Efficacy of Kensil Fine, a diatomaceous earth, when applied to protect maize stored under simulated and real farmer situations in Kenya

ABSTRACT

Kensil fine, a local diatomaceous earth was evaluated under simulated and real farmer storage conditions. Three serial concentrations of: 0.3%, 0.5% and 0.7% w/w were applied on 8kg of grain in mini sacks (simulation trial) or 90kg grain (full bags) under farmer storage conditions. The Australian amorphous silica diatomaceous earth (Dryacide) Dryacide and a cocktail of 1.6% Pirimiphos methyl and 0.3% permethrin (Actellic super), the currently recommended storage chemical dust were included for comparison. All treatments including the control were replicated four times in the simulation trial. Two bags represented each treatment in the farmer situation. Changes in the quantities of dust and foreign matter (fm), grain moisture, pest population (live and dead) and percent grain damage were monitored through sampling. For 24 weeks, there were no statistical differences among treatments or between them and the control at both sites and the trials were extended by three months. After 36 weeks, significant differences were observed between the control and treatments for each of the four parameters. However, no significant differences in the quantity of fm sieved from treatments which reflected the DE doses applied. Grain moisture was slightly influenced by climate while applied treatments effectively suppressed pest establishment resulting into very low grain damage. Higher Kensil doses suppressed infestation, but it was the lowest dose that did not pose health challenge to the farmer and still gave effective grain protection.

Key words: Grain protection, Diatomaceous earths, Storage insect pest. Pest damage

1. INTRODUCTION

Maize, the main staple in many developing countries can be attacked by storage insects, especially the *Sitophilus zeamais*, *Prostephanus truncatus* and *Sitotroga cereallela* (Dick, 1988; Golob, *et al*. 1996; Brice, *et al.* 1996; Marshall and Golob, 1996; Donaldson, *et al.* 1996) which cause loss of income and food insecurity to many farm families (Stathers, 2002). Over the years, storage insects have been responsible for the rising trend in grain damage and subsequent weight loss (de Lima, 1979; Muhihu and Kibata, 1985; Mutambuki and Ngatia, 2006) and farmers use both traditional methods and chemical pesticides to combat the menace (Golob

and Webley, 1980; Golob *et al.* 1982; Kamanula, *et al*. 2011). Although use of chemical pesticides was on the rise, the contrasting fact is that over the last few decades, grain weight loss has also been rising (de Lima, 1979; Muhihu and Kibata, 1985; Mutambuki and Ngatia, 2006). Several factors may explain the scenario but the possibility of pest resistance to chemicals (Champ and Dyte, 1976; FAO, 1970; Taylor, 1989 and Tyler, *et al*. 1983); farmers timing of the application, improper doses and methods of application (Mutambuki, *et al.* 2010) appear to play a major role. One of the economic consequences of the misuse of pesticides has been trade restrictions, which together with increased cost of treatment, strengthen the need for the search for effective alternatives that can also meet the international criteria of acceptance.

The search for effective pest control products is of interest to researchers, chemical firms and regulatory bodies mainly concerned with efficacy and safety both to user and the environment. Any pest control product must be seen in line with the above. Diatomaceous earths (DEs), a recent entrant as alternative candidate to chemical pesticides, are said to control wide range of storage insect pests (Barbosa, *et al.* 1994; Subramanyam, *et al.* 1998; Mewis and Ulrichs 2001; Arthur, 2002; Arthur and Throne, 2003; Athanassiou, *et al.* 2005; Wakil, *et al.* 2010). They are stable, with low mammalian toxicity (Fields, *et al.* 2002) and work by absorbing the epi-cuticle lipids leading to insect death through excessive water loss (Ebeling, 1961). They can combine with chemical pesticides or bio-control agents to enhance potency (Stathers, 2002; Ceruti and Lazzari, 2005; Lord, 2001 and Akbar, *et al.* 2004) making them suitable to protect stored grain (Stathers. 2004).

