

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 cerealella* (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

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

32 The search for effective pest control products is of interest to researchers, chemical
 33 firms and regulatory bodies mainly concerned with efficacy and safety both to user
 34 and the environment. Any pest control product must be seen in line with the above.
 35 Diatomaceous earths (DEs), a recent entrant as alternative candidate to chemical
 36 pesticides, are said to control wide range of storage insect pests (Barbosa, *et al*,
 37 1994; Subramanyam, *et al*, 1998; Mewis and Ulrichs 2001; Arthur, 2002; Arthur and
 38 Throne, 2003; Athanassiou, *et al*, 2005; Wakil, *et al*, 2010). They are stable, with
 39 low mammalian toxicity (Fields, *et al*, 2002) and absorb the epi-cuticle lipids leading
 40 to insect death through excessive water loss (Ebeling, 1961). They can combine
 41 with chemical pesticides or bio-control agents to enhance potency (Stathers 2002;
 42 Ceruti and Lazzari 2005; Lord 2001 and Akbar, *et al*, 2004) making them suitable to
 43 protect stored grain (Stathers 2004).

44 Although DEs occur in different parts of the world, their efficacy to vary with physical
 45 properties and diatom species (Kuronc 1998). Other factors include insect species
 46 (Chiu and Kuronc 1997), grain type (Athanassiou, *et al*, 2003), grain moisture,
 47 temperature and relative humidity (Fields and Kuronc 2000; Nikpay 2006;
 48 Athanassiou *et al*, 2006).

49 Local DEs must therefore be evaluated to generate pertinent information that can be
 50 used to register them for use in the food storage. Fields, et al, (2002) observed that
 51 the lack for a standardized methodology in DE testing and a creditable body to
 52 register was of concern. In the US, the Environmental Protection Agency (EPA)
 53 classifies DEs as 'generally regarded as safe (GRAS) thus allowing them to be
 54 incorporated in food as additives. Where storage is fully mechanized, the only
 55 adverse effect from DE use was grain flow. Under rural farmer set up, DE in halation
 56 could be the main risk factor and in Kenya, the Pest Control Products Board
 57 (PCPB), has the mandate to register products with proven efficacy and low human
 58 risk. Commercial firms must therefore seek permits to have their materials
 59 evaluated. The African Diatomite Industries Limited (ADIL) used their permit
 60 number: PCPB/112/Eval/VOL.1/11/146 to have Kensil evaluated by the post-harvest
 61 research team at KALRO Kabete.

62 Kensil is mined at the Kariandusi mines near Gilgil on the Nairobi to Nakuru
 63 highway. It is a fine light grey dust containing 85% Silicon dioxide (SiO_2) among
 64 other compounds. It is used to dilute insecticides, as coating agent for fertilizers and
 65 a filler in the soap manufacture among other uses. It is stable at high temperatures
 66 making it suitable for lagging boilers. Its evaluation against the storage insects was
 67 meant to diversify company uses and also broaden farmer options for pest control.

68 Trials were first carried out in laboratory to establish the effective dose to be
69 evaluated in the field. The field simulation trials at KALRO Kiboko assessed its
70 potential to protect stored maize and ran concurrently with full bag experiment under
71 farmer storage practice.

72

73 **2. MATERIAL AND METHODS**

74 **2.1 Simulation of farmer storage practice**

75 Eight kilograms of clean and thoroughly homogenized maize were weighed into each of
76 the 24 jute mini-bags of 10kg capacity and initial grain moisture (GMC) determined
77 using the Dickey john meter. Grain damage (GD) at 0 weeks was assessed from 500g
78 samples taken from individual mini-bags. Three sets of four bags were treated with
79 Kensil F at 0.3%, 0.5% and 0.7% w/w concentrations while four mini bags were treated
80 with a cocktail of 1.6% Pirimiphos methyl and 0.3% permethrin (Actellic Super Dust),
81 the recommended check, at 50g/90Kg of grain. Another four were treated with the
82 amorphous silica activated diatomaceous earth (Dryacide) at 0.5% w/w concentration
83 leaving the last set of four untreated. The mini bags were randomly placed on wooden
84 shelves in a completely randomized design (CRD). To enhance natural infestation,
85 strains of *Sitophilus zeamais* and *Prostephanus truncatus* were put in a sisal mini bag
86 and suspended from the roof in the experimental room. About 500g were sampled from
87 each mini bag using the short grain probe at 4 week intervals, the last being after 24
88 weeks. Each sample was sieved to remove foreign matter (fm) in form of dust, non-grain
89 material and free living insects. Grain moisture was determined as described above for
90 baseline. A riffle divider was used to reduce the samples until four sub-samples of
91 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 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.

