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Full Length Research Paper

Effect of grain moisture content and storage time on efficacy of inert and botanical dusts for the control of *Sitophilus zeamais* in stored maize

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The effect of grain moisture content and time of storage on the efficacy of inert and botanical dusts, conventional and bacterial metabolite insectcides were evaluated in the laboratory. Maize grains at 10, 12, 14 and 16% moisture content were admixed with inert powder (diatomaceous earth Kensil Superfine®), maize cob and bean trash ashes, and botanical (neem seed cake powder) at a dose rate of 0.9% w/w. Actellic Super® and Spintor® dusts applied at the recommended rate of 50 g/90 kg grain and diatomaceous earth Dryacide® at 0.9% w/w were included as positive controls. Untreated maize grain served as the negative control. Thirty (30) unsexed two –week-old *Sitophilus zeamais* Motsch. adults were introduced in the treated maize. The treatments were replicated four times and held undisturbed for 14 days at ambient conditions (26 ± 2℃ and 67 ± 3% r.h.), after which mortality was assessed. Results showed that grain moisture content significantly (p<0.05) affected efficacy of grain protectants and superior control was achieved when it did not exceed 12% for inert dusts and 14% for pesticides. For the evaluation of the effect of time of storage, 4 kg maize grain were admixed with each treatment except for Spintor® dust, maize cob ash, neem seed cake powder as described earlier and put into the 5 kg capacity hessian baglets, replicated four times. Untreated grain acted as the control. Adult *S. zeamais* (population of 1500) were put in the plastic Petri dish and left to infest the baglets naturally. The potency of the protectants began to wane significantly (p<0.05) after 6 months. Dryacide® followed by Kensil Superfine® dusts performed better than Actellic Super® with the grain weight loss of 2 and 4%, respectively, over a period of 9 months. The study demonstrates that Superfine® dust has the potential but should be further evaluated on – farm, for the control of storage insect pests and serve as another stored products protectant option.

Key words: *Sitophilus zeamais*, inert dusts, natural dusts, actellic super, stored maize.

INTRODUCTION

Maize (*Zea mays* L.) is an important staple cereal crop for most people in sub-Saharan Africa (Kling and Edmeades, 1997). In rural areas, the production of the crop is under subsistence farming and on-farm storage forms part of traditional practices. It is estimated that 60% of the total grain produced in Kenya is stored on – farm for various reasons and duration. Beside being a major source of food for both human and animals, it is also processed into various industrial products such as fuel ethanol and starches (Ogunsina et al., 2011). After harvest, maize is liable to be attach by a wide range of storage insect pests. The maize weevil (*Sitophilus*

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zeamais Motsch.) and the larger grain borer (*Prostephanus truncatus* Horn) cause considerable economic losses to smallholder farmers in Africa (Gueye et al., 2008; Oduor et al., 2000). Grain loss in Africa due to insect pests damage in storage systems is estimated at 20 to 30% (Pingali, 2001). Worldwide, *S. zeamais* cause more than 20% grain loss for untreated maize (Giga and Mazarura, 1991). The loss is off –set by correspondingly high grain imports. Infestation by *S. zeamais* starts with the female laying eggs into the grain, which on hatching the larvae feeds towards the inside of the grain until pupal stage is reached. The adults emerge by eating their way towards the testa causing rugged exit holes resulting in an insect damaged grain (Arthur and Throne, 2003). While satisfactory pest control has been obtained by use of synthetic pesticides, their adverse effects on environment, development of resistant strains and residues in food crops has motivated the search for safer alternative methods. Inert dusts such as diatomaceous earth (Nikpay, 2006), ash and plant powders (Idoko and Adebayo, 2011; Tadesse and Basedow, 2005) are such products that fill this void.

