Farmers' Practices and Combinations of Malathion and Neem Seed Powder Management Options against Sorghum and Maize Insect Pests during Storage at Bako, West Shoa Zone, Ethiopia

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Abstract: Some farmers' practices (layering of teff grain over sorghum grain in 20% proportion, mixing sorghum with teff at 30% w/w, mixing sorghum with partially ground hot pepper at the rate of 2and 1% w/w) including Malathion 5% D (50g/quintal) and untreated check were evaluated against stored sorghum insect pests at Bako Research Center, Western Ethiopia, during 2004/2005-2005/2006. Besides, combinations of different rates (T_1 = 0% (0 g)+ 00% (4 g), T_2 = 10% (0.01 g) + 50% (2 g), T_3 = 20% (0.02 g) + 40% (1.6 g), T_4 = 30% (0.03 g) + 30% (1.2 g), T_5 = 40% (0.04 g) + 20% (0.8 g), T_6 = 50% (0.05 g) + 10% (0.4 g), T_7 = 100% (0.1 g) + 0 % (standard check) and T_8 = untreated check) of Malathion 5% D and neem seed powder were separately evaluated against maize weevils *Sitophilus zeamais* Mostch in the laboratory at Bako from February to July 2006. Data collected include number of dead and alive species of insect pests in each treatment/sample, number and weight of damaged and undamaged grain, as well as percent weight losses/sample. Number and weight of damaged grains were significantly ($P \leq 0.05$) higher after layering of teff over sorghum with 20% w/w, followed by mixing sorghum with teff at 30% w/w and untreated check when compared to the other treatments. Number and weight of undamaged kernels was significantly ($P \leq 0.05$) higher with mixing sorghum mixed with hot pepper at 2 and 1% w/w than the other treatments. Similarly, percent weight losses were significantly ($P \leq 0.05$) lower in mixing sorghum with hot pepper at 2 and 1% w/w than the other treatments, which were similar to the standard check. With respect to combined treatments, mortality in case of all combinations ranged between 3.33 to 100%, while that of the untreated check ranged between 0 to 5.33% following 90 days of exposure. Number of progeny weevils emerged, percentages of grain damaged and kernel weight losses in all of the treatment combinations were significantly lower than that of the untreated check 90 days after infestation. Number of progeny weevils emerged, percentages of grain damaged and kernel weight losses for all these treatments were also found significantly lower than that of the untreated check. Significantly ($P \leq 0.05$) higher percentages of mortality, lower percentages of damaged grains and kernel weight losses were observed with Malathion dust treatment at 40 and 50% combined with neem seed powder than that of the other treatments next to the standard check 156 days following infestation. It could be thus concluded that mixing sorghum grain with partially ground hot pepper at the rates of 2 and 1% w/w can be used to suppress stored sorghum insect pests, and combinations of Malathion and neem seed powder at 40+20, and 50+10%, respectively, can be used to protect maize from the weevil. However, further study for one more additional year may be required for further validation of the results.

Keywords: Farmers Practices; Neem Seed Powder; Maize Insect Pest Mortality; Progeny; Stored Sorghum and Teff; Weevil

1. Introduction

Absence of maize and sorghum insect pest management technologies in storage forces growers to sell their produces immediately after harvest (Abraham, 1991; 2003; Emana and Assefa, 1998). Consequently, farmers receive low market prices for surplus grain they produce (Abraham, 1991; Beyene *et al*., 1996).

Although the use of pesticides is an important means of protecting stored grains, associated side effects on the environment and human health, development of genetically resistant insect strains, erratic supply and prohibitive costs have become major cause of concerns thus giving impetus to search for alternative methods of pest control.

Various methods are currently in vague for control of storage pests of sorghum and maize by farmers such as mixing sorghum and maize with small-seeded cereals like teff and finger millet to control storage pests in sorghum and maize producing areas. Other farmers mix the produce with partially ground hot pepper. A popular method of layering by putting one crop over the other, the produce that is liable to attack being in the middle and the other at the bottom and upper portions, is also practiced by some farmers. All these storage pest control options seem to be ideal for the management of stored sorghum or maize pests. However, the efficacy of such indigenous technologies have not yet been proved. Farmers' practices should be supported by research, as their adoption rate could be very high for wider applicability.

In addition, use of locally available plant products and vegetable oils are other options to reduce reliance on synthetic chemicals. A major limitation to the practical utilization of locally available plant products and vegetable oils are the high application rates required to effectively disinfest and protect grains (Don-Pedro, 1989). The possibility of using reduced level of plant products in combination with each other in simple mixtures can be a means of making their use more attractive and effective (Don-Pedro, 1989). Integrating

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one specific control strategy with another sustainable pest control method would provide synergistic effects and a long-lasting solution to losses in storage (Dobie, 1977). The importance of combining two or more control options is that it may minimize risk and costs of chemical, reduce pest resistance development against the treatments and increase effectiveness of the treatments.