~~Although~~ DEs ~~occur in different parts of the world, their efficacy~~ effectiveness ~~to~~ vary with physical properties and diatom species (Kuronic, 1998); ~~. Other factors include~~ insect species (Chiu and Kuronic, 1997), grain type (Athanassiou, *et al.* 2003), grain moisture, temperature and relative humidity (Fields and Kuronic, 2000; Nikpay, 2006; Athanassiou, *et al.*2006). Local DEs ~~must therefore be evaluated~~ evaluation are necessary to generate pertinent information that can be used to register them for use in the food storage. Fields, *et al*. (2002) observed ~~that~~ the lack for a standardized methodology in DE testing ~~and a creditable body to register~~ was of concern. In the US, the Environmental Protection Agency (EPA) classifies DEs as 'generally regarded as safe (GRAS) thus allowing them to be incorporated in food as additives. ~~Where~~ In fully mechanized storage, ~~is~~ the only adverse effect from DE use was grain flow, but under rural farmer set up, DE in halation could be the main risk. ~~factor and~~ In Kenya, the Pest Control Products Board (PCPB), has the mandate to register effective products ~~with proven efficacy and low human risk~~. Commercial firms ~~must therefore~~ have to seek permits to have their materials evaluated and the African Diatomite Industries Limited (ADIL) used ~~their~~ permit number: PCPB/112/Eval/VOL.1/11/146 to have Kensil evaluated ~~by the post-harvest research team~~ at KALRO Kabete.

Kensil is mined at the Kariandusi ~~mines~~ near Gilgil on the Nairobi ~~to~~ - Nakuru highway. It is a fine light grey dust containing 85% Silicon dioxide (SiO_2) among other compounds. It is used to dilute insecticides, as coating agent for fertilizers, ~~and~~ a filler in the soap manufacture and its good ~~among other uses. It is stable~~ stability at high temperatures ~~making~~ makes it suitable for lagging boilers. Its evaluation against the storage insects in Kenya was meant to diversify company

uses and ~~also~~ broaden farmer options for pest control. Trials were first carried out in laboratory to establish the effective dose ~~to be evaluated in the field~~ while the field simulation trials ~~at KALRO Kiboko~~ assessed ~~it's~~ the potential to protect stored maize. The latter ~~and~~ ran concurrently with full bag experiment under farmer storage ~~practice~~ conditions.

2. MATERIAL AND METHODS

2.1 Simulation of farmer storage practice

Eight kilograms of clean and thoroughly homogenized maize were weighed into each of the 24 jute mini-bags of 10kg capacity and initial grain moisture (GMC) determined using the Dickey john meter. Grain damage (GD) at 0 weeks was assessed from 500g samples taken from individual mini-bags before treatment. Three sets of four bags were treated with Kensil F at 0.3%, 0.5% and 0.7% w/w concentrations while four mini bags were treated with a cocktail of 1.6% Pirimiphos methyl and 0.3% permethrin (Actellic Super Dust), the recommended check, at 50g/90kg of grain. Another four were treated with the amorphous silica activated diatomaceous earth (Dryacide) at 0.5% w/w concentration leaving the last set of four untreated. The mini bags were randomly placed on wooden shelves in a completely randomized design (CRD). To enhance natural infestation, strains of *Sitophilus zeamais* and *Prostephanus truncatus* were put in a sisal mini bag and suspended from the roof in the experimental room. After every 4 weeks, about 500g were sampled from each mini bag using the short grain probe ~~at 4 week intervals,~~ the last analysis being after 24 weeks. Each sample was sieved to remove foreign matter (fm) in form of dust, non-grain material and free living insects. Grain moisture was determined as described above for baseline. A riffle divider was used to ~~reduce~~ divide the samples until four sub-samples of approximately 65g were obtained. Grain in three sub-samples were sorted into damage categories which were

counted, weighed and expressed as a percentage of the working sample. At 24 weeks, it was not easy to differentiate between the control and treatments and sampling was extended for another 3 months.

2.2 Real farmer situation

Twelve 90kg bags of freshly harvested maize were purchased locally and initial samples taken to establish levels of foreign matter (fm), grain moisture (gmc) and various categories of grain damage in individual bags. One set of two bags was treated with a cocktail of 1.6% Pirimiphos methyl and 0.3% permethrin (Actellic super dust) at 50g/90kg bag of shelled grain while another was treated with Dryacide at 0.5% w/w. Three sets were treated with 0.3%, 0.5% and 0.7% concentrations of Kensil F, leaving the last set untreated. Like in the case of mini bags, the bags were randomly placed in the farmer store such that no treatment was next to its replica. A five compartment double tube grain spear (Plate 1) was used to draw samples at 4 weekly intervals, the last of which was done 24 weeks post-treatment. Samples were analyzed as described for the simulation trial.

