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Farmers' Practices and Combinations of Malathion and Neem Seed Powder Management Options on Stored Cereal Insect Pests at Bako, West Shewa, Ethiopia

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Abstract

Field and laboratory experiments were conducted at Bako Research Center, Western Ethiopia, during 2010/11-2011/12 to evaluate farmers' traditional practices (layering of tef over sorghum with 20% proportion, mixing sorghum with tef at 30% w/w, mixing sorghum with partially grinded hot pepper at the rate of 2% w/w and 1% w/w) in comparison with Malathion 5% D and untreated check against insect pest of stored sorghum. Similarly, in a laboratory study combinations of different rates of Malathion 5% D (100, 50, 40, 30, 20, 10, 0%) and Neem seed powder (10, 20, 30, 40, 50%) were evaluated against maize weevils from February to - July 2012. Results of the study showed that the number and weight of damaged grains were significantly (p<0.05) higher in layering of tef over sorghum with 20% w/w, mixing sorghum with tef at 30% w/w and untreated check than the other treatments. Similarly, percent weight losses were significantly (p<0.05) lower in mixing sorghum with hot pepper at 2% and 1% w/w than the other treatments, when compared to standard check. Among treatments, mortality in all of the treatment combinations ranged from 3.33 to-100%, while that of the untreated check ranged from 0 to-5.33% following 90 days after infestation. Similarly, the number of progeny weevils emerged, percentages of grain damaged and seed weight losses in all the treatment combinations were significantly lower than that of the untreated check 90 days after infestation. Significantly (P<0.05) higher percentages of mortality, lower percentages were observed for damaged grains and seed weight losses in the Malathion dust at 40% and 50% combined with Neem seed powder than that of the other treatments next to the standard check 156 days after infestation. From these studies, it could be concluded that mixing sorghum with partially grinded chillies (hot pepper) at the rate of 2% w/w or 1% w/w can be used to protect stored sorghum from insect pests and the combinations of Malathion 5% D and Neem seed powder at 40%+20% and 50%+10% respectively, can be used to protect maize from the maize weevil.

Keywords: Neem seed powder, Farmers' practice, Malathion 5% D, Sorghum, Maize, Pests

Introduction

The dearth of maize and sorghum storage insect pest management technologies forces the growers to sell their produces immediately after harvest (Abraham, 1991; 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 are means of protecting stored grain pests, the associated adverse effects on the environment and human health, development of genetic resistance in insect strains, erratic supply and prohibitive costs have become a major concern and thus given impetus to the search for alternative methods of pest control (Abraham, 1991). Currently various methods are traditionally used to control storage pests by farmers in sorghum and maize producing areas. Among such methods are; the mixing of sorghum and maize with small seeded cereals such as *tef* and finger millet. Others were observed to mix the produce with partially grinded-hot pepper. Besides, layering by placing one crop over the other, the produce that is liable to attack being in the middle and the other at bottom and upper portion is also practiced by some farmers. Though these methods of storage pest control options seem to be good for the control of stored sorghum or maize pests but their efficacy has not been proved hence warranting further research for wider adoption by farming communities.

In addition, use of locally available plant botanicals and vegetable oils are other options to reduce reliance on chemical pesticides. A major limitation to the practical utilization of locally available plant products and vegetable oil are their high rates required to effectively disinfest grains (Don-Pedro, 1989). The possibility of using reduced levels of plant products in combination with each other in simple mixtures as a means of making their use can be more attractive and effective (Don-Pedro, 1989). Integrating one control strategy with another sustainable method may provide long lasting solution to losses in storage due to their synergetic effects (Dobie, 1977). Combining two or more control options may minimize risk and costs of chemical, reduce resistance development and increases effectiveness.

Therefore, these studies were undertaken to evaluate the effectiveness of some traditional pest control practices of farmers in controlling stored sorghum and maize insect pest, to 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/optimum effective rate(s) of the combinations that can provide adequate protection against the pest.

