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Evaluation of different rates of filter cake (by-products of Alumunium sulphate factory) for the management of the maize weevil, *Sitophilus zeamais* Mostch. (Coleoptera: Curculionidae) on stored maize at Bako, western Ethiopia

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The experiment was conducted in the laboratory at the Bako Research Center, western Ethiopia. Combinations of different rates of filter cake were evaluated against the maize weevil in no choice situations. Each experiment was laid out in a Randomized Complete Block Design with three replications. The experiment was re-infested to evaluate the persistence of the treatments 90 days after application. Data were collected on percentages of adult weevil mortality, numbers and weight of damaged and undamaged maize kernels, number of progeny weevils emerged, percentages of grain damaged, grain weight losses and seed germination. Analysis of variance showed significant differences among the treatments in all parameters. The number of progeny weevils emerged, percentages of grain damaged and seed weight losses in different rates of treatments were significantly lower than that of the untreated check. Filter (Melkabam) cake at 0.5% w/w and above showed significantly higher percentages of mortality and lower weight losses than that of the other treatments both after 90 and 156 days of infestation. With regard to seed germination, , significantly (P<0.05) higher percentages of seed germination were recorded in all rates of filter cake, except for the 0.0625% w/w and the untreated check following 156 days after treatments. It can be conclude that filter cake (Melkabam) at 0.5% w/w and above can be used to protect maize from the maize weevil.

Key: Filter cake (Melkabam), Malathion dust and maize weevil

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INTRODUCTION

Maize is one of the important cereal crops in Ethiopia, and grows in all parts of the country across varied agro ecological zones. It ranks first in production, productivity and in area coverage (1.4 million hectares) accounting for 21% of the total arable land allotted for all cereals in the country (CSA, 2005). However, the yield of maize is very low due to numerous constraints. The low yield is further lost in storage due to insect pests. Although many insect pests are known to cause losses to stored maize in Ethiopia, the maize weevil (*Sitophilus zeamais)* Mostchul. and the Angoumois grain moth (*Sitotroga cereallela*) (Oliv.) are the most important primary insect pests (Abraham, 1991; 1997; Mekuria, 1995; Emana and Assefa, 1998).

In Ethiopia, about 20% storage losses and 25% price reduction for the damaged grains were reported for maize, resulting in large income losses with value ratio not greater than one (Beyene *et al*., 1996). According to Abraham (1997), insect pests in the farm store caused over 16% loss on maize around Bako.

Different management options such as, inert dusts (wood ash, sand and SilicoSec), varietals screening, mixing with small cereal grains such as tef and dagussa, botanicals (plant powders and vegetable oil) and synthetic chemicals have been tested. SilicoSec at 0.1% w/w was recommended for use at the Bako condition. Moreover, mixing maize with tef at the rate of 30 to 50% w/w provided adequate protection for a short-term storage, however, for long term storage the rate should not be less than 70%. In respect to wood ash, 5 to 30% w/w could be suggested for use under the experimental conditions at Bako. Regarding sand, 30% w/w (for short-term storage) and 70% w/w (for long-term storage) were recommended (Abraham, 2003). As to chemical insecticides, Adane and Abraham (1995a) and Abraham *et al*. (1994) reported that deltmethrin, Malathion, metacrifos and pirimiphos-methyl gave effective control of the maize weevil on sorghum and maize.

Regardless of numerous control strategies available, storage insect pests are still problematic and Ethiopian farmers relay on synthetic chemicals. Although the use of pesticides are one means of protecting stored grain, the associated side effects on the environment and human health, development of genetically resistance insect strains, erratic supply and prohibitive costs have become a major concern and thus given imputes to the search for alternative methods of pest control.

This indicates the need for the development of alternative control options as part of integrated pest management. In view of this background that efforts have been made to move away from reliance on a single control options and instead to adopt an approach termed as Integrated Pest Management (IPM). Based on the above inspiration the present study is initiated with the following objectives: -

OBJECTIVE (S)

- To determine the minimum effective rate(s) of the filter cake that can provide adequate protection to maize against the pest
- To confirm the efficacy of filter cake (Melkabam) at different rates for the management of the maize weevil on maize at the Bako condition.