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.

114 3. RESULTS AND DISCUSSION

115

116 3.1 Results

117 3.1.1 Parameters assessed in the simulation of farmer storage practice

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

122

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

124 Treatment	Fm(g)	%GMC	Pest Population	% wt. of Pest damaged grains
126 ASD	0.49a	11.09a	4.44a	0.13a
127 KFa	1.22a	11.18a	5.78a	0.32a
128 DA	1.99ab	10.91a	1.22a	0.13a
129 KFb	2.52ab	10.95a	11.44a	0.74a
130 KFc	2.87ab	11.02a	7.11a	0.64a
131 Control	6.04b	11.66b	125.67b	31.90b
132 <i>P values</i>	0.05	0.05	0.05	0.0001

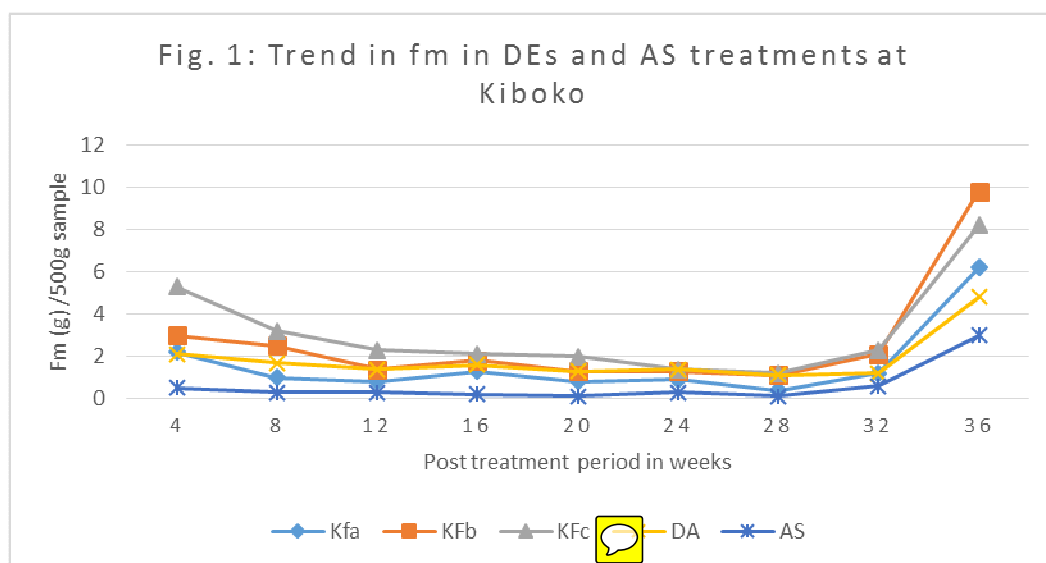
133 *Each datum is a mean of 4 reps sampled over a 9 month period*

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

135

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

142 $AS < DA < KFa < KFc < KFb$ from the least to the highest (Fig. 1).



143

144 The same trend was observed in the farmer situation where again the control was responsible for the
 145 significant differences ($P < 0.0001$) that occurred in different parameters (Table 2). At the onset, all
 146 the six sets of two bags had varying amounts of fm averaging from 1.3g to 3.7g in 1000g samples.
 147 After treatment, the quantity of fm first increased as a reflection of the DE amounts added. However,
 148 during the subsequent sampling intervals there was no credible increase even in the control. From
 149 24 weeks, differences emerged with 18g sieved out of the control as compared with < 8g from
 150 treatments. Again AS maintained low fm, while the DEs had slightly higher giving the final trend, from
 151 the least to the highest as: $AS < KF2 < KF3 < DA < KF1$ (Fig. 1(b)).