The objectives of the present study were, therefore, to evaluate the effectiveness of some pest control practices used by farmers for managing stored sorghum and maize insect pests determine the combined effects of malathion dust and neem seed powder against the maize weevil, *Sitophilus zeamais* Mostch, on maize and to determine the minimum effective rate(s) of the combination (s) that could provide adequate protection of maize against the storage insect pest.

2. Materials and Methods

2.1. Site Description

The experiments (1 and 2) were conducted at the Bako Agricultural Research Center (BARC) located in Bako, West Shoa Zone, Western Ethiopia. The first experiment was conducted on traditional but modified storage structures (*gotera*) during 2004/2005–2005/2006 cropping seasons and while the second was conducted in plastic containers in the laboratory at Bako Agricultural Research Center from February to July 2006.

Bako Agricultural Research Center lies at 09^o 06` N latitude and 37$^o$ 09` E longitude, 260 km west of Addis Ababa, at an altitude of 1650 meters above sea level (masl). The area is characterized by warm and humid climate. The annual average rainfall and relative humidity were 1341 mm and 60.11%, respectively**.** The average minimum and maximum atmospheric temperatures of the area during the study period were 12.58 and 27.21 ^{o}C, respectively.

2.2. Evaluation of Some Farmers' Practices Against Stored Sorghum Insect Pests

About 2.7 tons of sorghum (local variety Bobe) and 0.3 tons of *teff* were used to conduct a one-year storage experiment. Six treatments (layering of *teff* over sorghum with 20% proportion, mixing sorghum with *teff* at 30% w/w, mixing sorghum with partially ground chilies (hot pepper) at the rates of 1 and 2% w/w, Malathion 5% D at a rate of 50 g per quintal and untreated check were evaluated against stored sorghum insec**t** pests. The treatments were laid out in a randomized complete block design (RCBD) replicated three times. Plastic sheets were used to separate sorghum from *teff* in the layering treatments. Sample size of 350 g per plot or gotera was taken from each treatment using compartmented spear to assess the parameters from each treatment. Data collected were the number of alive and dead species of insect pests, number of damaged and undamaged grains and weight of damaged and undamaged grain, and percent weight loss was calculated. Evaluations were made 2, 4 and 6months after storage period. Percent weight losses were calculated by using the following formula (Boxall, 1986):-

$$\text{Weight loss (\%)} = \frac{(Wu \times Nd) - (Wd \times Nu)}{Wu \times (Nd + Nu)} \times 100$$

where, Wu = weight of undamaged grain, Wd = weight of damaged grain, Nu = number of undamaged grain and Nd = number of damaged grains. Combined analysis was done for two years data (2003/2004 and 2004/2005) using SAS version 6.12 computer software package.

2.3. Laboratory Study at Bako

The maize hybrid BH-540 was obtained from the BARC Maize Research Program for multiplication in the Center to obtain the F_2 generation seeds in sufficient amount for the experiments. Neem seed powder was obtained from Melka Worer Agricultural Research Center (MWARC) and Malathion 5% D was purchased from the market.

Maize weevils (*Sitophilus zeamais)* were collected from Bako Agricultural Research Center maize store and reared in the laboratory where the experiment was conducted. Weevils were cultured on BH-540 maize hybrid grain which is commonly and mostly grown by local farmers. Grains were cleaned and kept in a deep freezer at -20±2 ^{o}C for two weeks to disinfest them. The grains were then kept for two weeks at the experimental conditions for acclimatization (Abraham, 2003) and adjusted to moisture content of 12 to 13% before use by absorption of atmospheric humidity. Two-kilogram grain were placed in 3L capacity plastic containers covered with perforated lids. About 600 unsexed adult weevils were introduced into each of the plastic containers. After two weeks of oviposition, all adult weevils were removed, and the grains in which the adult weevils oviposited were kept for progeny emergence.

According to Abraham (1991), the average developmental time of the maize weevil on maize in the laboratory at BARC condition was about 42 days. Based on this information, progeny emergence was monitored daily and those emerged on the same day were transferred to fresh grains in plastic containers with lids and kept under the experimental conditions until a sufficient number of weevils was obtained.