MATERIALS AND METHODS

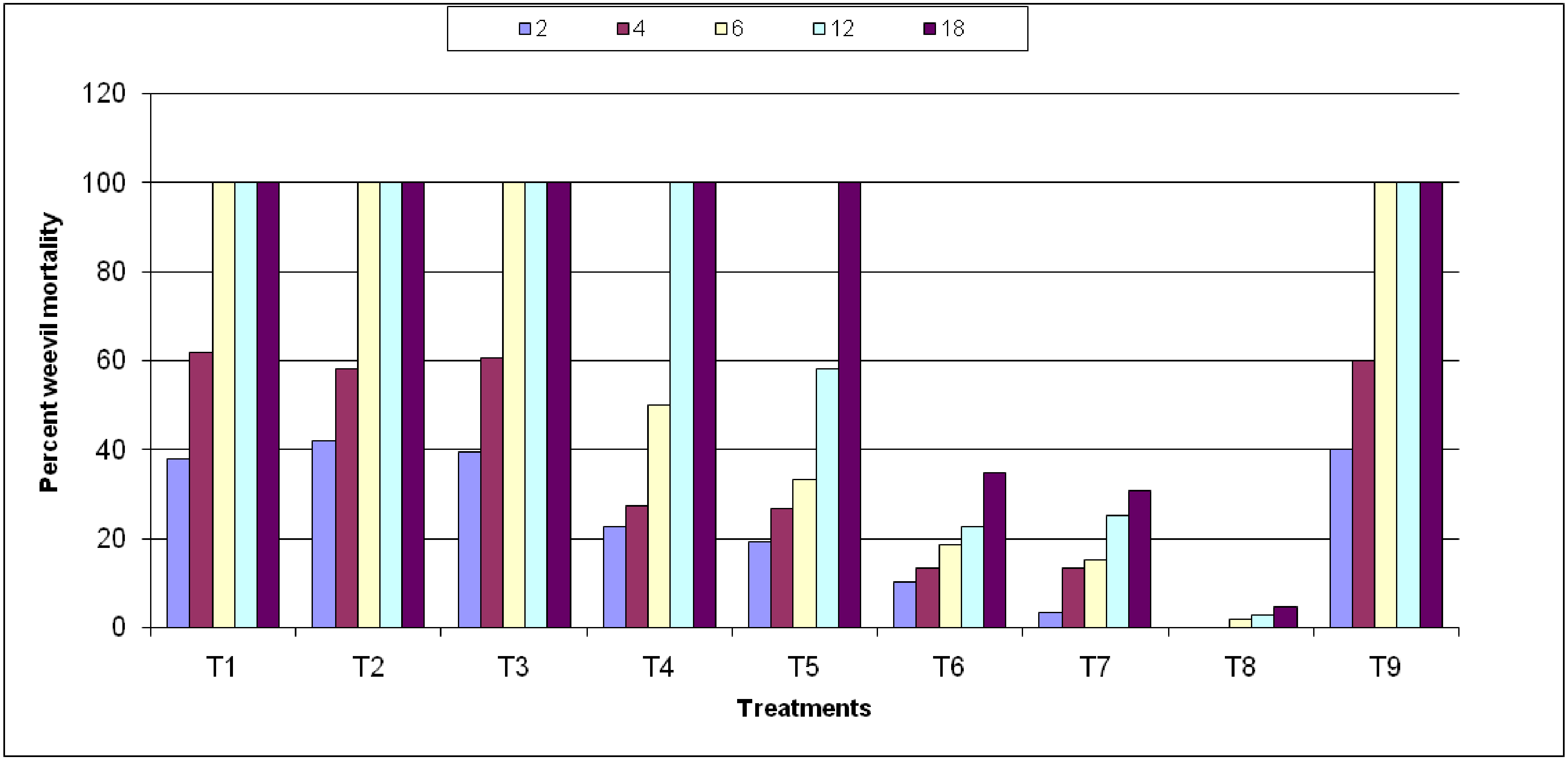
Maize hybrid BH-540 was obtained from Bako National Maize Research Program and multiplied in the center to obtain the F_2 generation seeds in sufficient amount for the experiments. Malathion 5%D was obtained from General Chemical Trading PLC. Filter cake (Melkabam) obtained from Melkassa Aluminum Sulphate factory.