Plate 1 Double tube grain spear

The data from the two trials was managed with Excel and analyzed using the statgraphic software. ANOVA showed the main effects on each parameter assessed while the Duncan's Multiple Range Test (DMRT) separated treatment means with significant differences. Grain damage < 5% over the entire period and insignificant rise in pest population confirmed the potential of the product to protect maize against infestation by storage insect pests.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Parameters assessed in the simulation of farmer storage practice

Changes in the quantity of dust and foreign matter (fm), grain moisture (gmc), total pest population and percent weight of insect damaged grains were the parameters used to judge the efficacy of the treatments as compared with the control (Tables 1). In nearly all cases, the untreated control contributed to the significant differences observed.

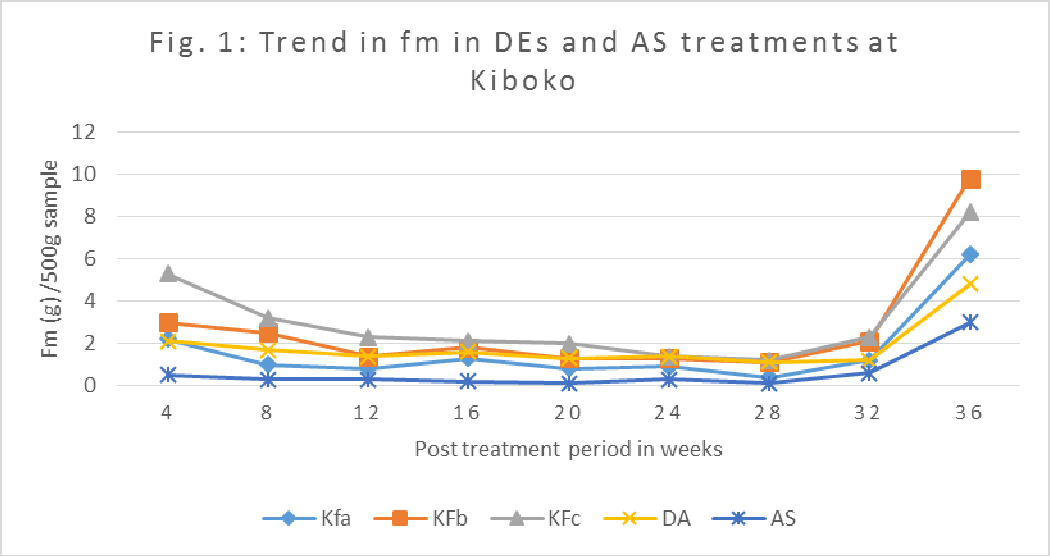
Table 1: Parameters for judging treatment effects in the field simulation

Treatment	Fm(g)	%GMC	Pest Population	% wt. of Pest damaged grains
ASD	0.49a	11.09a	4.44a	0.13a
KFa	1.22a	11.18a	5.78a	0.32a
DA	1.99ab	10.91a	1.22a	0.13a
KFb	2.52ab	10.95a	11.44a	0.74a
KFc	2.87ab	11.02a	7.11a	0.64a
Control	6.04b	11.66b	125.67b	31.90b
P values	*0.05*	*0.05*	*0.05*	*0.0001*

Each datum is a mean of 4 reps sampled over a 9 month period

Column values followed by same letter were not statistically different at 95% confidence level (DMRT)

Insect activity in the control samples was responsible for the significant increase ($P<0.05$) in fm when compared with treatments. Between 4 and 24 weeks, fm in all treatments was low and inseparable but at 28 weeks differences emerged culminating with >80g per 500g sample in control compared with below 10g among treatments at 36 weeks. AS maintained the lowest fm while among the DEs, Dryacide and the three concentrations of Kensil recorded declining levels in line with the quantities applied. It was only during the extended period that fm increased culminating in the order: AS<DA<KFa<KFc<KFb from the least to the highest (Fig. 1).



