta indica*) are used in the preservation of cowpea against cowpea storage weevil (*Callosobruchus maculatus*). Wood ash [12] and *P. guineense* [13\ have been shown among others to significantly reduce numbers of *C. maculatus* on cowpea in Nigeria. Ivbijaro and Agbaje [14] have also reported that pepper caused minimal mortality of the bruchid adult. Benson [15] also pointed out that wood ash and pepper are capable of controlling cowpea storage weevil (*C. maculatus*).

The lack of significant difference in efficacy of treatments at 1- 2 DAT and the non-attainment of 40% performance in the first 4 DAT may suggests that particle size may not have initially affected insect activities and mortality. This work corroborates the findings that pulverized fruits of botanicals were weak at causing mortality at 24 and 48hours post infestation. Reduction in adult emergence and prevention of oviposition by weevil might have resulted from dry and ground piperas reported by Ivbijaro [16] who stated that dry and ground leave of neem prevent oviposition by weevil. Also, as noted by Ofuya and Dawodu [17], that powder of piper is effective in protecting stored seeds of cowpea from infestation and damage by *Callosobruchus maculatus*. Particulalate nano insecticide effect of kaolin particle film treated and untreated (control) natural leaf surface on reduction of insect attachment ability has been examined on two important polyphagous pests characterized by different attachment devices [18]. Particle size affects dispersion and the fewer the particle the more uniformly the dust will spread on treated seeds and thus enhance the contact with the insect. Particle size has been known to enhance insecticidal action of botanical powders [19]).

The significance differences observed among the treatment in terms of insect emergence, insect mortality, number of seed damaged, number of exit holes and loss in seed weight at 45 and 52 DAW of parent weevils indicate the ability of particle size to extent play to exert varied protection to maize seeds or prevention of infestation by maize weevil. Insecticidal effect of *Adansonia digitata* stem bark and powders on *Dinoderus porcellus* has been reported by John *et al*. [20]. Particle size is also known to enhance insecticidal action of botanical powders [19].

Significant reductions in these parameters occurred in the treatments involving piper particle size 150 and 300 compared with the control. Insect emergence was found to reduce in the order of decreasing particle size, thus confirming that particle size might have hindered the adult weevils from laying eggs. The number of exit holes on seeds is also significantly low because of its effectiveness as an anti-feedant [21].

4. CONCLUSIONS

The efficacy of piper in the control of maize storage weevil at different particle sizes from 5 DAT show that graduating piper particle size has significant effects on its insecticidal activity. Based on the trend observed in the study, it can be concluded that the use of 150 µm particle size of ground piper is most effective particle size and therefore recommended to farmer for effective control of maize weevils in storage.

As no dilution is added to the active ingredient content of the treatment, the powdery nature of piper may also be a contributory factor in its insecticidal properties and its potency. This work can further help or contribute to future development of physical method of control and thereby aid in the development of a sustainable integrated pest management.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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