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Efficacy of Kensil Fine, a Diatomaceous Earth, When Applied to Protect Maize Stored under Simulated and Real Farmer Situations in Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Author CMN designed the study, wrote the protocol, managed the data literature searches, analyses of the study and wrote the first draft of the manuscript. Author JNM was proof read the manuscript. Author KM improved the write up. All authors read and approved the final manuscript.

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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 8 kg of grain in mini sacks (simulation trial) or 90 kg 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

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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.

Keywords: 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* [1] which cause loss of income and food insecurity to many farm families [2]. Over the years, storage insects have been responsible for the rising trend in grain damage and subsequent weight loss [3-5] and farmers use both traditional methods and chemical pesticides to combat the menace [6-9]. 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 [3-5]. Factors that may explain the scenario include pest resistance to chemicals [10-13]; timing of the application, improper doses and methods of application, [14] together with increased cost of treatment, strengthen the need for the search for effective alternatives that can also meet the international criteria of acceptance.

Diatomaceous earths (DEs), are said to control wide range of storage insect pests [15-21]. They are stable, with low mammalian toxicity [22] and work by absorbing the epi-cuticle lipids leading to insect death through excessive water loss [23]. They can combine with chemical pesticides or bio-control agents to enhance potency [2,24,25] making them suitable to protect stored grain.

DEs effectiveness vary with physical properties and diatom species [26]; grain type [27], grain moisture, temperature and relative humidity [28-30]. Evaluation of local DEs are therefore necessary to generate pertinent information that can be used to register them for use in the food storage. [22] observed that lack for a standardized methodology in DE testing was of concern. The Environmental Protection Agency (EPA) [31] classifies DEs as ‘generally regarded as safe (GRAS) thus allowing them to be incorporated in food as additives. In fully mechanized storage, the only adverse effect from DE use was grain flow, but under rural farmer set up, inhalation could be the main risk. To manage and monitor pesticide use in Kenya, the Pest Control Products Board (PCPB), has the mandate to register effective products. Commercial firms have to seek permits to have their materials evaluated. The African Diatomite Industries Limited (ADIL) used permit number: PCPB/112/Eval/VOL.1/11/146 to have Kensil evaluated at KARI Kabete.

Kensil is mined at Kariandusi near Gilgil on the Nairobi - Nakuru highway. It is a fine light grey dust containing 85% Silicon dioxide (SiO2) among other compounds. It is used to dilute insecticides, as coating agent for fertilizers, a filler in the soap manufacture and its good stability at high temperatures makes it suitable for lagging boilers. The evaluation against the storage insects in Kenya was meant to diversify company uses and broaden farmer options for pest control. Trials were first carried out in laboratory to establish the effective dose while the field simulation trials assessed the potential to protect stored maize. The latter ran concurrently with full bag experiment under farmer storage conditions.

2. MATERIALS 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 10 kg capacity and initial grain moisture (GMC) determined using the Dickey john meter. Grain damage (GD) at 0 weeks was assessed from 500 g 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 50 g/90 kg 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 500 g were sampled from each mini bag using the short grain probe the last 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 divide the samples until four sub-samples of approximately 65 g were obtained. Grain in three sub-samples was 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 90 kg 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 50 g/90 kg 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.

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. 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.

Plate 1. Double tube grain spear

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Parameters assessed in the simulation of farmer storage practice

Table 1 shows the quantity of dust and foreign matter (fm), grain moisture (gmc), total pest population and percent weight of insect damaged grains. In nearly all cases, the untreated control contributed to the significant differences observed.

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 >80 g per 500 g sample in control compared with below 10 g 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(a)).

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 1.3 g to 3.7 g in

1000 g 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 18 g sieved out of the control as compared with < 8 g 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 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)