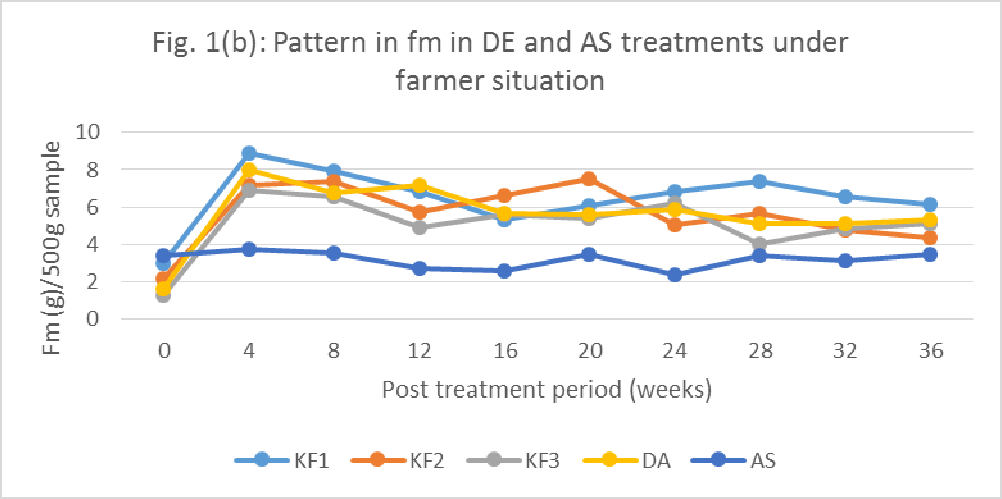
The same trend was observed in the farmer situation where again the control was responsible for the significant differences (P<0.0001) that occurred in different parameters (Table 2). At the onset, all the six sets of two bags had varying amounts of fm averaging from 1.3g to 3.7g in 1000g samples. After treatment, the quantity of fm first increased as a reflection of the DE amounts added. However, during the subsequent sampling intervals there was no credible increase even in the control. From 24 weeks, differences emerged with 18g sieved out of the control as compared with < 8g from treatments. Again AS maintained low fm, while the DEs had slightly higher giving the final trend, from the least to the highest as: AS< KF2< KF3< DA< KF1 (Fig. 1(b)).

Table 2: Parameters for judging treatment effects in the farmer trials

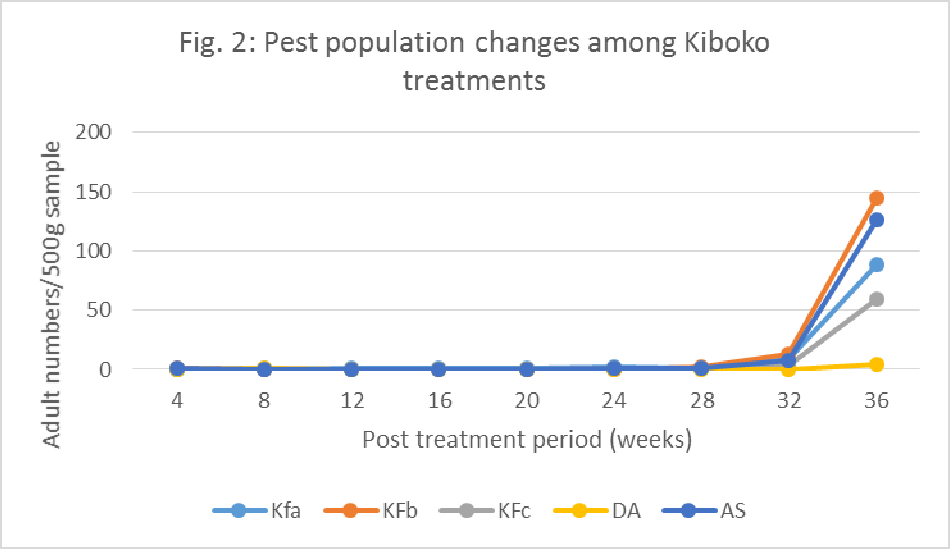
Treatment	Fm(g)	%GMC	Pest Population	% wt. of Pest damaged grains
ASD	3.39a	11.84a	0.7a	0.04a
KFa	5.77b	11.568a	1.5b	0.80a
DA	4.62a	11.63a	0.2a	0.41a
KFb	4.79ab	11.46a	0.3a	0.51a
KFc	6.39b	11.62a	0.84ab	0.46a
Control	8.54c	12.08b	2.94c	4.33b
P values	*0.0003*	*0.0505*	*0.0001*	*0.0001*