Materials and Methods

Two experiments were conducted on cereal storage insect pest from 2010/11 –2011/12 and February to July 2012 cropping seasons, respectively, at Bako Agricultural Research Center, West Shewa, Ethiopia The first experiment was on sorghum and conducted in traditional but modified storage structures (*gotera*). The second experiment was conducted in the laboratory on maize by the use of plastic jar having the capacity of 2kg seeds. The Center lies at 9° 6`N latitude and 37°09`E longitude, 260 km west of Addis Ababa, at an altitude of 1650 m.a.s.l. The area is characterized by warm and humid climate. The annual average rainfall and relative humidity were 1341 mm and 70.11% respectively during the study period. The average minimum and maximum atmospheric temperatures of the area during the study period were 16.58°c and 27.21°c respectively.

Field experiment

Twenty-seven quintals of sorghum (variety Bobe) and three quintals of tef were used to conduct the experiment for one year. Six treatments (Layering of tef over sorghum with 20% w/w, Mixing with tef at 30%w/w, Mixing with partially grinded chilies (hot pepper) at the rate of 2% w/mixing with partially grinded chillies (hot pepper) at the rate of 1% w/w, mixing Malathion 5% D at the rate of 50g/q and untreated control were evaluated for the control of stored sorghum insect pests.

The experiment was laid out in randomized complete block design replicated three times. Plastic sheets were used to separate sorghum from tef in the layering treatments. Sample size of 350 g /plot or gotera was taken from each treatment using compartmented spear to assess the parameters from each treatment. Data were collected on the number of live and mortal insects infesting the grain in each treatment, number of damaged and undamaged grains, weight of damaged and undamaged grains and percent weight loss/sample. Evaluation was made at 60, 120 and 180 days of storage. Percent weight loss was calculated using the following formula:

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

Where, Wu = Weight of undamaged grains, WD = Weight of damaged grains, Nu=Number of undamaged grains, Nd=Number of damaged grains. Combined analysis was done for 2010/2011 and 2011/2012 using SAS version 6.12 computer software

Laboratory experiment

Seed of maize hybrid BH-540 was obtained from the BARC maize research program and multiplied in the center to obtain the F_2 generation seeds sufficient for the experiment. Neem seed powder was obtained from Melka worer research center. Malathion 5% D was purchased from the market.

Maize weevils were collected from maize store of Bako Agricultural Research Center and reared in the laboratory where the experiment was conducted. The weevils were cultured on BH-540 maize hybrid which is popularly grown by local farmers. Seeds were cleaned and stored in a deep freezer at -20 ± 2°C for two weeks in order to disinfest. The seeds 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 kilograms of maize seeds were placed in three liter 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 seeds were kept for weevil progeny emergence. The average developmental period of the maize weevil on maize in the laboratory condition was about 42 days (Abraham, 1991). Therefore progeny weevil emergence was monitored daily, and those emerged on the same day were transferred to fresh seed 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). Two hundred grams of maize kernels were placed in 250 cm^3 capacity glass jars with brass screen lids that permit ventilation. The treatments comprising of Malathion 5% D and Neem seed powder(0% (0 g) + 100% (4 g), 10% (0.01 g) + 50% (2 g), 20% (0.02 g) + 40% (1.6 g), 30% (0.03 g) + 30% (1.2 g), 40% (0.04 g) + 20% (0.8 gm), 50% (0.05 gm) + 10% (0.4 gm), 100% (0.1 gm) + 0 % and untreated check) were then applied to the maize kernels.

The treated maize kernels were thoroughly mixed to ensure uniform distribution of treatments. Adult maize weevils were introduced into each jar at the ratio of one weevil to two to three (1: 2-3 g) maize kernels (50 weevils/ 200 g maize). The treatments were arranged in a completely randomized block design with three replications. The temperature and relative humidity of the laboratory were recorded daily. In order to investigate the persistence/residual effect of the treatments used, the same number of weevils (50 weevils/ 200g seed) was re-introduced into the grain following 90 days after the treatment application. Similar data were collected 156 days after re-infestation

Data collection

Data were collected on the following parameters on maize seed:

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

F_1 progeny weevil emergence: Thirty days after application of treatment, after removing dead and alive weevils, the seeds 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 and continued until all progeny emerged.