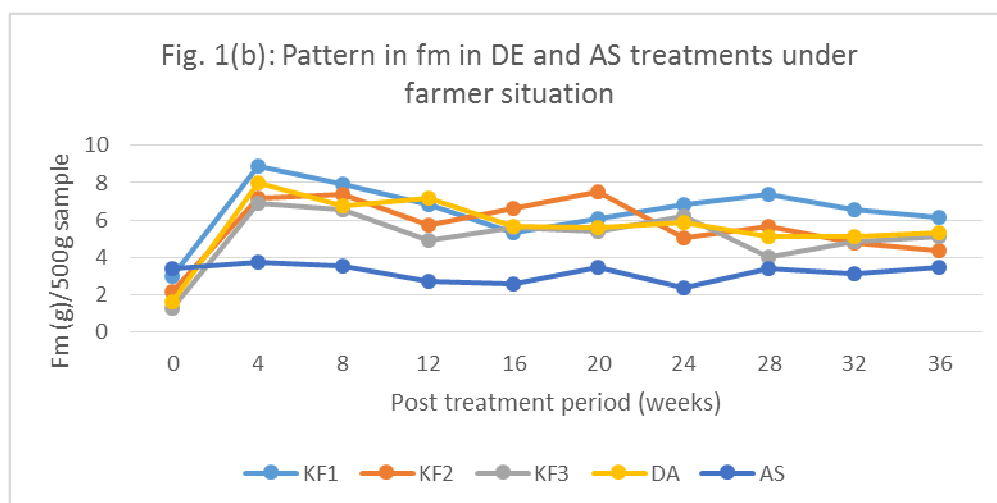
152 **Table 2: Parameters for judging treatment effects in the farmer trials**

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

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

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

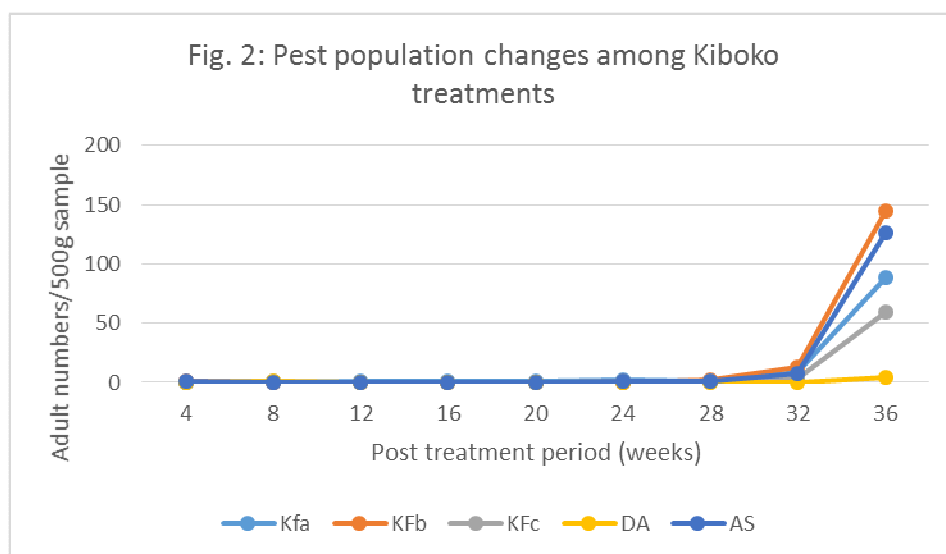
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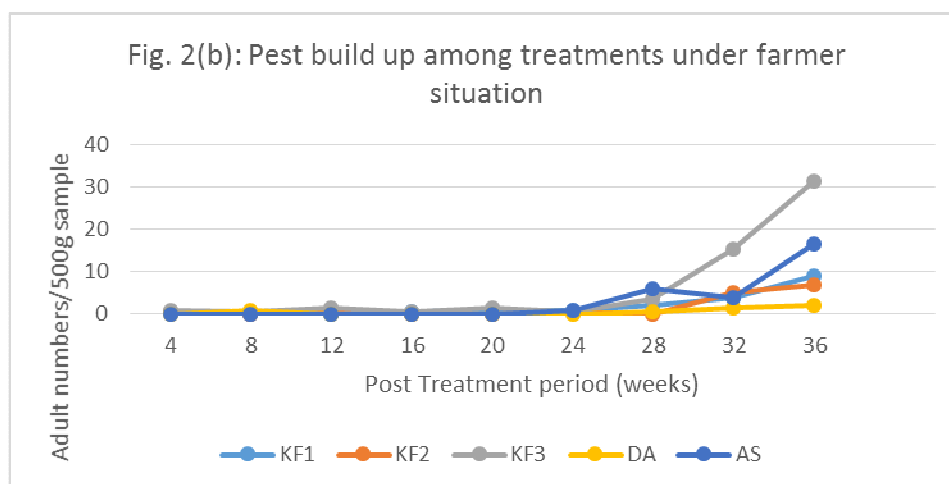
165 Grain moisture showed no significant differences among treatments (10.9% – 11.2%) but the 11.7%
 166 for the control was significantly ($P < 0.05$) higher. The variations noted had no implication since the
 167 grain moisture was within the safe level for storage, at below 13.5%. The same trend was observed
 168 under farmer storage conditions with grain moisture (11.5% - 11.8%) for treatments being
 169 significantly different ($P < 0.05$) from the 12.1% in the control.