Each datum is a mean of 4 reps sampled over a 9 month period

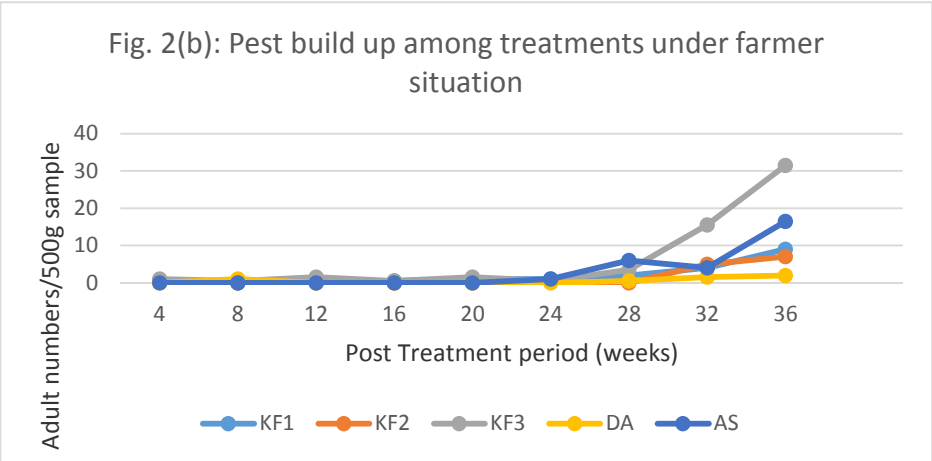
Column values followed by same letter were not statistically different at 95% confidence level (DMRT)



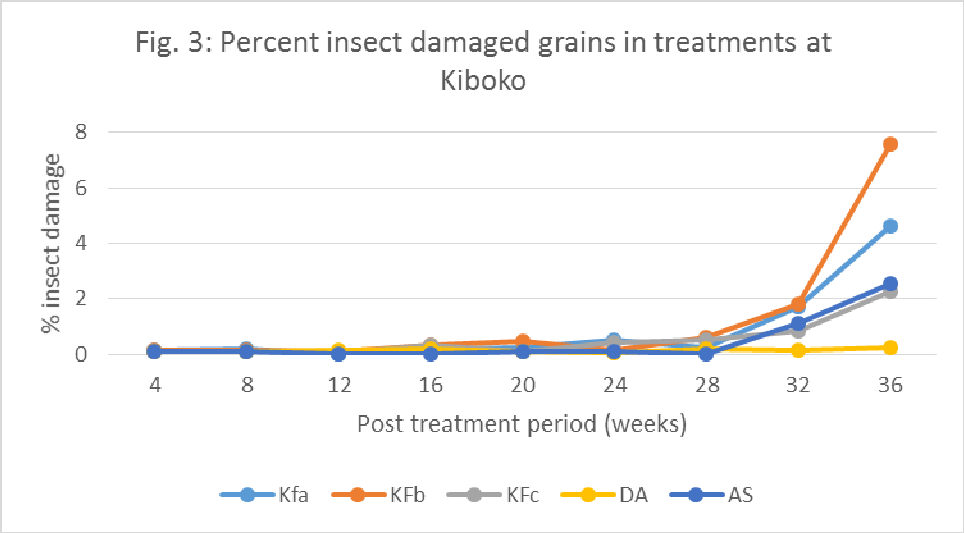
Grain moisture showed no significant differences among treatments (10.9% – 11.2%) but the 11.7% for the control was significantly ($P < 0.05$) higher. The variations noted had no implication since the grain moisture was within the safe level for storage, at below 13.5%. The same trend was observed under farmer storage conditions with grain moisture (11.5% - 11.8%) for treatments being significantly different ($P<0.05$) from the 12.1% in the control. Total pest population (live and dead) was another indicator used. It reflected a gradual rise from 1 adult at first sampling to >1600 adults in the control at 36 weeks. Between 4 and 24 weeks, there were no significant differences ($P<0.05$) between the control and treatments but pest population increased from 28 weeks to more than 1600 in the control. Figure 2 shows no credible difference in insect numbers up to 32 weeks when pest population improved to a high of 145 adults per 500g sample with the order of pest suppression: DA < KFc < KFa <AS < KFb.