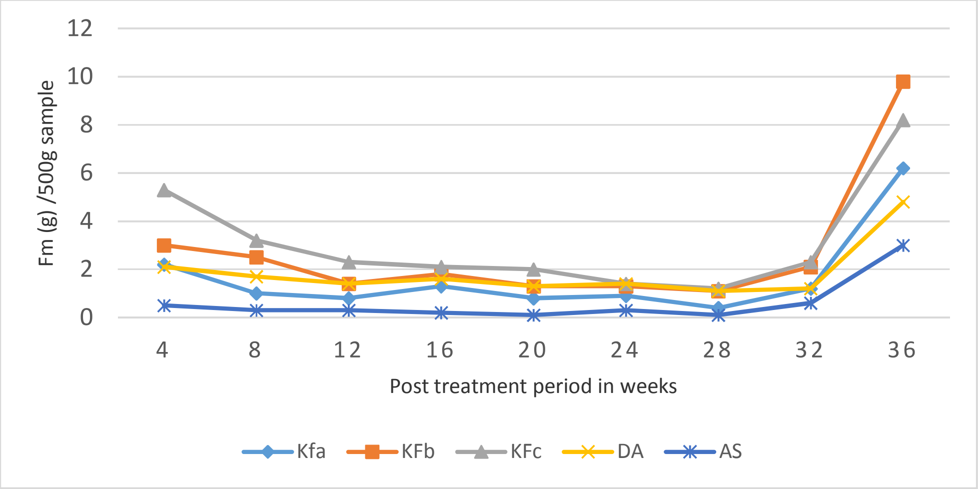

Fig. 1(a). Trend in fm in DEs and AS treatments at Kiboko

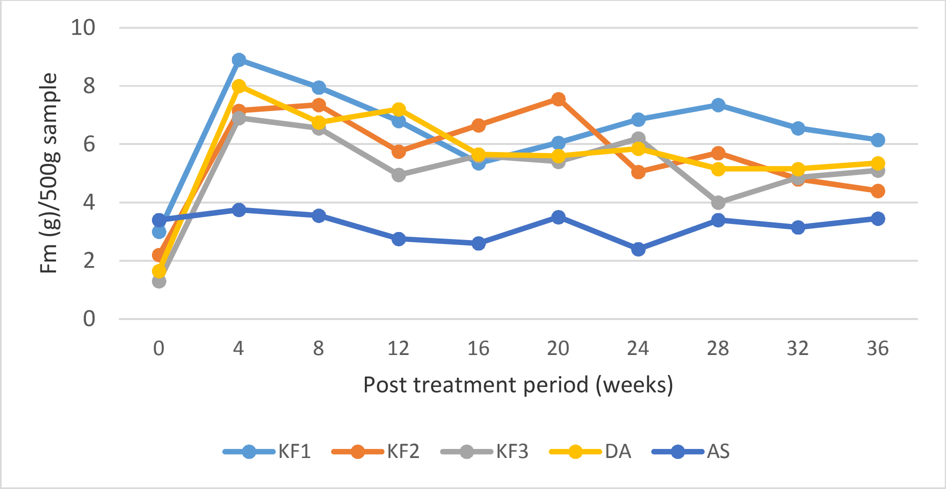

Fig. 1(b). Pattern in fm in DE and AS treatments under farmer situation

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. Fig. 2(a) shows no credible difference in insect numbers up to 32 weeks when pest population improved to a high of 145 adults per 500 g 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 500 g 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 (Fig. 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(a)). 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 were 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 Fig. 2(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