Diatomaceous earths (DEs) are fossilised skeletons of diatoms comprising of amorphous or shapeless silicon dioxide (silica) and small amounts of other mineral elements (Stadler et al., 2012). In contrast to synthetic chemicals, DE dusts mainly adsorbs the epicuticular lipid layers inducing mortality mainly as a result of excessive water loss through the cuticle of the insects (Korunic, 1998; Mewis and Ulrichs, 2001; Athanassiou and Steenberg, 2007). Whereas, several commercial DEs are effective against an array of insect pests, the potential of locally produced DE, Kensil Superfine®, as a grain protectant for the control of insect pests found in stored grain remains to be studied. Subramanyam (2006) qualifies a protectant as one with a broad spectrum activity against insect pests associated with the grain, be persistent on the treated commodities with little loss of insecticidal activity for one year and have low mammalian toxicity. Kensil superfine® from Kariandusi mines near Gilgil in Kenya poses low risk to mammals and only dust mask is required during handling and there is great interest to study this dust on its potential use as a grain protectant.

Grain moisture content is one of the most important factors influencing efficacy in pest control products. An increase in the moisture content decreases the efficacy of synthetic insecticides (Snelson, 1987; Afride et al., 2001) by degrading faster. Since the mode of action of DE dusts is desiccation, higher grain moisture content also reduces their efficacy (Aldryhim, 1990; Fields and Korunic, 2000). It would be appropriate to establish the effect of different grain moisture contents on the efficacy of DEs. The objective of the present study was therefore to determine the effect of varied grain moisture contents and storage period on the efficacy of local DE Kensil Superfine® and to compare its effectiveness with the effectiveness of botanical neem seed cake powder, Spintor (spinosad) powder and Actellic Super® powder (primiphos methyl plus permethrin) against *S. zeamais* on stored maize.

MATERIALS AND METHODS

Grain protectants

The local DE Kensil Superfine® was obtained from African diatomite Industries (K) Limited at Kariandusi Gilgil along Nairobi – Nakuru Highway. It is a fine creamy white dust composed of silica dioxide (83.20%), alumimium dioxide (4.81%) and ferrous dioxide (2.19%), other compounds (9.80%), retained moisture content (8%) and particle size retention of 0.1% when subjected to 106 µ (150 mesh) screen analysis. Its slow flow rate natural filter aid used for beer and other filtration applications where high degree of clarity is required. Neem seed cake powder was obtained from International Centre for Insect Physiology and Ecology (ICIPE), Nairobi. Dryacide® was sourced from Kenya Agricultural Research (KARI) Kabete, where it had been kept for nine years since being obtained from Australia. The Dryacide® is a fine grey dust that contains amorphous silica (86%), retained moisture (2%), clay minerals (8%) and carbon (4%) (Aldryhim, 1990). Actellic super® and Spintor® (0.125% spinosad) dusts were bought from agrochemical shop in Nairobi. Actellic super® dust is a mixture of 1.6% Pirimiphos – methyl + 0.3% Permethrin. Pirimiphos – methyl is an organophosphate that controls traditional stored products insect pests while permethrin is a pyrethroid that works against Bostrichid pests such as lesser (*Rhyzopertha dominica*) and larger grain (*P. trunctus*) borers.

Spintor® is a 0.125% spinosad dust formulation that was first registered in Kenya in 2003 as a grain protectant (Mutambuki et al., 2012) and has since been registered in more than 15 African countries for domestic use only, with no export of Spintor® treated grain (Hertlein et al., 2011). Maize cob and red haricot bean trash (remains of the plant after seed has been threshed) were separately burned on sheet metal and then passed across a sieve of 1 mm aperture size to obtain dust with uniform particle size.

Test insect pest

S. zeamais was reared in the laboratory at ambient conditions (26 ± 2℃ and 67 ± 3% r.h.) according to the method descri bed by Khakame et al. (2010). The parent adults were obtained from culture stock at National Cereals and Produce Board (NCPB), Embakasi depot in Nairobi. Susceptible whole hybrid maize grain (614 D variety) at 13% wet basis moisture content level was used as food substrate. The grain had been disinfested by fumigating using phosphine. Unsexed 2- week-old adult insects were used in the experiments.