Seed damage and weight loss: Ninety days after the introduction of adult maize weevils, the number and weight of damaged and undamaged seeds were recorded. Seed weight loss was calculated by using the count and weigh method (Boxall, 1986).

Seed germination: In order to assess the viability of seeds, seed germination was tested 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 plates and the number of germinated seeds was recorded after ten days.

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 (1925) correction formula:- $\%CM = \frac{(\%T - \%C)}{(100 - \%C)} * 100$; where CM is corrected mortality, T is mortality in treated seed, and C is mortality in untreated seed. Damaged seeds were expressed as a percentage of the total number of seeds in each replicate. 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 statistical analysis, in order to stabilize the variances. Percentage of germination was not transformed. All data were subjected to analysis of variance. Differences among means were determined using Student-Newman-Keuls Test. Back-transformed means are presented. Data were analyzed using SAS Version 6.12 computer software.

Results

Field study

The result of farmers' traditional practices on number of weevils and *Sitotroga cerealella* (Oliver) dead and alive is presented in Table 1. Significant differences were observed among farmers' traditional practices on number of weevils and *Sitotroga cerealella* (Oliver) dead and alive. Higher number of dead weevils were observed in the untreated check compared to the other treatments. The number of weevils alive was significantly higher in the layering of tef over sorghum with 20% w/w, mixing sorghum with tef at 30%w/w and in the untreated check than the other treatments. Numbers of *S. cerealella* (Oliver) dead and alive were significantly higher in the untreated check followed by layering of tef over sorghum with 20% proportions and mixing sorghum with tef at 30% w/w. However, significantly (P<0.05) lower numbers of *Sitotroga cerealella* (Oliver) dead and alive were recorded in mixing sorghum with partially grinded hot pepper at the rate of 2% w/w and 1% w/w and in the standard check (Table 1).

Variations were observed among 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). Number and weight of grains damaged were significant (P<0.05) and higher in the layering of tef over sorghum with 20% w/w, mixing sorghum with tef at 30% w/w and in the untreated check than the other treatments. Similarly number and weight of grains undamaged were significantly higher in mixing sorghum with partially grinded-hot pepper at the rate of 2% w/w, 1% w/w and Malathion 5% D than the other treatments (Table 2). Percent weight losses were significantly lower in mixing sorghum with partially grinded chilies (hot pepper) at the rate of 2% w/w and 1% w/w, and Malathion 5% D than in the other treatments (Table 2). Species of insect pests infesting the free choice test treatments are presented in Table 3. Among the species recorded *Tribolium spp, Sitophilus spp and Sitotroga cerealella (Oliver*) are the most abundant species followed by *Carpophilus spp* and *Cryptolestes spp.* The other species such as *Lasioderma serricorine* (F), *Oryzaephilus spp* and *Rhizopertha dominica* (F) appeared occasionally.

Table 1. Effects of some farmers' practices, on numbers of weevil and *Sitotroga* dead and alive at Bako, West Shewa Ethiopia

	Treatments (farmers practices)	Number of weevil/sample		Number of Sitotroga/ samples	
		Dead	**Alive**	**Dead**	**Alive**
1	Layering of tef over sorghum with 20% w/w	79.54 [b]	85.37 [a]	82.35 [bc]	29.94 [b]
2	Mixing with *tef* at 30%w/w	79.71 [b]	84.60 [a]	97.27 [b]	27.40 [b]
3	Mixing with partially groundchilies (hot pepper) at the rate of 2% w/w.	94.40 [b]	33.52 [b]	51.78 [de]	3.07 [c]
4	Mixing with partially groundchilies (hot pepper) at the rate of 1% w/w.	90.35 [b]	41.92 [b]	71.63 [cd]	3.79 [c]
5	Insecticide (Malathion 5% D) at the rate of 50g/qt	97.71 [b]	**12.25 [c]**	33.16 e	0.92 [c]
6	Control (untreated check)	217.56 [a]	82.64 [a]	223.15 [a]	58.81 [a]
CV (%)		**10.54**	**21.16**	**15.57**	**55.22**
LSD		**19.56**	**20.44**	**24.97**	**19.43**