Maize 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). The treatments included different rates of Malathion 5% D and neem seed powder combinations: T_1= 0% (0 g) + 100% (4 g), T_2 = 10% (0.01 g) + 50% (2 g), T_3 = 20% (0.02 g) + 40% (1.6 g), T_4 = 30% (0.03 g) + 30% (1.2 g), T_5 = 40% (0.04 g) + 20% (0.8 g), T_6 = 50% (0.05 g) + 10% (0.4 g), T_7 = 100% (0.1 g) + 0% (standard check) and T_8 = untreated check. Two hundred gram maize kernels were put into 250 ml capacity glass jars with brass screen lids that permit ventilation. The treatments were then applied to the maize kernels. Treated maize kernels were thoroughly mixed to ensure uniform distribution of treatments. Adult maize weevils were introduced into each jar in the ratio of one weevil to two to three gram maize kernels (i.e. 50 weevils/200 g maize). The treatments were arranged in a completely randomized design (CRD) with three replications. The temperature and relative humidity of the laboratory were recorded daily.

To investigate the persistence of the treatments used, the same number of weevils (50 weevils/200 g grain) was re-introduced into the grain following 90 days after the treatment application. Same data were collected 156 days after re-infestation.

2.4. Data Collection

Mortality was assessed 2, 4, 6, 12 and 18 days following treatment application. Dead adult weevils were removed and counted during each assessment. The assessment periods selected were based on an earlier report by Dobie (1984).

Thirty days after treatment application and following removal of dead and alive weevils, the grains were kept under the same conditions to assess emergence of F_1 progenies. The number of F_1 progeny weevils emerged was recorded every day for 60 days. Emerged adults were removed from the jar on each assessment day. This recording continued until all F_1 progeny weevils were emerged.

90 days after the introduction of adult maize weevils, the number and weight of damaged and undamaged grains were recorded. Grain weight loss was calculated by using the count and weigh method (Boxall, 1986).

To assess the viability of seeds, germination test was conducted using 100 randomly picked seeds from undamaged grains after separation of damaged and undamaged grains in each jar. The seeds were placed on a moistened filter paper in plastic Petri dishes and the number of germinated seeds was recorded ten days after planting in the jars.

2.5. Statistical Analysis

The number of dead weevils in each replicate was converted into proportions of the total number of adult weevils introduced and expressed as percentage. Mortality data were corrected for natural control mortality using Abbott's correction formula,

$$\mathrm{CM}(\%) = \frac{(\%)T - \%C}{(100 - \%C)} * 100$$

where CM = corrected mortality, T = mortality in treated seed and C is mortality in untreated seed (Abbot, 1925). Damaged seeds were expressed as a percentage of the total number of seeds in each replicate. Grain weight loss data were also expressed as percentages. Percentage mortality was angular transformed, while number of progeny weevils emerged, percentage grain damaged and grain weight losses were square root transformed prior to data statistical analyses, to stabilize the variances. However, percentage of germination was not transformed. All data were subjected to analysis of variance (ANOVA). Differences among treatment means were determined using Student-Newman-Keul's Test at 5% level of probability. Data were analyzed using SAS Version 6.12 computer software package.

3. Results of the experiments

3.1. Evaluation of Some Farmers' Practices against Stored Sorghum Insect Pests

Significant differences were recorded among farmers' practices on number of weevils and Angoumois grain moth (*S.cerealella)* dead and alive individuals (Table 1). Significantly ($P \leq 0.05$) higher numbers of dead weevils were observed in the untreated check than the other treatments. Number of weevils alive was significantly ($P \leq 0.05$) higher in the treatments layering of *teff* over sorghum with 20% w/w, mixing sorghum with *teff* at 30% w/w and in the untreated check than the other treatments. Numbers of *S. cerealella* dead and alive were significantly higher in the untreated check followed by layering of *teff* over sorghum with 20% proportions and mixing sorghum with *teff* at 30% w/w. However, significantly ($P \leq 0.05$) lower number of *S. cerealella* dead and alive individuals was recorded in mixing sorghum with partially ground hot pepper at the rate of 1 and 2% w/w and in the standard check (Table 1).

Variations were observed among some farmers' practices evaluated against storage insect pests of sorghum with respect to number of grains damaged and undamaged, weight of grains damaged and undamaged and percent weight losses (Table 2). The number and weight of grains damaged were significantly ($P \leq 0.05$) higher in the layering of *teff* over sorghum with 20% w/w, mixing sorghum with *teff* at 30% w/w and in the untreated check as compared to other treatments. Similarly, the number and weight of undamaged grains were significantly higher in mixing sorghum with partially ground hot pepper at the rate of 1 w/w, 2% w/w and Malathion 5% D than the other treatments(Table 2). Percent weight losses were significantly lower in mixing sorghum with partially ground chilies (hot pepper) at the rate of 1 and 2% w/w, and Malathion 5% D than in the other treatments (Table 2).