Conditioning maize grain to different moisture content

Hybrid maize 614 D obtained from a farmer in Bungoma County was cleaned by passing across 6.7 mm aperture size screen to remove foreign matter, small and broken grains. Initial moisture content of the grain was 13% (wet basis) as determined by the digital moisture computer (Burrows model 700). Four moisture content levels that could be found in storage (10, 12, 14 and 16%) were chosen. The grain was then reconditioned to 10, 12, 14 and 16% moisture content (mc) levels. To obtain grain with 10 and 12% mc, maize was dried in a ventilated oven at 35℃ an d mc determined at intervals of 30 min till the required mc levels were achieved. For mc above the initial pre-determined amounts of distilled water were added to the grains which was thoroughly mixed until 14 and 16% mc were achieved. The amount of water added was calculated according to Boxall (1986). For example to condition the grain to 16% mc:

$$\text{Quantity of water required (g)} = \frac{\text{Weight of grain} \times (16 - 13\%\ \text{mc})}{100 - 16\%\ \text{mc}}$$

Maize grain (500 g) was weighed into 1 L glass jar allowing sufficient headspace for mixing and then the calculated amount of distilled water was added. The water was measured out as volume since 1 g of water occupies 1 ml. The jars were tumbled daily for three weeks before being kept in the refrigerator maintained at 5℃. The lower temperatures inhibited mould growth and grain germination. At the end of three weeks, the final mc of the grains was determined as earlier described.

Maize treatment and introduction of test insects

Maize grains were weighed (100 g) into 0.25 L plastic jars, replicated four times, for each of the four grain mc levels (10, 12, 14 and 16%, respectively). The grains were then separately admixed with the following treatments: Actellic super® and Spintor® dusts at the rates of 50 g/90 kg grain each (10.5 and 0.7 ppm, respectively); Dryacide®, Kensil superfine®, maize cob ash, bean trash ash and neem seed cake powder at 0.9% w/w (9000 ppm) each. The contents of each jar were mixed thoroughly to allow even distribution of the dusts in the whole grain mass. The untreated maize grains served as the negative control. Thirty (30) unsexed two- week - old *S. zeamais* adults were introduced in each jar and kept on wooden shelves in completely randomized design (CRD) undisturbed at ambient conditions (26 ± 2℃ and 67 ± 3% r.h.) for 14 days when mortality was assessed. The exposure period was chosen because it was found to result in satisfactory control of *S. zeamais* when using the lowest dose rate of DE (Ceruti and Lazzari, 2005) and neem extracts (Nukenine et al., 2011). Insects were considered dead on failure to respond by moving to three probings with blunt tweezer or small paintbrush. Percent mortality was determined as follows:

$$\text{Mortality} = \frac{100 \times \text{number of dead insect}}{\text{Total number of insects introduced}}$$

Removed dead and live adults were discarded after mortality assessment and the grains were incubated for a further 42 days to assess progeny emergence. Percent reduction in F1 progeny was calculated according to Arthur and Throne (2003) as follows:

$$\%\ \text{Progeny reduction} = \frac{100 \times (1 - F_{1T})}{F_{1C}}$$

Where F_{1T} and F_{1C} are the mean number of F_1 adults in treated grain and untreated grains, respectively.

Persistence of inert dust in treated grain

Four kilogramme of the grains (13% mc) were weighed into 5-kg capacity hessian baglets. Dryacide®, Kensil Superfine® dust and bean trash ash were separately thoroughly admixed with the weighed grains at the rate of 36 g each and Actellic Super® at the rate of 2.4 g to allow even distribution in the whole grain mass. Actellic Super® and Dryacide® dusts were included as positive controls. Untreated grains served as negative control in the trial. Four replications of each of the five treatments were prepared and each baglet kept on wooden shelves in completely randomized design (CRD) at room conditions (26 ± 2℃ and 67 ± 3% r. h.). Adult *S. zeamais* (population of 1500 active adults, 2-week-old) were put in the plastic Petri dish and placed at the centre of the floor of the experimental room. The insects were allowed to fly freely to the baglets, simulating natural infestation from a known source. Under laboratory conditions of 25 ± 1℃ and 75% relative humidity, *S. zeamais* showed intense flight activity than *Sitophilus oryzae* (Vasquez – Castro et al., 2009). A baseline sample was taken at the setup of the trial (hereafter referred to as 0 month) and analysed for *S. zeamais* grain damage. Subsequent grain sampling was done every month for nine months using a bag-sampling spear. At each sampling occasion, grain samples were drawn from the two corners of the baglet diagonally, vertically at the middle of the mouth and horizontally at the middle of the side of the baglets. Grain drawn as such from each baglet was combined to give a representative sample size of about 300 g. The samples were put in clean labelled plastic bags for subsequent grain damage analysis.

