Effects of Malathion Dust and Mexican Tea Powder (*Chenopodium ambrosoides*) Combinations on the Maize Weevil, *Sitophilus zeamais* Mostch (Coleoptera: Curculionidae) on maize

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Abstract

The experiment was conducted in the laboratory at Bako Agricultural Research Center, from February to July 2006. Combinations of different rates of malathion and Mexican tea powder were evaluated against the maize weevil in no choice situations. The treatments were laid out in a randomized complete block design with three replications. After three months of initial infestation the duration of their effectiveness of the treatments was evaluated by re-infesting with the same number of weevils as the previous. Analysis of variance indicated significant differences among the treatments in all of the parameters measured. The rate of mortality in all of the treatment combinations ranged from 19-100%, while that of the untreated check ranged from 0-3% following 90 days after infestation. Similarly, the number of progeny weevils emerged, percentages of grain damaged and seed weight losses in all of the treatment combinations were significantly lower than that of the untreated check after 90 days of infestation. In terms of adult mortality all of the combinations were as effective as standard check following 90 days after infestation. The combination treatments showed persistent effect and gave significant control over the untreated check for up to five months. However, from economic analysis (cost of treatments) point of view the least cost was observed in treatment six (T_6) and can be used as a component of maize weevil management strategy.

Introduction

Maize is one of the important cereal crops in Ethiopia, and grows in all parts of the country across varied agro ecological zones. However, the yield of maize is very low due to several constraints. Although many insect pests are known to cause losses to stored maize in Ethiopia, the maize weevil (*Sitophilus zeamais)* Mostch. and the Angoumois grain moth (*Sitotroga cereallela*) (Oliv.) are the most important primary insect pests (Abraham 1991, 1997, Emana and Assefa 1998, Mekuria 1995). From a survey conducted on the productivity gains of maize hybrids Beyene et al. (1996) found that about 20% storage losses and 25% price reduction for the weevil damaged grains resulted in large income losses with value ratio not greater than one. According to Abraham (1997) and Firdisa and Abraham (1998), insect pests in the farm store caused over 16% loss on maize in the Bako area.

Different management options such as physical (solar heating), inert dusts (wood ash, sand and SilicoSec), varietal tolerance, mixing with small cereal grains such as tef and millet (*eragrostic tef*), botanicals (plant powders and vegetable oil) and synthetic chemicals have been recommended to mitigate the problem. For instance, among the botanicals tested so far the Mexican tea (*Chenopodium ambrosiodes* (L.)) leaf powder was found to be the most effective and comparable to the synthetic insecticides (pirimiphos-methyl 2% D) at 5%w/w (Mekuria 1995; Abraham 2003). According to Mekruia (1995), MTP at 2 and 4% was comparable to actelic 2% dust in protecting maize from Sitophilus weevils. Tapondjou et al. (2002) tested powder and essential oil obtained from dry ground leaves of *Chenopodium ambrosiodes* at the rates ranging from 0.8 to 6.4% against six insect pests including the granary and the maize weevils on wheat and maize and reported that the highest dosage of 6.4% induced 100% mortality of both species two days after treatment, although mortality of larger grain borer was only 44%.

Regardless of numerous control methods 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.

A major limitation to the practical utilization of locally available plant products and vegetable oil is the high volume required to effectively disinfest grains (Don-Pedro 1989). Lale and Mustapha (1999) reported that the integrations of natural plant products from locally available plants and malathion dust for use in storage against bruchids (*Callosobruchus maculates)* may lead to the sustainable management of the bruchid especially in subsistence agriculture. Larry (2002) also reported the importance of integrating several tactics lies in the desire for sustainability or durability of management program. Moreover, combining two or more control options may minimize the risk and costs of chemicals, reduce resistance development against the treatments and increase effectiveness of the treatments. The objectives of this study were to asses the combined effect of a botanical, Mexican tea (*Chenopodium ambrosoides)* leaf powder and malathion dust recommended for use against the maize weevil, and determine the minimum effective rate(s) of the combinations that can provide adequate protection to maize against the pest.

Materials and Methods

Preparation of experimental materials

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 experiment. Mexican tea leaf was collected from Holetta and Addis Ababa areas along roadside. The botanical was dried under shade, decorticated and ground into fine powder with mortar and pestle. Malathion 5%D was obtained from the General Chemical Trading PLC, Addis Ababa.