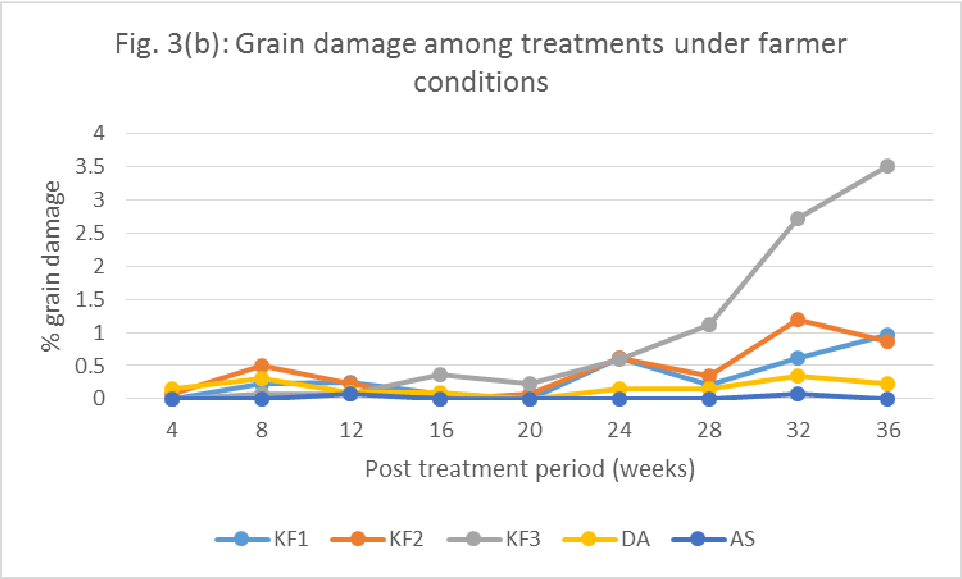
The trend of low infestation was the same under farmer situation, but the influence of the control in terms of significant pest population growth difference was observed much earlier, at 20 weeks when 50 adult insects were sieved from 500g samples compared to about 1 in treatments. From 16 weeks, pest population in the control sharply rose to peak at 150 insects at 28 weeks followed by a slight decline to about 100 at 36 weeks. Among treatments, the only meaningful increase was recorded from 32 weeks and at 36 weeks the three Kensil doses recorded 7, 9 and 32 insects while AS had 17 and DA 3 (figure 2(b)) giving the order of merit from the least numbers as: DA< KF2< KF1<AS< KF3.



The low pest population was responsible for the minimal grain damage in the two trial sites. At Kiboko, grain damage of between 0.1% and 0.7% among treatments, was significantly (P<0.001) differed from 31.9% caused by 294 adult pests in the control. For the first 3 months, there was no difference between treatments and the control, but from 16 weeks, the control registered progressively higher levels, with almost 100% at 36 weeks. Among treatments, insect damaged grains remained <1% and only rose to about 8% at the end of trial (Fig. 3). The order of merit, again from the lowest grain damage was DA<ASD<KFc<KFa<KFb.



The grain damage under farmer conditions was a close replica of the Kiboko simulation results. From onset to 12 weeks, there was no differences in the level of insect damage between the control and treatments. After 16 weeks, the damage level in the control rose sharply at every sampling interval and leveled at 80% between 32 and 36 weeks. Among treatments, pest damage remained low, less than 1% for most of the times and ranged from 1% to 3.5% among the Kensil concentrations. AS and DA had the lowest pest damage and figure 3(b) shows the order of merit as: AS< DA< KF2< KF1< KF3.