The content of each sample bag was sieved out to separate grain from dust (flour generated due to insect feeding activity) and insects present using 6 mm aperture size screen. The dust and insects were discarded. The grain was sorted out into damaged and undamaged fractions. No distinction was made between damaged grains with one or more holes (which is common with moth or bruchid damage on cereals and legume, respectively). The number of grain in each fraction and weight were recorded. Weight loss was then calculated according to Boxall (1986) as follows:

$$\%\ \text{weight loss} = \frac{(U \times N_d) - (D \times N_u)}{U \times (N_d + N_u)} \times 100$$

Where U = weight of undamaged grains, D = weight of damaged grains, N_d = number of damaged grains and N_u = number of undamaged grains.

Apart from being an economic indicator, % weight loss was used in this trial to indicate treatment effectiveness as storage period increased (Hertlein et al., 2011). Weight loss has also been found significantly positively correlated to number of insects (Olakojo and Akinlosotu, 2004).

Data analysis

Data on adult mortality, emergence and grain weight loss were recorded. The data obtained was then subjected to analysis of variance (ANOVA) using the general linear model procedure (GenStat software Relaese 12.1 for windows, 2009), with mortality as the response variable and; grain moisture content and treatments as the factors. Significant differences were separated using Fisher's protected least significant difference (LSD) test at 5% level. Data on mortality and weight loss were subjected to square root arcsine transformation while those on adult emergence was log transformed to normalise the data prior to analysis.

RESULTS

The results for effect of grain moisture content on the efficacy of test grain protectants are presented in Table 1.

Table 1. Mean mortality (%)[1] of *Sitophilus zeamais* adults exposed to treated maize grain at different grain moisture contents after 14 days period.

Treatment	Grain moisture content (%)				Mean
	10	12	14	16	
Actellic super® dust	100^{a}	100^{a}	98.8^{a}	98.8^{a}	99.4
Dryacide® dust	100^{a}	97.9ab	93.9^{abc}	90.8^{cd}	95.7
Spintor® dust	91.3^{bcd}	90.4^{cd}	88.3^{cde}	78.8^{fg}	87.2
Kensil Superfine® dust	86.7^{de}	83.3^{ef}	73.3^{ghi}	68.8^{ij}	78.0
Maize cob ash	76.3^{gh}	71.7^{hij}	52.5^{k}	41.3^{l}	60.4
Bean trash ash	73.8^{ghi}	66.3^{j}	48.9^{k}	47.4^{kl}	59.1
Neem seed cake powder	8.3^{m}	7.5^{mn}	5.0^{mn}	6.2^{mn}	6.8
Control (untreated)	1.3^{n}	1.7^{mn}	2.5^{mn}	0.8^{n}	1.6

[1]Means followed by the same superscript letter are not significantly different at p ≤ 0.05. Each data is the mean of four replicates.

Table 2. Mean[1] number of adult F_1 *Sitophilus zeamais* emergence in treated maize grain at different moisture contents.

Treatment	Grain moisture content (%)				Mean	% F_1 progeny reduction relative to the control
	10	12	14	16		
Actellic Super® dust	0.0^{l}	0.0^{l}	0.0^{l}	0.5^{l}	0.1	98.1
Dryacide® dust	0.0^{l}	0.0^{l}	0.9^{l}	3.6^{j}	1.1	86.4
Spintor® dust	0.8^{l}	0.5^{l}	2.9^{jk}	13.4^{g}	4.4	52.5
Kensil Superfine® dust	0.9^{l}	2.4^{kl}	10.6^{h}	13.4^{g}	6.6	52.8
Bean trash ash	6.1^{i}	6.4^{i}	26.1^{e}	27.4^{e}	16.3	19.6
Maize cob ash	6.5^{i}	7.3^{i}	28.5^{e}	29.6^{d}	17.5	12.8
Neem seed cake powder	10.8^{h}	9.8^{h}	34.6^{c}	35.1^{c}	22.7	8.3
Control (untreated)	17.3^{f}	16.4^{f}	40.0^{b}	43.8^{a}	29.4	

[1]Means followed by the same superscript letter are not significantly different at p ≤ 0.05. Each data is the mean of four replicates.