Species of insect pests infesting the free choice test treatments are depicted in a tabular form (Table 3). Among the storage insect pests recorded, *Tribolium* and *Sitophilus* spp. and *Sitotroga cerealella* (Oliver) are the most abundant species, followed by *Carpophilus* and *Cryptolestes* spp. Other species, such as *Lasioderma serricorine* F., *Oryzaephilus* spp and *Rhizopertha dominica* F. also appeared though occurred rarely.

Table 1.Effects of farmers' practices on numbers of weevil and angoumoise grain moth at Bako, west Shoa Zone, Ethiopia (NB: Combined ANOVA of data of 2004/2005 and 2005/2006 cropping seasons).

Treatments (farmers' practices)	Number of weevil/sample		Number of angoumoise grain moth/sample	
	Dead	Alive	Dead	Alive
Layering of *teff* over sorghum with 20% w/w (T_1)	79.54[b]	85.37[a]	82.35[bc]	29.94[b]
Mixing with *teff* at 30% w/w (T_2)	79.71[b]	84.60[a]	97.27[b]	27.40[b]
Mixing with partially ground chilies (hot pepper) at the rate of 2% w/w (T_3)	94.40[b]	33.52[b]	51.78[de]	3.07[c]
Mixing with partially ground chilies (hot pepper) at the rate of 1% w/w (T_4)	90.35[b]	41.92[b]	71.63[cd]	3.79[c]
Insecticide (Malathion 5% D) at the rate of 50 g/100 kg (T_5)	97.71[b]	12.25[c]	33.16e	0.92[c]
Control (untreated check) (T_6)	217.56[a]	82.64[a]	223.15[a]	58.81[a]
Coefficient of Variation (%)	10.54	21.16	15.57	55.22
Least Significant Difference (0.05)	19.56	20.44	24.97	19.43

Means within a column followed by same letter are not significantly different from each other at 5% level of probability (Student Newman Kewl's range test)

Table 2. Effect of farmers' practices on number of damaged and undamaged grains, weight of damaged and undamaged grains and percent weight losses in stored sorghum due to insect pests at Bako, West Shoa Zone, Ethiopia (NB: Combined ANOVA of 2004/2005 and 2005/2006 data).

	Number of grains/sample		Weight of grains/sample		Weight losses
Treatments (farmers practices)	Damaged	Undamaged	Damaged (g)	Undamaged (g)	(%)
Layering of *teff* over sorghum at 20% w/w (T_1)	421.41[a]	10472.19[bc]	4.17[a]	225.84[c]	2.07[a]
Mixing with *teff* at 30% w/w (T_2)	393.91[a]	111150.60[b]	3.75[a]	221.95[c]	1.78[a]
Mixing with partially ground chilies (hot pepper) at the rate of 2% w/w (T_3)	216.24[b]	14300.01[a]	2.71[b]	335.58[a]	0.68[b]
Mixing with partially ground chilies (hot pepper)at the rate of 1% w/w (T_4)	208.68[b]	13300.84[a]	2.64[b]	304.83[b]	0.74[b]
Insecticide (Malathion 5% D) at the rate of 50 g/100 kg (T_5)	199.86[b]	14340.98[a]	2.37[b]	332.90[a]	0.66[b]
Control (check) (T_6)	414.14[a]	9692.76[c]	4.25[a]	217.69[c]	2.23[a]
Coefficient of Variation (%)	13.94	5.21	16.40	5.10	24.35
Least Significant Difference (0.05)	73.37	1083	0.93	23.72	0.56

Means within a column followed by same letters are not significantly different from each other at 5% level of probability (Student Newman Kewl's range test)

Table 3. Species of insect recorded in stored sorghum.

Order/species	Common name	Pest status	Type of insect (pests/beneficial)
Colleoptera			
Tribolium spp.	Maize/rice weevils	Very common	Pest
Sitophilus spp.	Maize/rice weevils	Very common	Pest
Carpophilus spp.	Sap beetles	Common	Pest
Cryptolestes spp.	Flat grain beetles	Common	Pest
Lasiodermaserricorine (F.)	Saw toothed grain beetles	Rare	Pest
Oryzaephilus spp.	Lesser grain borer	Rare	Pest
Rhizoperthadominica (F.)	Red/confused flower beetles	Rare	Pest
Lepidoptera			
Sitotrogacerealella (Oliver)	Angoumois grain moth	Very common	Pest
Hymenoptera			
Parasitic wasp	Flour mite		Beneficial
Archnida			
Acarussiro (L.)			Pest

3.2. Efficacy of Mixing Malathion 5% D with Neem (*Azadirachta indica* A. Juss) Seed Powder against *Zeamais* on Stored Maize.