170 Total pest population (live and dead) was another indicator used. It reflected a gradual rise
 171 from 1 adult at first sampling to >1600 adults in the control at 36 weeks. Between 4 and 24
 172 weeks, there were no significant differences ($P < 0.05$) between the control and treatments
 173 but pest population increased from 28 weeks to more than 1600 in the control. Figure 2
 174 shows no credible difference in insect numbers up to 32 weeks when pest population
 175 improved to a high of 145 adults per 500g sample with the order of pest suppression: DA <
 176 KFc < KFa < AS < Kfb.



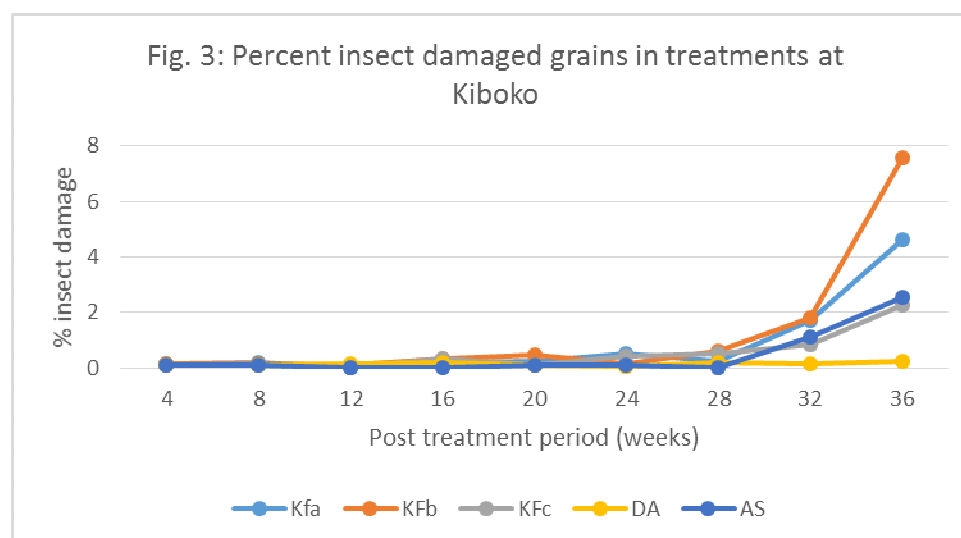
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178 The trend of low infestation was the same under farmer situation, but the influence of the
 179 control in terms of significant pest population growth difference was observed much earlier,
 180 at 20 weeks when 50 adult insects were sieved from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