The mortality differred significantly with grain moisture level ($F_{(3.93)}$ = 51.64, P< 0.001) and treatment ($F_{(7.93)}$ = 1017.36, p< 0.001). However, there was significant interaction ($F_{(21.93)}$ = 6.70, p< 0.001) between grain moisture content and treatment on the effect of mortality. Least significant difference mean comparisons revealed downward trend in the mortality rate of *S. zeamais* adults as the moisture content increased for Dryacide®, Spintor® and Kensil superfine® dusts; maize cob and bean trash ashes. Actellic super® dust and neem seed cake powder were unaffected. The treatments showed different efficacies as the grain moisture content increased. Unexpectedly, Actellic super® dust was most effective in controlling *S. zeamais* (98 to 100% mortality) across the grain moisture content levels tested. The performance of maize cob and bean trash ash did not differ significantly. Adequate control of *S. zeamais* was achieved by Dryacide® dusts only on treated grain at 10 and 12% grain moisture content levels. When grain moisture content increased from 12 to 16%, the effectiveness was found to decrease by 1.2% for Actellic Super® dust; 7.1% for Dryacide® dust; 11.6% for Spintor® dust; 14.5% for Kensil superfine® dust; 30.4% for maize cob ash, 18.9% for bean trash ash and 1.3% for neem seed cake powder. The efficacy of maize cob ash was more affected by increase in grain moisture content than that of bean trash. Of all the treatments evaluated, neem seed cake powder was little affected by increase in grain moisture content, and showed inferior control of *S. zeamais* and its performance was comparable to the untreated control when grain moisture content increased from 12 to 16%. The results demonstrate that grain protectants would achieve inferior control of *S. zeamais* when grain moisture content exceeds 12% level.

The mean number of adult *S. zeamais* emergence after 42-day incubation period is shown in Table 2. The F1 progeny emergence differed significantly with grain moisture content ($F_{(3.93)}$ = 1106.26, p<0.001) and treatments ($F_{(7.93)}$ = 946.96, p<0.001). Again, there was significant interaction ($F_{(21.93)}$ = 143.60, p<0.001) between grain moisture content and treatments. Actellic Super® and Dryacide® dusts significantly reduced F_1 progeny emergence relative to the untreated control. When moisture content increased from 10 to 16%, the progeny emerged in grain treated with Actellic Super® dust increased from 0 to 0.5 compared to the untreated grain

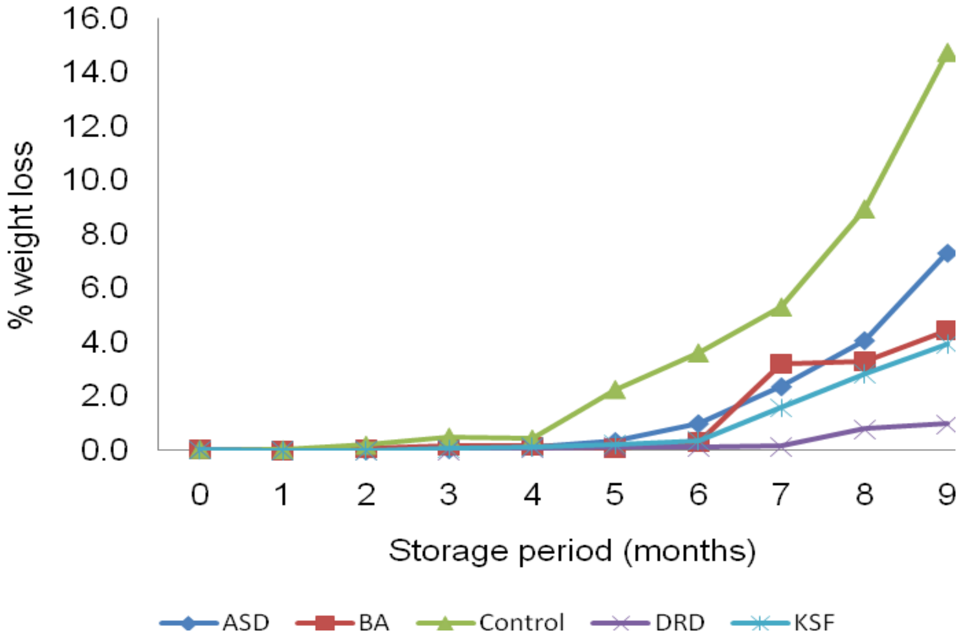

Figure 1. Mean % weight loss caused by *S. zeamais* over a period of nine months. Key: ASD – Actelic Super® dust, DRD – Dryacide® dust, BA – bean trash ash, C - control and KSF – Kensil Superfine® dust.