Sufficient number of adult *S. zeamais* was reared on F_2 seeds BH540 maize variety following procedure suggested by Strong and Subur (1968) and used by Abraham (1991). Hundred kilograms of the maize variety with moisture content of 12.5-13% were disinfested by putting in deep freezer at -20^{o}c for fortnight. The kernels were divided into two (2 kg each) parts. The kernels were put in three-liter capacity plastic jars and arranged into five replications. Adult weevils that were collected from the farm Bako Agricultural Research Center store were introduced into each replication in the ratio of 1 (weevil): 2-3 gm kernels (600 weevils/ 2 kg maize)) for incubation. Seven days later the adult weevils were sieved and transferred to another disinfested and newly prepared kernels of the same variety. Finally, all of the adult weevils were removed and discarded. The grain was kept for progeny emergence. As soon as the progeny emergence begun, emerged adults were collected on daily basis until sufficient numbers of weevils for the studies were obtained. Those emerged on the same day were transferred to a one-glass jar. So that each jar was containing adults of identical age for the experiments.

The maize experimental kernels were cleaned and disinfested following the same procedure as above. The moisture content of the kernels was adjusted by slow drying under shade or by adding water as recommended by Wright *et al.* (1989). Two hundred gram maize kernels were put in 250 cm^3 capacity glass jars with brass screen lids that permit ventilation. Adult maize weevils were introduced in each jar at the ratio of one weevil to two to three (1:2-3 gm) maize kernels (50 weevils/200 gm maize). Daily temperature and relative humidity of the laboratory were recorded. Treatments were applied accordingly and each treatment was arranged in a completely randomized block design (CRD) with three replications.

Comparisons among different rates of filter cake

T_1 = 5 % w/w (recommended rate), T_2 = 1 % w/w , T_3 = 0.75 % w/w, T_4 = 0.5 % w/w, T_5 = 0.25 % w/w, T_6 = 0.125 % w/w, T_7 = 0.0625 % w/w, T_8 = Untreated check, T_9 = Malathion 5 % D (0.1gm) standard check (FC= Filter cake (Melkabam))



T_1 = 5% w/w, T_2 = 1% w/w , T_3 =0.75% w/w , T_4 =0.5% w/w, T_5 =0.25% w/w, T_6 =0.125% w/w, T_7 =0.0625% w/w, T_8 =Untreated check, T_9 = Malathion 5% D (standard check), T= treatment, dai= days after infestation

Figure 1. Effects of different rates of filter cake (Melkabam) on the weevil mortality

Table 1. Effects of different rates of Melkabam (filter cake) on progeny emerged, percentage grain damage, grain weight losses and seed germination following 3 months after treatment.

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman-Keul`s Range Test).

Filter cake (FC) (5% w/w)	Number of progeny weevils emerged	Percent damaged grain	Percent grain weight loss	Percent seed germination
T_1 = 5% w/w	0.00(0.71) ± 0.00 [d]	0.00(0.71) ± 0.00 [d]	0.00(0.710) ± 0.00 [d]	89.33 ± 1.76 [a]
T_2 = 1% w/w	0.00(0.71) ± 0.00 [d]	0.00(0.71) ± 0.00 [d]	0.00(0.710) ± 0.00 [d]	95.33 ± 0.67 [a]
T_3 = 0.75% w/w	0.00(0.71) ± 0.00 [d]	0.00(0.71) ± 0.00 [d]	0.00(0.710) ± 0.00 [d]	94.67 ± 0.67 [a]
T_4 = 0.5% w/w	0.00(0.71) ± 0.00 [d]	0.00(0.71) ± 0.00 [d]	0.00(0.710) ± 0.00 [d]	94.00 ± 1.33 [a]
T_5 = 0.25% w/w	4.33(2.19) ± 0.33 [c]	0.73(1.11) ± 0.07 [c]	0.01(0.713) ± 0.00 [d]	95.00 ± 0.67 [a]
T_6 = 0.125% w/w	28.67(5.39) ± 1.20 [b]	7.69(2.86) ± 0.24 [b]	0.18(0.820) ± 0.00 [b]	95.33 ± 0.67 [a]
T_7 = 0.0625% w/w	29.67(5.49) ± 1.20 [b]	8.23(2.95) ± 0.40 [b]	0.12(0.790) ± 0.01 [c]	96.00 ± 0.00 [a]
T_8 = Untreated check	73.00(8.57) ± 2.64 [a]	11.66(3.48) ± 0.35 [a]	1.24(0.860) ± 0.01 [a]	94.65 ± 1.33 [a]
T_9 = Malathion 5% D (0.1gm) (standard check)	0.00(0.71) ± 0.00 [d]	0.00(0.71) ± 0.00 [d]	0.00(0.710) ± 0.00 [d]	95.33 ± 0.67 [a]
CV (%)	*5.02*	*3.92*	*0.65*	*1.72*
LSD	*0.243*	*0.105*	*0.008*	*1.62*

ANOVA was conducted on transformed values. FC=filter cake, T= treatment. Values in the parenthesis are square root transformed value. CV (%), Lsd and mean separations were calculated from transformed value.