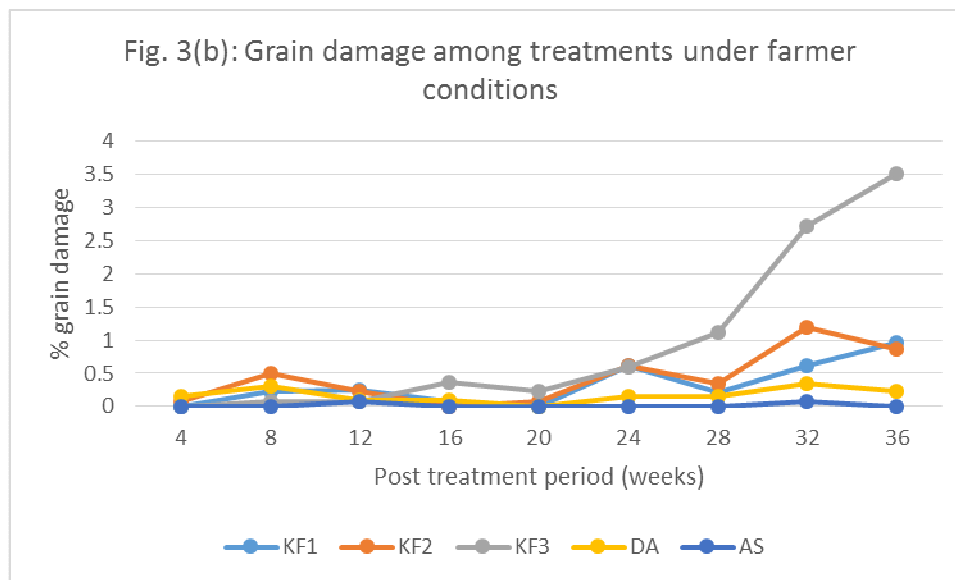


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187 The low pest population was responsible for the minimal grain damage in the two trial sites.
 188 At Kiboko, grain damage of between 0.1% and 0.7% among treatments, was significantly
 189 ($P<0.001$) differed from 31.9% caused by 294 adult pests in the control. For the first 3
 190 months, there was no difference between treatments and the control, but from 16 weeks, the
 191 control registered progressively higher levels, with almost 100% at 36 weeks. Among
 192 treatments, insect damaged grains remained $<1\%$ and only rose to about 8% at the end of
 193 trial (Fig. 3). The order of merit, again from the lowest grain damage was
 194 $DA<ASD<KFc<KF_a<KF_b$.



195 The grain damage under farmer conditions was a close replica of the Kiboko simulation results. From
 196 onset to 12 weeks, there was no differences in the level of insect damage between the control and
 197 treatments. After 16 weeks, the damage level in the control rose sharply at every sampling interval
 198 and leveled at 80% between 32 and 36 weeks. Among treatments, pest damage remained low, less
 199 than 1% for most of the times and ranged from 1% to 3.5% among the Kensil concentrations. AS and
 200 DA had the lowest pest damage and figure 3(b) shows the order of merit as: $AS<DA<KF_2<KF_1<$
 201 KF_3 .



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

221 treatments) compared with 1 – 6 for farmer trial. This was due to the seeding. It was evident
 222 that higher Kensil concentration gave best pest suppression. With low pest establishment,
 223 the corresponding grain damage was unimpressive among treatments in the two sites, with
 224 slightly more than 1% recorded during 32 and 28 weeks in simulation and farmer situation
 225 respectively. The average weighted insect damage show that despite seeding, untreated
 226 farmer samples suffered slightly higher damage, 35.6% compared with 33.9% at Kiboko. At
 227 the end, lower Kensil concentration's average insect damage was 0.9% (Kiboko) compared
 228 with 0.3% in farmer store. In terms of weight loss, the above represented 0.5% and 0.2% at
 229 the two sites respectively.

230 4. RECOMMENDATIONS

231 The evaluation was meant to prove that Kensil could be the next alternative for farmers to use
 232 against stored insect pests. Less than 5% grain damage over the entire storage season is the
 233 criterion used for a pest control product to be considered effective. For the 6 months of trial, grain
 234 damage in the treatments remained <1% and only rose to <4% after the period was extended by 3
 235 months. This was a big contrast with the control which crossed the 5% threshold between 4th and 5th
 236 intervals. The results establish the fact that the low grain damage was due to the effect of treatments
 237 applied. The next question could be: "At what concentration should Kensil be applied?" All the Kensil
 238 concentrations had the lowest mean grain damage at <1% indicating very good performance.
 239 However, after extension, there were signs of weakening in the lower concentrations which recorded
 240 between 4.6% and 7.6%, leaving the higher one at below the threshold level. Higher concentrations
 241 were found to hamper grain sampling at farmer store and so the lower level should be preferred in
 242 order to reduce the DE effect on physical properties of the grain.
 243 The simulation results when compared very well with those from the real farmer situation in
 244 the Nakuru where the slight differences appear to indicate how climate affected grain
 245 damage. While the Kiboko trial recorded 98% grain damage in the control samples, the
 246 Nakuru trial had much lower, at slightly above 80% damage. However, grain moisture

247 remained within the safe bracket for storage. In both sites, all treatments effectively
248 protected the stored maize.

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5. CONCLUSION

251 Inert dusts have a definite role to play in the management of storage insect pests. They are not
252 instant in their efficacy as would be for chemical pesticides. Bioassay results have shown differences
253 exist in how pest species respond to DE treatments. Apart from the physical DE properties, the
254 differences could also be related to insect behaviour. *S. zeamais* is more active in flight and walking
255 in comparison to the Bostrichid beetles, *P. truncatus* and *R. dominica*, which spend most of their time
256 feeding inside the grain. Being more active resulted in higher mortality under controlled conditions.
257 Between the two borers, *P. truncatus* was the more voracious feeder thereby avoiding contact with
258 DE.

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

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