Combinations of different rates of Malathion 5% dust and neem seed powder caused higher mortality than the untreated control (Table 4). The parent weevil mortality was significantly ($P \leq 0.01$) higher in T_5, T_6 and in the standard check than that of the other treatments following two and four days of infestation. Percentages of mortality were significantly lower in T_2 and T_3 six days after infestation than the other treatment combinations followed by T_5 and T_6. The rates of weevil mortality reached 100% in T_1, T_4, T_5, T_6 and T_7 12 days after infestation (Dai) (Table 4). However, 48 and 66% mortality were recorded with T_3 and T_2 treatments, respectively, following 12 Dai and the difference between these treatments was significant. The rates of mortality reached 100% with all the treatments except for the untreated check following 18 Dai (Table 4).

The number of progeny weevils emerged, percentages of damaged grain and grain weight losses recorded in the combined treatments were observed significantly lower than that of untreated control (Table 5). Differences among the treatment combinations were not significant for the indicated parameters (Table 5).

Significant differences were observed in weevil mortality among the different combinations of Malathion dust and neem seed powder (Table 6).The percentages of mortality were significantly higher with T_5 and T_6treatments than that of the other treatment combinations following all the days considered. Mortality in the untreated check was the lowest. The percentages of mortality were significantly lower with T_2, T_3 and T_4 than T_5 and T_6treatments following two, four, six and 12 days after infestation. Following 18 Dai, the rates of mortality in case of T_2, T_3 and T_4treatments were significantly lower as compared the other combinations (Table 6).

Different rates of Malathion dust and neem seed powder combinations had varying degrees of residual effects with reference to the number of progeny weevil emergence, percentage of damaged grain, grain weight losses and seed germination (Table 7). Number of progeny weevil emergence, percentages of damaged grain and grain weight losses in all treatments were significantly ($P \leq 0.01$) lower than the neem seed powder alone and in the untreated check. Neem seed powder treatment was found to be weak in curbing the development of progeny weevils as it was with the second large progeny emergence. The lowest progeny emergence and seed damage were recorded with T_7 treatments (Table 7). Number of progeny weevils emerged, percentages of damaged grain and grain weight losses were significantly lower in T_5 and T_6 than T_1, T_2, T_3 and T_4. The differences among T_2, T_3 and T_4 treatments as well as between T_5 and T_6 were not significant for the above-mentioned parameters. Percentages of seed germination were significantly ($P \leq 0.01$) higher with all of the treatments than in the untreated check (Table 7).

Table 4. Effects of different rates of Malathion 5% D and neem seed powder combinations on weevil mortality in the laboratory at Bako Agricultural Research Center.

	Percent weevil mortality				
Treatment	2 Dai	4 Dai	6 Dai	12 Dai	18 Dai
T_1	3.33(10.4)±0.67^{d}	8.67(19.05)±0.67^{c}	87.33(69.24)±1.33^{b}	100.00(89.50)±0.00^{a}	100.00(89.50)±0.00^{a}
T_2	3.33(10.4)±0.67^{d}	18.67(24.53)±3.27^{bc}	45.33(42.31)±4.4c^{d}	66.00(59.46)±5.00^{b}	100.00(89.50)±0.00^{a}
T_3	5.33(13.3)±0.67^{c}	10.00(18.38)±1.15^{c}	36.67(37.28)± 0.67^{d}	48.00(43.87)±1.15^{c}	100.00(89.50)±0.00^{a}
T_4	3.33(10.4)±0.67^{d}	10.67(19.05)±0.67^{c}	86.00(68.09)±1.15^{b}	100.00(89.50)±0.00^{a}	100.00(89.50)± 0.00^{a}
T_5	12.00(20.23)±1.15^{b}	31.33(34.05)±0.67^{b}	56.67(48.85)±0.69^{c}	100.00(89.50)±0.00^{a}	100.00(89.50)± 0.00^{a}
T_6	10.67(19.05)±0.67^{b}	32.00(34.45)±4.16^{b}	57.33(49.26)±4.05^{c}	100.00(89.50)±0.00^{a}	100.00(89.50)±0.00^{a}
T_7	22.67(28.44)±0.67^{a}	77.33(61.60)± 0.67^{a}	100.00(89.50)±0.00^{a}	100.00(89.50)±0.00^{a}	100.00(89.50)±0.00^{a}
T_8	0.00(0.41)±0.00^{e}	0.00(0.41)±0.00^{d}	2.00(6.69)±1.15^{e}	5.33(13.17)±1.33^{d}	6.67(14.80)±1.33^{b}
CV (%)	10.25	27.32	6.25	11.79	1.16
LSD (0.05)	2.77	13.74	6.02	14.82	1.02

Means within a column followed by the same letter are not significantly different from each other at 5% level of probability (Student-Newman-Keul`s Range Test). Values in the parenthesis are angular transformed data. Dai = Days after infestation;T_1= 0% (0 g) + 100% (4 g); T_2 = 10% (0.01 g) + 50% (2 g); T_3 = 20% (0.02 g) + 40% (1.6 g); T_4 = 30% (0.03 g) + 30% (1.2 g); T_5 = 40% (0.04 g) + 20% (0.8 g); T_6 = 50% (0.05 g) + 10% (0.4 g); T_7 = 100% (0.1 g) + 0 % (standard check) ; T_8 = Untreated check; CV = Coefficient of variation; LSD = Least significand difference.