3.2 Discussion

The above results depict the common scenarios in the field under natural infestation. Infestation establishment is normally slow, which in the simulation case necessitated seeding. Even after this, the impact remained very low and a three month extension was necessary. Of the four parameters used, the declining pattern in the amounts of fm were similar for the two sites but farmer samples had higher quantities, a reflection of the concentrations applied in relation to the ratio of the grain mass. The 0.3% Kensil concentration had the lowest fm after DA and AS. The

weighted average shows marked differences between the two sites with 12.9g fm (untreated Kiboko trial) compared with 8.6g in untreated farmer trial. While the 0.3% Kensil (Kiboko) ended with 1.6g fm, the same under farmer conditions had 5.1g due to reasons given above. Grain moisture did not show any adverse effects except slight climatically adduced differences of 11% - 11.7% (average) in the simulation compared with 12.7% to 13.5% at farmer condition. The control recorded higher grain moisture in both sites compared with treatments. Although there was evidence of pest population rise from the control, it appears the insects which got access into treated maize were either killed or inhibited from establishment. Like in fm, the weighted average pest population clearly show the Kiboko had much higher, between 1 and 18 (among treatments) compared with 1 – 6 for farmer trial. This was due to the seeding. It was evident that higher Kensil concentration gave best pest suppression. With low pest establishment, the corresponding grain damage was unimpressive among treatments in the two sites, with slightly more than 1% recorded during 32 and 28 weeks in simulation and farmer situation respectively. The average weighted insect damage show that despite seeding, untreated farmer samples suffered slightly higher damage, 35.6% compared with 33.9% at Kiboko. At the end, lower Kensil concentration's average insect damage was 0.9% (Kiboko) compared with 0.3% in farmer store. In terms of weight loss, the above represented 0.5% and 0.2% at the two sites respectively.

4. CONCLUSION

Inert dusts have a definite role to play in the management of storage insect pests. They are not instant in their efficacy as would be for chemical pesticides. Bioassay results have shown differences exist in how pest species respond to DE treatments. Apart from the

physical DE properties, the differences could also be related to insect behaviour. *S. zeamais* is more active in flight and walking in comparison to the Bostrichid beetles, *P. truncatus* and *R. dominica*, which spend most of their time feeding inside the grain. Being more active resulted in higher mortality under controlled conditions. Between the two borers, *P. truncatus* was the more voracious feeder thereby avoiding contact with DE.

The choice of the dose should not be based on insect mortality alone, but the effect on the physical properties of the grain should be considered. Indeed, this was evident in the extra force required to push grain probe during sampling from DE treated bags. The 0.3%w/w Kensil concentration gave effective grain protection, was easier to sample and is therefore the best option for use by farmers. However, protection against dust inhalation must be emphasized, ~~Apart from~~ use of the correct dose, timing and the method of application should be carefully considered. ~~and The post-harvest scientists could conduct on-farm demonstrations if and when consulted.~~

~~5. RECOMMENDATIONS~~

~~The evaluation was meant to prove that Kensil could be the next alternative for farmers to use against stored insect pests. Less than 5% grain damage over the entire storage season is the criterion used for a pest control product to be considered effective. For the 6 months of trial, grain damage in the treatments remained <1% and only rose to <4% after the period was extended by 3 months. This was a big contrast with the control which crossed the 5% threshold between 4th and 5th intervals. The results establish the fact that the low grain damage was due to the effect of treatments applied. The next question could be: "At what concentration should Kensil be applied?" All the Kensil concentrations had the lowest mean grain damage at <1% indicating very good performance. However, after extension, there~~

~~were signs of weakening in the lower concentrations which recorded between 4.6% and 7.6%, leaving the higher one at below the threshold level. Higher concentrations were found to hamper grain sampling at farmer store and so the lower level should be preferred in order to reduce the DE effect on physical properties of the grain.~~

~~The simulation results when compared very well with those from the real farmer situation in the Nakuru where the slight differences appear to indicate how climate affected grain damage. While the Kiboko trial recorded 98% grain damage in the control samples, the Nakuru trial had much lower, at slightly above 80% damage. However, grain moisture remained within the safe bracket for storage. In both sites, all treatments effectively protected the stored maize.~~

6. REFERENCES

Anon, 1975: Recommended methods for detection and measurement of resistance of agricultural pests to pesticides. Tentative method for adults of some major pest species of stored cereals, with methyl bromide and phosphine –FAO Method No 16. FAO Plant Protection Bulletin. No. 23, 12 - 25.