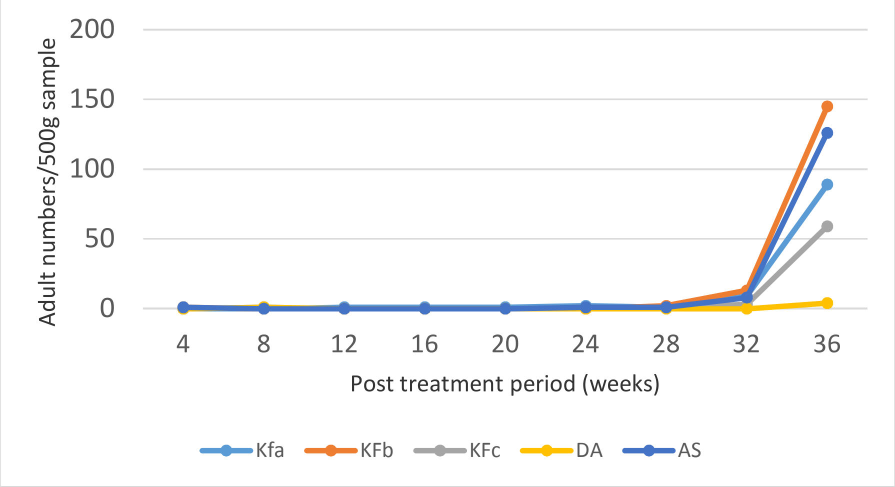

Fig. 2(a). Pest population changes among Kiboko treatments

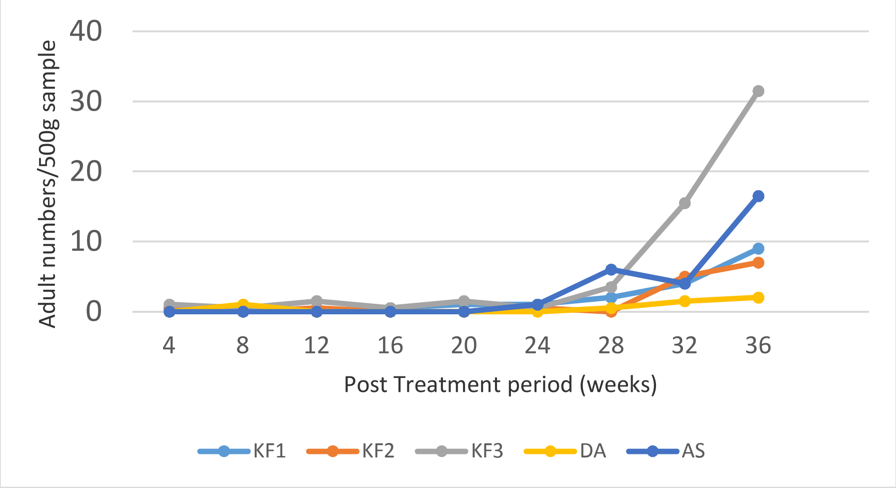

Fig. 2(b). Pest build up among treatments under farmer situation

12.9 g fm (untreated Kiboko trial) compared with 8.6 g in untreated farmer trial. While the 0.3% Kensil (Kiboko) ended with 1.6 g fm, the same under farmer conditions had 5.1 g 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.

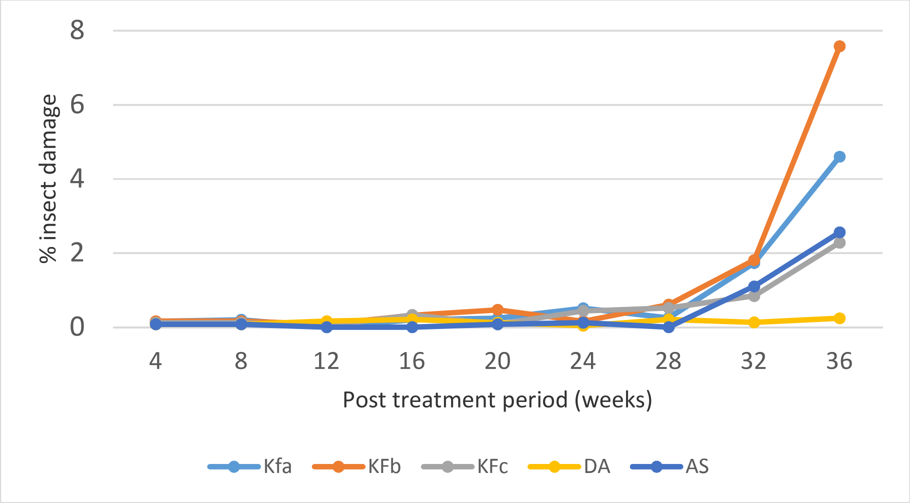

Fig. 3(a). Percent insect damaged grains in treatments at Kiboko

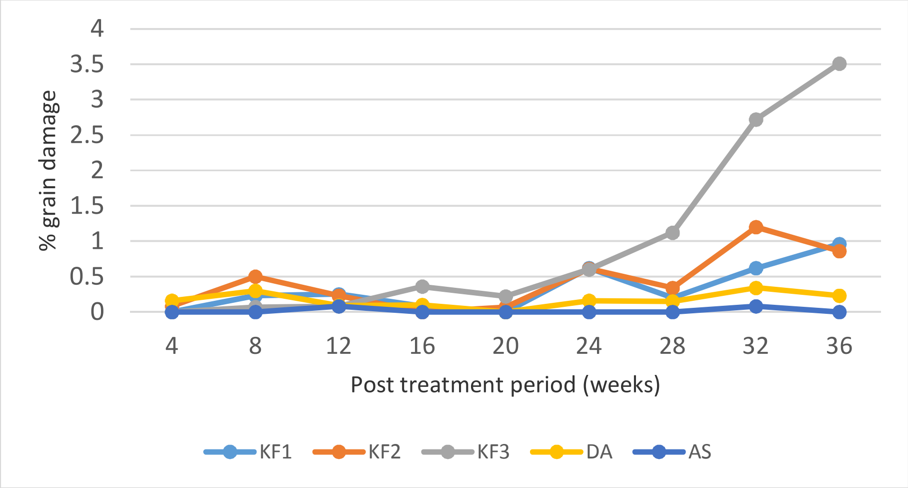

Fig. 3(b). Grain damage among treatments under farmer conditions

4. CONCLUSION

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 was the criterion used for a pest control product to be considered effective. For the six 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 therefore established 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 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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