Table 2. Residual effects of different rates of filter cake (Melkabam) on the weevil mortality when the grains were re-infested after three months of treatment

Filter cake (FC)	Percent weevils mortality				
	2 dari	4 dari	6 dari	12 dari	18 dari
T_1 = 5% w/w	29.33(32.79) ± 1.33 a	70.67(57.24) ± 1.33 a	100.00(89.47) ± 0.00 a	100.00(89.47) ± 0.00 a	100.00(89.47) ± 0.00 [a]
T_2 = 1% w/w	19.33(26.09) ± 0.67 b	37.33(37.68) ± 0.67 b	43.33(41.19) ± 0.67 b	100.00(89.47) ± 0.00 a	100.00 (89.47)± 0.00 [a]
T_3 = 0.75% w/w	17.33(24.61) ± 0.67 b	38.00(38.06) ± 2.31 b	48.67(44.25) ± 5.20 b	100.00 (89.47)± 0.00 a	100.00(89.47) ± 0.00 [a]
T_4 = 0.5% w/w	18.67(25.60) ± 0.67 b	32.67(34.81) ± 3.33 b	48.67(44.26) ± 3.71 b	100.00(89.47) ± 0.00 a	100.00(89.47) ± 0.00 [a]
T_5 = 0.25% w/w	10.00(18.44) ± 0.00 c	15.33(23.05) ± 0.67 c	16.00(23.59) ± 0.00 c	16.67(24.10) ± 0.67 b	38.67(38.43) ± 3.33 [b]
T_6 = 0.125% w/w	9.33(17.77) ± 0.67 c	13.33(21.33) ± 1.76 c	18.00(24.95) ± 3.05 c	23.33(28.72) ± 4.05 b	25.33(30.20) ± 1.76 [c]

DATA COLLECTION

Dead weevils were counted at the 2nd, 4th, 6th, 12th, 24th and 30th days after infestation. At the 30th day, both dead and live weevils were counted and removed and the grains were kept under the same conditions for emergence of F_1 generation. The F_1 progeny weevils were counted and removed each day until emergence was ceased. Data was collected on number of adult weevil mortality, percent grain damaged, number of progeny weevils emerged, number and weight of damaged and undamaged grains. Percentages of seed weight losses were calculated using the count and weigh method (Boxall, 1986).

$$\%\text{Weight loss} = \frac{(W_u \times N_d) - (W_d \times N_u)}{W_u\,(N_d + N_u)} \times 100$$

Where, Wu= weight of undamaged seed, Nu=Number of undamaged seed, Wd= weight of damaged grains, Nd= Number of damaged seed. Seed germination was determined by taking one hundred randomly collected seed from each replication and placing on moist filter paper in a Petri dish for five days. All experimental seeds were re-infested with the same number of weevils after the first data was collected (3 months) to see the persistence of the different treatments used.

STATISTICAL ANALYSIS

All parameters were expressed in percentages except for the number of progeny weevils emerged. Mortality data was corrected before analysis using Abbot's formula,

$$\%CM = \frac{(\%T - \%C)}{(100 - \%C)} \times 100;$$

Where CM corrected mortality, T mortality in treated grain and C mortality in untreated grain (Abbott, 1925). All data were transformed prior to analysis, except for percentages of germinations. Percentages of mortality were transformed by angular (ASIN) transformation and number of progeny weevils emerged, percentage grain damaged and grain weight losses were transformed into square root. Data were subjected to statistical analyses using SAS Version 6.12 computer software. Mean separations were made using Student-Newman-Keuls (SNK) Range Test.