in which the emergence increased from 17.3 to 43.8, representing 98.1% reduction (Table 2). Similarly, the emergence in grain treated with neem seed cake powder increased from 10.8 to 35.1, representing 8.3% suppression. Overall, grains treated with either Drayacide or Spintor dusts did not differ significantly in mean number of emergence (Table 2). Similar trends were observed for bean trash and maize cob ashes. The period of protection conferred by Kensil Superfine® and bean trash ash to treated maize grain against *S. zeamais* damage is presented in Figure 1. Apart from the control, almost all the treatments restricted *S. zeamais* damage as measured by weight loss for upto six months. The mean weight loss was significantly different ($p<0.05$) among the treatments over the study period. The differences in grain damage (as measured by weight loss) due to protection conferred by the treatments became apparent after 2 months for untreated grain; 5 months for Actellic Super® dust; 6 months for bean trash ash and Kensil Superfine® dust and 7 months for Dryacide® dust (Figure 1).

Dryacide® dust performed much better than any other dust treatment followed by Kensil Superfine® dust. The performance of Actellic Super® dust tended towards the margin of being effective at 7 to 9 months storage period. At 9 months, untreated grain suffered 16% weight loss compared to 1, 3.9, 4 and 7% in grains treated with Dryacide® dust, Kensil Superfine® dust, bean trash ash and Actellic Super® dust, respectively, indicating good persistence or stability of the treatments.

DISCUSSION

The efficacy of inert dusts, neem and Actelic Super® is affected by variation in grain moisture content. The potency breakdown of pesticide protectants has been shown to be dependent on grain moisture content, temperature and time of storage and that it is slower at lower moisture content and temperature (Afridi et al., 2001). The inert dusts efficacy (Fields and Korunic, 2000) and that of synthetic pesticides (Snelson,1987) decrease with increase in grain moisture content level. The results of this study show significant drop in adult *S. zeamais* mortality in grain treated with inert dusts (Dryacide®, Kensil Superfine®, maize cob and bean trash ash), insecticide (Spintor®) and botanical (neem seed cake powder) as grain moisture content increased from 12 to 16% (Table 1). These differences in mc did not have effect on Actellic Super dust effectiveness under the testing conditions. Apart from Dryacide® dust, these protectants achieved moderate control of *S. zeamais* even on treated grain at lessthan 14% moisture content. The unsatisfactory control observed in this study confirms earlier findings by Khakame et al. (2010). The loss or drop in potency of inert dusts could probably be attributed to slower capacity to adsorb the oily or waxy epicuticular lipid layers by direct contact under wet conditions (Ebeling, 1961). The findings are consistent with Fields and Korunic (2000) report that the efficacy of diatomaceous earth decreased when *Tribolium castaneum* Herbst, *S. oryzae* L., *Cryptolestes ferrugineus*

(Stephens), *Oryzaephilus surinamensis* (L.) and *Rhyzopertaha dominica* (Fabr.) were exposed to wheat having a higher moisture content (14 to 17%) treated with commercial inert dusts Protect-it, Dryacide® and Insecto.