Means followed by same letter within a column are not significantly different from each other at 5% level of probability (student new man kewls range test (SNK)

Table 2. Effect of some farmers practices on number of grains damaged and undamaged, weight of grains damaged and undamaged and percent weight losses in stored sorghum insect pests at Bako, West Shewa, Ethiopia

Treatments (farmers practices)	Number of grains/sample		Weight of grains/ samples		Percent weight losses
	Damaged	Undamaged	Damaged (gm)	Undamaged (gm)	
Layering of tef over sorghum at 20% w/w	421.41 [a]	10472.19 [bc]	4.17 [a]	225.84 [c]	2.07 [a]
Mixing with *tef* at 30%w/w	393.91 [a]	111150.60 [b]	3.75 [a]	221.95 [c]	1.78 [a]
Mixing with partially groundchilies (hot pepper) at the rate of 2% w/w.	216.24 [b]	14300.01 [a]	2.71 [b]	335.58 [a]	0.68 [b]
Mixing with partially groundchilies (hot pepper) at the rate of 1% w/w.	208.68 [b]	13300.84 [a]	2.64 [b]	304.83 [b]	0.74 [b]
Insecticide (Malathion 5% D) at the rate of 50g /qt	199.86 [b]	14340.98 [a]	2.37 [b]	332.90 [a]	0.66 [b]
Control (check)	414.14 [a]	9692.76 [c]	4.25 [a]	217.69 [c]	2.23 [a]

13.94	**5.21**	**16.40**	**5.10**	**24.35**
73.37	**1083**	**0.93**	**23.72**	**0.56**

Means followed by similar letter within a column are not significantly different from each other at 5% level of probability (SNK)

Table 3. Species of insect pests recorded in stored sorghum at Bako Agricultural Research center/ sample

Order/species	Common name	Status/abundance of the pest in the storage	Types of insect Pests/beneficial
Colleoptera			
Tribolium spp			
Sitophilus spp	Maize /rice weevils	Very common	Pest
Carpophilus spp	Maize /rice weevils	Very common	Pest
Cryptolestes spp.	Sap beetles	Common	Pest
Lasioderma serricorine(F)	Flat grain beetles	Common	Pest
Oryzaephilus spp	Saw toothed grain beetles	Rare	Pest
Rhizopertha dominica(F)	Lesser grain borer	Rare	Pest
Lepidoptera	Red/confused flower beetles	Rare	Pest
Sitotroga cerealella (Oliver)	Angoumois grain moth	Very common	Pest
Hymenoptera			
Parasitic wasp			Beneficial
Archnida			
Acarus siro (L)	Flour mite		Pest

Laboratory study

Results showed that the combinations of different rates of Malathion dust and Neem seed powder caused higher mortality than the untreated control (Table 4). The parent weevil mortality was significantly ($p<0.01$) higher in T_5, T_6 and the standard check than that of the other treatments two and four days after infestation (DAI). Six days after infestation, the percentages of mortality were significantly lower in T_2 and T_3 than the other treatment combinations and 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 after 12 DAI (Table 4). However, 48% and 66% of mortality were recorded in T_3 and T_2, respectively, following 12