RESULTS

Experiment (I). Comparisons among different rates of filter cake (Melkabam)

The percentage of weevil mortality was significantly increased with Melkabam treatments (Fig. 1). The percentages of mortality in all of the treatments were significantly higher than that of in the untreated check in all of the observed days. The mortality rates in T_6 and T_7 were significantly lower than that of in T_1, T_2, T_3 T_4 and T_5 at all dates of observation. Significantly ($p<0.01$) higher percentages of mortality were observed in T_1, T_2, T_3, T_9, than that of the other treatments following two, four and six days after infestation (Fig. 1). At 12 dai, the rate of mortality was found to be 100% in T_1, T_2, T_3, T_4 and T_9. Similar trends were observed with 18 days after infestation including T_5. Following 18 days after infestation, the levels of weevil mortality were significantly lower in T_7 and T_6 than T_1, T_2, T_3, T_4, T_5 and T_9. The difference between T_7 and T_6 as well as among the other treatments was not significant (Figure 1).

Melkabam treatment had also effected on progeny emergence, amount of grain damage and grain weight losses (Table 1). All of Melkabam treatments resulted in significantly lower number of progeny weevils emergence, percentage of damaged grain and grain weight losses than in the untreated check (Table 1). There was no progeny emergence, grain damaged and grain weight losses were recorded in treatments T_1, T_2, T_3, and T_4. The lower rates of Melkabam (T_6 and T_7) had significantly higher levels of weevils emerged and grain damaged, although these were lower than the untreated check. T_5 was intermediated in progeny emergence and the amount of grain damage. Seed germination was significantly higher in all of the treatments following 3 months after treatments (Table 1).

Days after infestation (dai)

Melkabam (Filter cake) treatments showed residual effects as evidenced by the mortality of adult weevils introduced after 3 months of treatment (Table 2). Higher percentages of mortality were observed in T_1 and in the synthetic insecticide treatment two, four and six days after re-infestation. Low levels of mortality were recorded in the T_5, T_6 and T_7 which only reached 39%, 25% and 17% after 18 days of re-infestation, respectively. On the other hand, T_1, T_2, T_3, and T_4 treatments caused complete mortality within 12 days of re-infestation (Table 2).

The number of progeny weevils emerged, percentages of grain damaged, grain weight losses and seed germination were affected by the different rates of Melkabam treatments (Table 3). The treatments T_1, T_2, T_3, T_4 and T_9 had significantly lower numbers of progeny weevils emerged, percentages of grain damaged and grain weight losses than that of the other treatments. These treatments had higher levels of seed germination than in T_7 and in the untreated check (Table 3).

Table 2. Continuation

T_7 = 0.0625% w/w	4.64(12.43) ± 0.67d	6.00(13.67) ± 2.00 d	13.33(21.38) ± 1.33 ^{c}	17.33(24.17) ± 5.33 ^{b}	16.67(23.87) ± 3.71 ^{c}
T_8 =Untreated check	2.67(9.26) ± 0.67 e	3.33(8.71) ± 1.76 d	2.00(8.13) ± 0.00 ^{d}	4.67(12.17) ± 1.33 ^{c}	5.33(11.09) ± 2.67 ^{d}
T_9 = Malathion 5% D (0.1gm)(Standard check)	28.00(31.95) ± 1.77 a	72.00(58.09) ± 1.15 a	100.00(89.47) ± 0.00 a	100.00(89.47) ± 0.00 a	100.00(89.47) ± 0.00 ^{a}
CV%	5.86	10.42	6.31	5.20	6.36
LSD	2.240	5.860	4.690	5.360	6.34

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman-Keul`s Range Test). ANOVA was conducted on transformed values. FC=filter cake, dari= days after re-infestation, T= treatment. Values in the parenthesis are angular transformed. CV (%), Lsd and mean separations were calculated from transformed value.

Table 3. Residual effect of different rates of filter cake (Melkabam) on progeny emerged, percentage of grain damaged, grain weight loss and seed germination when the grains were re-infested after three months of treatment.