Table 5. Effects of different rates of Malathion dust and neem seed powder combinations on progeny emerged, percentages of damaged grain, grain weight losses and seed germination three months after treatment application and infestation.

Treatment	Number of progeny weevils emerged	Percent damaged grain	Percent grain weight loss	Percent seed germination
T_1	1.33(1.34)±0.33^{b}	0.25(0.86)±0.01^{b}	0.013(0.72)±0.00^{b}	95.00±0.58^{a}
T_2	1.67(1.46)±0.33^{b}	0.25(0.86)±0.01^{b}	0.010(0.71)±0.00^{b}	95.00±0.58^{a}
T_3	1.67(1.46)±0.33^{b}	0.21(0.84)±0.02^{bc}	0.010(0.71)±0.00^{b}	94.67±0.33^{a}
T_4	1.67(1.46)±0.33^{b}	0.20(0.84)±0.02^{bc}	0.013(0.72)±0.00^{b}	95.67±0.33^{a}
T_5	1.67(1.46)±0.33^{b}	0.19(0.83)±0.01^{bc}	0.010(0.71)±0.00^{b}	95.00±0.58^{a}
T_6	1.67(1.46)±0.33^{b}	0.16(0.81)±0.04^{c}	0.010(0.71)±0.00^{b}	95.33±0.33^{a}
T_7	0.00(0.71)±0.00^{c}	0.00(0.71)±0.00^{d}	0.00(0.701)±0.00^{c}	95.00±0.58^{a}
T_8	57.00(7.58)±0.57^{a}	12.06(3.54)±0.07^{a}	0.820(1.14)±0.01^{a}	91.00±0.58^{a}
CV (%)	9.06	1.82	0.49	1.14
LSD (0.05)	0.310	0.035		1.079

Means followed by the same letter within a column are not significantly different from each other at 5% level of probability (Student-Newman-Keul`s Range Test). Values in the parenthesis are square root transformed. T_1= 0% (0 g) + 100% (4 g); T_2 = 10% (0.01 g) + 50% (2 gm); T_3 = 20% (0.02 g) + 40% (1.6 g); T_4= 30% (0.03 g) + 30% (1.2 g); T_5 = 40% (0.04 g) + 20% (0.8 g); T_6 = 50% (0.05 g) + 10% (0.4 g); T_7 = 100% (0.1 g) + 0 % (standard check); T_8 = Untreated check; CV = Coefficient of variation; LSD = Least significand difference.

Table.6. Residual effects of different rates of Malathion 5% D and Neem seed powder combinations on the percentage of weevil mortality when grains were re-infested three months after treatment.

Treatment	Weevils' mortality (%)				
	2 Dai	4 Dai	6 Dai	12 Dai	18 Dai
T_1	0.67(2.98)±0.67[cd]	4.33(11.33)±1.00[d]	16.00(23.56)±1.15[c]	28.00(31.95)±1.15	52.00(46.14)±2.00[b]
T_2	2.67(9.27)±0.67[c]	8.67(17.12)±0.67[c]	12.67(20.85)±0.67[d]	16.00(23.56)±1.15[d]	26.67(31.09)±0.67[c]
T_3	2.65(7.83)±1.33[c]	5.33(13.30)±0.67[d]	11.33(19.67)±0.67[d]	16.67(24.09)±0.67[d]	22.00(27.97)±2.00[d]
T_4	0.005(7.83)±0.00[c]	4.67(12.17)±1.33[d]	12.00(20.28)±0.00[d]	16.00(23.59)± 0.00[d]	26.00(30.66)±1.15[c]
T_5	8.00(16.36)±1.15 [b]	18.67(25.60)±0.67[b]	22.67(28.44)±0.67[b]	50.67(45.40)±0.67[b]	100.00(89.47)±0.00[a]
T_6	8.67(17.02)±1.33[b]	18.67(25.60)±0.67[b]	22.00(27.97)±1.15[b]	50.67(45.40)±0.67[b]	100.00(89.47)±0.00[a]
T_7	25.33(30.66)±1.76[a]	74.67(59.84)±1.76[a]	100.00(89.47)±0.00[a]	100.00(89.47)±0.00[a]	100.00(89.47)±0.00[a]
T_8	0.02(0.41)±0.01[d]	0.67(2.98)±0.67[e]	4.00(11.29)±1.15[e]	4.67(12.42)± 0.67[e]	2.00(8.13)±0.00[e]
CV (%)	27.62	7.34	3.79	1.83	2.14
LSD (0.05)	6.50	3.21	2.42	1.35	2.03