DAI and the difference between the treatments was significant. The rates of mortality reached 100% in all of the treatments except for the untreated check following 18 DAI (Table 4). The number of progeny weevils emerged, percentages of grain damaged and grain weight losses recorded in the combined treatments were significantly lower than that of untreated control (Table 5). However the differences among the treatment combinations were not significant for the indicated parameters. Significant differences were observed in weevil mortality among the different combinations of Malathion dust and Neem seed powder (Table 6). The percentage of mortality was significantly higher in T_5 and T_6 than that of the other treatment combinations in all of the days considered. Mortality in the untreated check was the lowest. The percentages of mortality were significantly lower in T_2, T_3 and T_4 than in T_5 and T_6 following two, four, six and 12 days after infestation. Following 18 DAI, the rate of mortality in T_2, T_3 and T_4 was significantly lower than that in all other combinations (Table 6). Different rates of Malathion dust and Neem seed powder combinations had varying degree of residual effects where the number of progeny weevil emergence, percentages of grain damaged and grain weight losses in all treatments were significantly ($P<0.01$) lower than Neem seed powder alone and in the untreated check. The Neem seed powder treatment was found to be ineffective in stopping the development of progeny weevils as it had the second largest progeny emerged. The lowest progeny emergence and seed damage were recorded in T_7 (Table 7). The number of progeny weevils emerged, percentages of grain damaged and grain weight losses were significantly lower in T_5, T_6 and T_7 than in T_1, T_2, T_3 and T_4. The differences among T_2, T_3 and T_4 as well as between T_5 and T_6 were not significant for the above-mentioned parameters. The percentages of seed germination were significantly ($p<0.01$) higher in all of the treatments than in the untreated check (Table 7).

Table 4. The effects of different rates of Malathion 5% D and Neem seed powder combinations on weevil mortality

Treatment	Percent weevil mortality				
	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) ± 5.02 ^{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	2.77	13.74	6.02	14.82	1.02

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). dai=days after infestation, T=treatment. Values in the parenthesis are angular transformed value.

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 after three months of 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	0.310	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 gm) + 100% (4 gm), **T_2** = 10% (0.01 gm) + 50% (2 gm), **T_3** = 20% (0.02 gm) + 40% (1.6 gm), **T_4**= 30% (0.03 gm) + 30% (1.2 gm), **T_5** = 40% (0.04 gm) + 20% (0.8 gm), **T_6** = 50% (0.05 gm) + 10% (0.4 gm), **T_7** = 100% (0.1 gm) + 0 % (standard check) and **T_8** = Untreated check

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 after three months of treatment.

Treatment	Percent 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 ^{c}	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	**6.50**	**3.21**	**2.42**	**1.35**	**2.03**

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). dai=days after infestation. Values in the parenthesis are angular transformed value. $\mathbf{T_1}$ = 0% (0 gm) + 100% (4 gm), $\mathbf{T_2}$ = 10% (0.01 gm) + 50% (2 gm), $\mathbf{T_3}$ = 20% (0.02 gm) + 40% (1.6 gm), $\mathbf{T_4}$= 30% (0.03 gm) + 30% (1.2 gm), $\mathbf{T_5}$ = 40% (0.04 gm) + 20% (0.8 gm), $\mathbf{T_6}$ = 50% (0.05 gm) + 10% (0.4 gm), $\mathbf{T_7}$ = 100% (0.1 gm) + 0 % (standard check) and $\mathbf{T_8}$ = Untreated check

Table 7. Residual effects of different rates of Malathion 5% dust and Neem seed powder combinations on progeny emerged, percentages of grain damaged, grain weight losses and seed germination when the grains was e-infested after three months of treatment.

Treatment	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	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]	0.13(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]	0.14(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 ± 2.85 [b]
CV %	3.36	2.02	0.92	4.06
LSD	0.250	0.072	0.018	3.450

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 ange Test). dari=days after re-infestation, dai= days after infestation. Values in the parenthesis are square root transformed. **T_1** = 0% (0 gm) + 100% (4 gm), **T_2** = 10% (0.01 gm) + 50% (2 gm), **T_3** = 20% (0.02 gm) + 40% (1.6 gm), **T_4**= 30% (0.03 gm) + 30% (1.2 gm), **T_5** = 40% (0.04 gm) + 20% (0.8 gm), **T_6** = 50% (0.05 gm) + 10% (0.4 gm), **T_7** = 100% (0.1 gm) + 0 % (standard check) and **T_8** = Untreated check