Anon (1991): Environmental Protection Agency R.E.D. FACTS: Silicon Gel; 21T – 1021, 1 – 4, September 1991.

Champ and Dyte, 1976: Report of the FAO Global Survey of Pesticide susceptibility of stored grain pests. FAO Plant Protection Series, No 5. 1976.

De Lima, C. P. F. 1979. The assessment of losses due to insects and rodents in maize stored for subsistence in Kenya. Tropical Stored Products Information, 38, 21 – 25.

Dick, K. 1988: A review of insect infestation in farm storage in Africa with special reference to the ecology and control of *Prostephanus truncatus* (Horn) (Coleoptera: Botrichidae). Overseas Development, NRI Bulletin No 18, v + 42pp.

Ebeling, W. (1971): Sorptive dusts for pest control. Annual Review of Entomology 16, 123 – 158.

Fields, P. G. and Kuronic, Z. (2002): Postharvest insect control with inert dusts. In: Pimentel, D. (Ed.), Dekker Encyclopedia of Pest Management. Marcel Dekker, New York, pp 650 – 653.

Fields, P. G., Allen, S., Kuronic, Z., McLaughlin, A. and Stathers, T. (2002): Standardized testing for diatomaceous earth. Proceedings of the 8th International Working Conference of Stored Products Protection, York, U.K., July 2002.

Golob, P and Webley, D. J. 1980. The use of plants and minerals as traditional protectants of stored products. Report of the Tropical Products Institute, G138, vi+ 32pp.

Golob, P., Mwambula, J., Mhango, V. and Ngulube, F. 1982. The use of locally available materials as protectants of maize grain against insect infestation during storage in Malawi. J. of Stored Products Research, Vol. 18, pp 67 – 74.

Golob, P. (1997): Current status and future perspectives for inert dusts for the control of stored product insects. J. Stored Prod. Res. Vol. 33, No.1, pp69 -79, 1997.

Kamanula, J., Gudeta, W. S., Steven, R. B., Phosiso, S., Mvumi, B. M., Nyirenda, G. K. C., Nyirenda, S. P., Stevenson, P. C. (2011): Farmers' insect pest management practices and pesticidal plant se in the protection of stored maize and beans in Southern Africa, International Journal of Pest Management; Vol. 57,No. 1, January-March 2011, 41-49.

Kavallieratos, N. G., Athanassiou, C. G., Mpakou, F. D. and Mpassoukou A. E. (2007): Factors affecting Laboratory bioassays with DE on stored wheat: Effect of insect density, grain quantity and cracked kernel contamination. J. Econ. Entomol. 100(5): 1724 – 1731 (2007).

Kuronic, Z. (1998): Review: diatomaceous earths, a group of natural insecticides. J. Stored Prod. Res. Vol. 34, No. 2/3, pp 87 – 97, 1998.

Muhihu, S. K. and Kibata, G. N. 1985. Developing a control programme to combat an

outbreak of *Prostephanus truncatus (Horn), (Coleoptera: Bostrichidae)* in Kenya. Tropical Science, 25, 239 – 248.

Mutambuki, K. and Ngatia, C. M., 2006. Loss assessment of on-farm stored maize in semi-arid areas of Kitui District, Kenya. In: Lorini, I. Bacultchuk, B., Beckel, H., Deckles, D. Proceedings of the 9th International Working Conference on Stored Products Protection. Campinas, Sao Paulo, Brazil.

Mutambuki, K., Ngatia, C. M. and Mbugua, J. N. 2010. Post-harvest technology transfer to reduce on-farm grain losses in Kitui District, Kenya. Proceedings of 10th International working Conference on Stored Products Protection, 27th June – 2nd July 2010, Estoril, Portugal.

Nikpay, A. (2006): Diatomaceous earths as alternatives to chemical insecticides in stored grain. Insect Science (2006) 13, 421 – 429.

Taylor, R. W., 1989: Phosphine – a major grain fumigant at risk. International Pest Control 31, 10 – 14.

Tyler, P. S., Tatlor, R. W. and Rees, D. P., 1983: Insect resistance to phosphine fumigation in food warehouses in Bangladesh. International Pest Control 25, 10 – 21.