While moderate control of *S. zeama*is was observed on grain treated with Spintor® dust across the moisture content levels tested, unexpectedly, Actellic Super® dust was stable and its potency reduced marginally by 1.2% achieving satisfactory control. This is consistent with Mulungu et al. (2010) documentation that Actellic Super® dust is most effective in killing *S. zeamais*. Neem seed cake powder potency was unaffected by increasing grain moisture levels as its mortality values were almost the same at all moisture levels tested. Maribet and Aurea (2008) observed that the powder from *Azadirachta indica* A. Juss indicated some repellence effect to the *S. zeamais* but could not cause any significant mortality to the pest. This could explain its poor performance in the protection of the maize grain against *S. zeamais*. The results demonstrate that grain protectants would achieve superior control of *S. zeamais* when grain moisture content does not exceed 12% level. Effective control of protectants is qualified as mortality of adult and/or immature, confirmed by lack of progeny generation (Hertlein et al., 2011). Although, Actellic Super® dust achieved satisfactory control across the moisture content levels tested, it only effectvely suppressed F_1 progeny production in treated maize grain of upto 14% moisture content level followed by Dryacide® dust at 12% moisture content (Table 2). Our results are in agreement with the earlier study that found pirimiphos-methyl, a component of Actellic Super® dust, completely supressed *S. zeamais* F_1 progeny production (Mbah and Okorie, 2009).

In tests with *Sitophilus granarius* (L.), a member of the same family as *S. zeamais*, exposure to commercial FossilShield® DE killed adults but did not completely suppress progeny emergency (Mewis and Ulrichs, 2001). This study produced similar results. Spintor® and Kensil Superfine® dusts treatments resulted in moderate suppression as more F_1 adults emerged from grain across moisture content levels tested; even when parent mortality was above 50%. The probable reason for this could be that although the adult parents will be killed by exposure to the treatments, the degree of kill may not be fast and there were eggs laid before they died. Hertlein et al. (2011) documented 80% adult mortality and about 82% F_1 progeny suppression of *S. zeamais* on maize grain treated with 1 ppm Spinosad applied as a liquid formulation and although dust formulation was used in this study at 0.7 ppm, our results confirm this findings. Ash and neem seed cake powder showed ineffectiveness to provide the level of F_1 progeny reduction (Table 2) comparable to that of Actellic Super® and Dryacide® dusts (positive controls). Based on lack of reduction of progeny production, we speculate that ash and neem seed cake powder had little impact on the kill of adult parents and the immatures developing inside the grain.

Grain weight loss (an indicator of damaged grain) increased with increase in storage period for the control treatment. For treated grain, this was apparent after five months. This may be ascribed to increase in the population of live insects and loss of effectiveness of the protectants (Tuluker and Howse, 1994). Overall, weight loss of treated maize grain was much lower compared to untreated grains (control). Of the inert dusts evaluated, Dryacide® followed by Kensil Superfine® dusts provided effective protection to stored maize grain against *S. zeamais* for 9 months. The potency of the treatments began to decrease after 5 months (Figure 1) relative to the control for Actellic Super® followed by Kensil Superfine® dusts at 6 months storage period. Although, grain protectants would provide 6 to 12 months protection to stored grain (Hertlein et al., 2011), our study show that this could not be achieved by Actellic Super® dust. This confirms farmers' concern that Actellic Super® dust efficacy wane before six months and a repeat application of the pesticide is made at fifth month or sell their grain early thus receiving a low price and endanger their own food security. Mvumi and Giga (1994) reported less than 8% weight loss after 9 months period post - treatment with 2% dust formulation of pirimiphos –methyl applied at a normal rate of 4.9 ppm. Whereas, several laboratory studies indicated 2 to 4 ppm pirimiphos – methyl effectively controls many insect pests; there are concerns that survival and emergence of insects which if allowed to build up may increase the population of resistant individuals.

To reduce the likelihood of resistance developing, Mvumi and Giga (1994) suggested application rate be increased while Adesuyi (1979) recommended 10 ppm to achieve a 7 – months protection in farm stores. Our experiments revealed a grain weight loss of about 7% over the same period. The results of this study demonstrate the potentiality of Kensil Superfine® dust in pest management programme. However, further investigations aimed at improving its potency are required before any recommendations can be made to farmers. Use of Kensil Superfine® dust in combination with varietal resistance of maize could be exploited for the control of *S. zeamais* in stored grain and aid in prevention of economic damage. In conclusion, the present study has revealed that some of the inert dusts used as grain protectants would achieve superior control of *S. zeamais* when grain moisture content does not exceed 12% for inert dusts and 14% for pesticides. The study demonstrates Kensil Superfine® dust potential to be further evaluated on – farm, for the control of storage insect pests and serve as a stored products protectant.

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