Discussions

The study showed that mixing sorghum with partially grinded chilies (hot pepper) at the rates of 1% w/w and 2% w/w were found potentially effective against stored sorghum insect pests and comparable results were obtained with Malathion 5% D (Table 3). The findings conform to the traditional practice of farmers in sorghum producing areas where they mix their produce with partially grinded chilies (hot pepper). Some farmers also mix sorghum with small seed cereals such as tef and finger millet and layering of tef over sorghum with different proportions. Our findings are not in tune with framers` practice with respect to mixing sorghum with tef and layering tef over sorghum, as higher quantity of grain was damaged per sample leaving less weight of undamaged grain per sample in the experiment (Table 2). Prolonged storage of maize admixing with low rates of tef may result in high damage to the produce. According to Abraham (2003), as the rates of tef decreased (<30 % w/w), the efficacy decreased, though admixing maize with different rates of tef was better than the untreated check.

Significantly higher mortality of adult weevils was observed from all combinations of Malathion dust and Neem seed powder than the untreated check following 90 DAI. This result was in accordance with earlier works. Obeng-Ofori and Amiteye (2003) reported that lower dosages of the oil and pirimiphos-mehyl when combined were highly toxic to adult *S. zeamais.* The same study reported that a mixture of 1 ml of the oils +1/16 of recommended rate of pirimiphos-methyl showed mortality of over 80% of the weevils exposed within 24 hr. Besides, significantly ($P<0.05$) lower number of weevil progeny, lower percentage of damaged grain and lower seed weight loss were recorded from all combinations of the treatments following 90 days after infestations. Similarly, the combination of Diatomaceous Earth (DE) and plant extracts at reduced level or with soil bacteria metabolites, formulated as “All Natural” and “Spindeba”, prevented progeny emergence of *Prostephanus truncatus* at 50-100 ppm (Stather and Credland, 2003). A reduced level of the combinations provided adequate protection to maize against maize weevils for more than six months (Credland, 2003). Ulrich and Mewis (2000) also showed that combination of Diatomaceous Earth 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 *T. castaneum* and *S. oryzae* for more than three months. Arthur (2002) reported that significantly high mortality and low progeny weevils emerged from insecticidal 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.

The persistence or residual effect of the treatments following 90 days after infestation showed that mortality in all the treatment combinations was significantly higher than in the untreated check. However, the effects on the mortality were gradual in all the treatment combinations except for the Malathion dust rates at 40% and 50% combinations with Neem seed powder (NSP) at 20% and 10%, respectively. The number of weevil progeny, percentage of damaged grain, and grain weight loss were significantly lower with the above-mentioned rates. These are in accordance with the reports of (Srenarayanan *et al.*, 1999) where the combinations of Malathion with olive oil resulted in effective control of the maize weevil, the effectiveness was similar to recommended rates following sixty days after infestation. On the other hand, the decreased potency of NSP with time after infestation is in line with the results of many reports which indicated that the effectiveness of botanical powder decreases with time after infestation. This study also confirmed that, the applications of NSP effectively controlled weevils for 3 months and further applications will be required thereafter. The rates of Malathion dust at 40% and 50% combinations with Neem seed at 20% and 10% can effectively protect maize from the maize weevils for about five months. The efficacy of Neem seed powder declined with time and combinations with higher rates of Malathion dust, provided better protection to the maize grain than the lower rates. Controlled the maize weevil and prolonged their persistence than the use of the individual materials.

Conclusion

Among the farmers practices tested, mixing sorghum with partially grinded chilies (hot pepper) at the rate of 2% w/w and 1% w/w was more effective against stored sorghum insect pests and comparable to standard check with the period of protection lasting for about six months. Malathion dust at 40% and 50% combined with Neem seed powder at 20% and 10%, were found to provide significant protection to maize grain next to standard check, 156 days after infestation. The study therefore clearly indicated that the use of synthetic insecticide mixtures and botanicals proved better and more effective than single treatments.

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