Meanswithin a column followed by the same letter are not significantly different from each other at 5% level of probability (Student-Newman-Keul`s Range Test). Values in the parenthesis are angular transformed value. Dai = Days after infestation; T_1= 0% (0 g) + 100% (4 g); T_2= 10% (0.01 g) + 50% (2 g); T_3 = 20% (0.02 g) + 40% (1.6 g); T_4= 30% (0.03 g) + 30% (1.2 g); T_5 = 40% (0.04 g) + 20% (0.8 g); T_6 = 50% (0.05 g) + 10% (0.4 g); T_7 = 100% (0.1 g) + 0% (standard check); T_8 = Untreated check;CV = Coefficient of variation; LSD = Least significand difference.

Table 7. Residual effects of different rates of Malathion 5% dust and neem seed powder combinations on weevil progeny emerged, percentage of damaged grain, grain weight losses and seed germination when the grains were re-infested three months after treatment.

	Number of progeny weevils emerged	Percent damaged grain	Percent grain weight loss	Percent seed germination
Treatment	66 Dari	156 Dai	156 Dai	156 Dai
T_1	47.67(6.94)±0.33[b]	9.74(3.20)±0.20[b]	1.33(1.35)±0.01[b]	88.67±0.67[a]
T_2	15.00(3.93)±0.57[c]	3.84(2.08)±0.06[c]	1.18(1.29)±0.03[c]	88.00±1.15[a]
T_3	15.33(3.97)±0.33[c]	3.51(2.00)±0.13[d]	1.15(1.28)±0.01[c]	88.61±0.33[a]
T_4	14.33(3.84)±0.88[c]	3.58(2.01)±0.11[cd]	1.15(1.28)±0.02[c]	91.67±0.33[a]
T_5	6.00(2.54)± 0.57[d]	1.14(1.28)±0.02[e]	0.1(0.79)±0.01[d]	90.67±2.40[a]
T_6	5.67(2.48)±0.33[d]	1.17(1.29)±0.02[e]	0.1(0.79)±0.00[d]	90.00±3.05[a]
T_7	1.00(1.22)±0.00[e]	0.03(0.72)±0.01[f]	0.01(0.72)±0.00[e]	90.33±2.03[a]
T_8	140.33(11.86)±1.20[a]	26.11(5.15)±0.40[a]	3.49(1.99)±0.03[a]	45.33±.85[b]
CV (%)	3.36	2.02	0.92	4.06
LSD (0.05)	0.250	0.072	0.018	3.450

Means within a column followed by the same letters are not significantly different from each other at 5% level of probability (Student-Newman-Keul`s Range Test). Values in the parenthesis are square root transformed. Dari = days after re-infestation; Dai = days after infestation;T_1= 0% (0 g) + 100% (4 g);T_2= 10% (0.01 g) + 50% (2 g); T_3 = 20% (0.02 g) + 40% (1.6 g); T_4= 30% (0.03 g) + 30% (1.2 g); T_5 = 40% (0.04 g) + 20% (0.8 g); T_6 = 50% (0.05 g) + 10% (0.4 g); T_7 = 100% (0.1 g) + 0 % (standard check) ; T_8 = Untreated check; CV = Coefficient of variation; LSD = Least significand difference.

4. Discussion

4.1. Evaluation of Some Farmers' Practices against Stored Sorghum Insect Pests

The study indicated that mixing sorghum with partially grounded chilies (hot pepper) at the rates of 1 and 2% w/w gave potential control method against stored sorghum insect pests while the results were comparable with Malathion 5% D (Table 3). The present findings are in agreement with that of the farmers' practices in sorghum producing areas where they mix their produce with partially ground chilies (hot pepper, personal observation). Some farmers also mix sorghum with small-seeded cereals, such as *teff* and finger millet and layering of *teff* over sorghum with different proportions. However, this finding did not agree with farmers` practices in the case of mixing sorghum with *teff* and layering *teff* over sorghum as higher weight of damaged grain per sample and lower weight of undamaged grain per sample were observed during the experiment (Table 2). Prolonged storage of maize admixed with low rates of *teff* might result in high damage to the produce.