Treatments	Number of progeny weevils emerged 66 dari	Percent damaged grain 156 dai	Percent grain weight loss 156 dai	Percent seed germination 156 dai
T_1 = 5% w/w	0.00(0.71) ± 0.00 ^{e}	0.00(0.71) ± 0.00 ^{e}	0.00(0.71) ± 0.00 ^{e}	91.33 ± 0.67 ^{a}
T_2 = 1% w/w	0.00(0.71) ± 0.00 ^{e}	0.00(0.71) ± 0.00 ^{e}	0.00(0.71) ± 0.00 ^{e}	91.33 ± 0.67 ^{a}
T_3 = 0.75% w/w	0.00 (0.71) ± 0.00 ^{e}	0.00(0.71) ± 0.00 ^{e}	0.00(0.71) ± 0.00 ^{e}	90.67 ± 2.40 ^{a}
T_4 = 0.5% w/w	0.00(0.71) ± 0.00 ^{e}	0.00(0.71) ± 0.00 ^{e}	0.00(0.71) ± 0.00 ^{e}	90.33 ± 1.86 ^{a}
T_5 = 0.25% w/w	18.67(4.37) ± 0.88 ^{d}	4.12(2.14) ± 0.17 ^{d}	0.45(0.97) ± 0.03 ^{d}	90.67 ± 1.76 ^{a}
T_6 = 0.125% w/w	41.33(6.46) ± 1.20 ^{c}	8.95(3.07) ± 0.11 ^{c}	1.15(1.28) ± 0.01 ^{c}	89.00 ± 1.73 ^{a}
T_7 = 0.0625% w/w	66.33(8.17) ± 0.88 ^{b}	14.51(3.87) ± 0.11 ^{b}	1.25(1.32) ± 0.06 ^{b}	82.66 ± 1.76 ^{b}
T_8 =Untreated check	135.00(10.15) ± 3.78 ^{a}	28.16(5.35) ± 0.35 ^{a}	3.08(1.89) ± 0.07 ^{a}	41.33 ± 2.91 ^{c}
T_9 = Malathion 5% D (0.1gm) (standard check)	0.00(0.71) ± 0.00 ^{e}	0.00(0.71) ± 0.00 ^{e}	0.00(0.71) ± 0.00 ^{e}	90.67 ± 0.67 ^{a}
CV%	3.32	1.72	1.77	3.72
LSD	0.218	0.059	0.030	3.131

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman-Keul`s Range Test). ANOVA was conducted on transformed values. T= treatment, dari=days after re-infestation, dai= days after infestation. Values in the parenthesis are square root transformed. CV (%), Lsd and mean separations were calculated from transformed values.

DISCUSSION AND CONCLUSION

The study showed that filter cake (Melkabam) applied at 0.5% (w/w) and above causes higher level of mortality, which is similar with earlier works of Abraham, 2005. Abraham (2005) reported that filter cake (Melkabam) applied at 0.5% and 5% (w/w) effectively controlled the bean bruchid and the maize weevil, respectively. According to Abraham (2005), Filter cake or Melkabam (by-products of Aluminum sulfate factor) has desiccating effects and can clog insect spiracles and then lead to death. The current study showed that lower rate (0.5% w/w) was effective against the maize weevil. On this study, Melkabam did not impair seed germination as seeds treated with high levels of Melkabam application had high seed germination and the findings are similar to the finding of various researchers at different places on ash. Ashes from different sources have been demonstrated to vary in effectiveness. The materials impede entry and movements of insects within inter granular spaces (Katanga Apuuli and Villet, 1996; Chinwada and Giga, 1997; Abraham, 2003), which in turn affects reproduction, oviposition and population growth. Wood ashes and sand may have desiccating effect on the adult insects and crawling larvae with which they come into surface contact (Chinwada & Giga, 1997). There are also suggestions that the ash particles may clog insects spiracles and trachea, causing suffocation (Wolfson *et al.*, 1991). *Aloemarlothi* ash is also particularly useful for protecting seed (Katanga Apuuli and Villet, 1996), it does not affect germination and there is some suggestion that the cations in the ash may even enhance growth (Wolfson *et al.,* 1991). Similarly, Laboratory trials in Zimbabwe found mixing ash from mixed tree species with stored beans at concentrations of 1:1, 1:2, and 1:4 v/v reduced both the damage and number of F_1 bruchid emerging (Chinwada & Giga, 1997). However, sand was only effective at reducing F_1 bruchids at higher (1:1 v/v) application rates of. In laboratory studies in Botswana, cow dung ash and sand applied to cowpeas at 30% and 100% w/w, respectively, reduced infestation by *C. maculatus* (Katanga Apuuli and Villet, 1996; Chinwada and Giga, 1997). Most of the studies on the use of ashes to protect cowpeas recommend the use of high dose (50-100% w/w) (Wolfson *et al.*, 1991).

The rates of Melkabam at 0.5% w/w and above provided significant protection to maize from the maize weevil for more than five months. From these studies, it can be concluded that Melkabam (Filter cake) at 0.5% w/w and above can be used to protect maize from the maize weevil.

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