According to Abraham (2003), as the rates of *teff* decrease (< 30% w/w), the efficacy would also decrease even though admixed maize with different rates of *teff* was better than in the untreated check. On the other hand, the findings did not agree with investigations of Firdisa and Abraham (1998) who reported that maize grain mixed with hot pepper resulted in low protection from storage insect pests due to low pungency of the pepper they were used. Nevertheless, according to GTZ (1980), beans mixed with hot pepper before storage were kept for several months without suffering greatly by storage pests. Therefore, among the farmers' practices tested so far, mixing sorghum with hot pepper at 1 and 2%w/w resulted in promising effects in suppressing storage insect pests and could be recommended to the farmers.

4.2. Efficacy of Mixing Malathion 5% D with Neem (*Azadirachta indica* A. Juss) Seed Powder against *Zeamais* on Stored Maize

Significantly higher mortality of adult weevils was observed from all combinations of Malathion dust and neem seed powder treatments when compared to the untreated check following 90 dai which is in accordance with previous works. Obeng-Oforiand Amiteye (2003) reported that lower dosages of the vegetable oil and pirimiphos-methyl, when combined together, were found highly toxic to adult *S. zeamais*. In the same study, it was also reported that a mixture of 1 ml of the oils and 1/16 of recommended rate of pirimiphos-methyl could kill over 80% of the weevils exposed to mixture within 24 hr. In addition, significantly ($P \leq 0.05$) lower number of progeny, lower percentages of damaged grain and lower seed weight loss were recorded from all combinations of the treatments following 90 days after infestation. Similarly, combination of diatomaceous earth (DE) and plant extracts at reduced level or with soil bacterial metabolites, formulated as "All Natural" and "Spindeba", prevented progeny emergence of *Prostephanus truncatus* at 50-100 mg kg^{-1} (Stather and Credland, 2003). A reduced level of the combinations provided adequate protection to maize from weevils for more than six months (Stathers and Credland, 2003). Ulrich and Mewis (2000) showed that combination of DE fossil shield (1 g kg^{-1}) and a commercial neem product Azal-T/S (1 g kg^{-1}) resulted in higher mortality of weevils, low progeny emergence and effective control of *Tribolium castaneum* and *Sitophilus oryzae* for more than three months. Arthur (2002) reported that significantly high mortality and low progeny weevils emerged from the insecticide pyrazole applied at rates of 7.5 and 10 ppm either alone or in combination with deltamethrin, piperonyl butoxide and chloropyriphos-methyl against the red flour beetles.

Persistence of insecticidal treatments following 90 days after infestation showed that mortality in case of all of the treatment combinations was significantly higher than the untreated check. However, the effects on the mortality were gradual in all of the combinations of the treatments, except in case of Malathion D rates at 40 and 50% combinations with Neem seed powder at 20 and 10%, respectively. The number of progeny, percentages of damaged grain, and grain weight loss were significantly lower in the above-mentioned rates. These finding are in accordance with the reports of Srrenarayanan *et al.* (1999) and Kassis *et al.* (2002) who reported that all the combinations of Malathion and olive oil resulted in effective control of the zeamais maize and the effectiveness was similar to the recommended rates after sixty days of infestation. On the other hand, decreased potency of NSP with increased time after infestation is in line with the results of many authors (Emana, 1998; Firdisa *et al.*, 1998), which proved that the effectiveness of plant powder decreases with increasing time after infestation. The study further confirmed that application of NSP effectively controlled insect infestation for 3 months and further application would be required after this time.

Thus, rates of Malathion dust at 40 and 50% combinations with neem seed at 20 and 10% effectively protect maize from weevils for almost five months. The two higher rates (40 and 50%) of Malathion dust combined with neem seed was capable of managing maize weevil for about five months. Efficacy of neem seed powder declined with time and combinations, i.e. the treatment with higher rates of Malathion dust provided better protection to the maize as compared to rates of combinations. Generally, the current study clearly showed that use of mixtures of synthetic insecticide with botanicals effectively controlled the maize weevil and prolonged their persistence more than the use of the individual materials alone.

5. Conclusions

Among the farmers' practices tested, mixing sorghum with partially ground chilies (hot pepper) at the rates of 1 and 2% w/w showed better effects against stored sorghum insect pests as compared to other treatments. Equivalent results were recorded with the standard check in controlling insect pests in stored sorghum. The period of protection lasted for about six months. Mixing ground chilies at the rates of 1 and 2% w/w could safely be used to suppress stored sorghum insect pests.

Percentage of damaged grain and grain weight losses were significantly lower in all the combinations of Malathion dust and neem seed powder than that of the untreated check 90 days after infestation. Following 156 days after infestation, Malathion dust at 40 and 50% combined with neem seed powder at 20 and 10%, respectively, provided significant protection to the maize grain next to the standard check. The period of protection extended to five months under the conditions of the experiment.

From this study, it can be concluded that combination of treatments are better than the use of a single treatment alone. Respective combinations of Malathion dust and neem seed powder at 40+20% and 50+10% can be used effectively against maize weevil.

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