Establishment of *S. zeamais* culture

Sufficient number of adult *S. zeamais* was reared on F_2 seeds of BH540 hybrid maize variety following the procedure suggested by Strong and Subur (1968). Hundred kilograms of the seed with moisture contents of 12.5-13% were disinfested by keeping in a deep freezer at -20°C for fortnight and divided into 2 kg. Two kg of each seed was put in a three-liter capacity plastic jar and there were arranged in to five replications. Adult weevils that were collected from the Bako agricultural research center store were introduced into each replication in the ratio of 1 weevil to 2-3 g kernels (660 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 began, adults were collected daily until sufficient number of weevils for the studies was obtained. Those emerged on the same day were transferred to the same glass jar, so that each jar had adults of identical age for the experiments.

Treatment application

The treatment details are shown in Table 1. The maize kernels were cleaned and disinfested following the same procedure as above. The moisture content of the grains was adjusted by adding water as recommended by Wright et al. (1989). Two hundred grams of kernels were put in a 250 cm^3 capacity glass jar with brass screen lid that permit ventilation. Adult maize weevils were introduced in each jar at the ratio of one weevil to two to three (1:2-3) g kernels (50 weevils/200 g maize). Recommended rates of Malathion dust (MTD) and Mexican tea leaf powder (MTP) being 50gm/100 kg and 5%w/w, respectively, their various proportional combinations shown in table 1 were the treatments applied immediately after introduction of the weevil including the untreated check. The experiment was laid out in a completely randomized block design with three reapplications. Ninety days after the initial infestation the treated seeds were re-infested with the same number of weevils to evaluate the persistence of the treatments. Germination of the seeds under each treatment was tested on 100 seeds randomly picked from respective treatments and placed on moist filter paper in a petridish for five days. Temperature and relative humidity of the laboratory were recorded daily.

Table 1. Proportions of malathion 5% dust and Mexican tea powder (*C. ambrosoides)* of the respective treatment combinations used in the experiment.

Treatment code	Treatment combinations (Malathion 5% D MTD	+	Mexican tea leaf powder MTP
T_1	0% (0 g)	+	100% (10 g)
T_2	10% (0.01 g)	+	50% (5 g)
T_3	20% (0.02 g)	+	40% (4 g)
T_4	30% (0.03 g)	+	30% (3 g)
T_5	40% (0.04 g)	+	20% (2 g)
T_6	50% (0.05 g)	+	10% (1 g)
T_7	100% (0.1 g)	+	0% (0 g)
T_8	Untreated check		

T=treatment, MTD= Malathion Dust, MTP=Mexican tea powder

Data collection

Dead weevils were counted at the 2, 4, 6, 12, 18, 24 and 30 days after initial infestation (dai). During the last counting, both dead and live weevils were counted and removed and the grains were kept under the same conditions for the emergence of the F_1 generation. Upon emergence the F_1 progeny weevils were counted and removed each day until no further emergence. Data on the number of dead adult weevils, number of emerged progeny weevils, number and weight of damaged and undamaged grains were collected. The percentages of seed weight losses were calculated using the count and weigh method (Boxall, 1986) as follows:-

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

Where, Wu = weight of undamaged seed, Nu = number of undamaged seed, Wd = weight of damaged seed, Nd = number of damaged seed.

Similar data were collected following the re-infestation. The proportion of germinated seeds to the total was taken as percentage seed germination.

Statistical analysis

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). Percentages of mortality were transformed by angular (ASIN) transformation and number of emerged progeny weevils, percentage damaged grain and grain weight losses were square root transformed. Data were subjected to statistical analyses using SAS Version 6.12 computer software. Means were separated using Student-Newman-Keuls (SNK) Range Test.

Results

The rates of mortality in all of the combinations of MTD and MTP and their respective pure treatments were significantly (p<0.05) higher than that of the untreated check (Table 2). Mortality in T_5 and T_6 were significantly (p<0.05) higher than that of the other treatment combinations at two, four and six days after infestations. The rate of mortality in T_2, T_3 and T_4 at 2, 4 and 6 dai was low ranging from 19-26%, 30-36% and 42.67-50.67%, respectively. The rate of mortality reached 100% as early as 6 dai in T_1, T_5, T_6 and T_7, while the remaining treatments except the untreated check attained this level on 12 dai (Table 2). This shows that efficacy of the combination treatments has improved with the increase in the proportion of MTD in the mixture.

Significant differences were observed among the different combinations of malathion dust and Mexican tea powder with respect to progeny emergence, grain damage, grain weight losses and seed germination (Table 3). No progeny emergence, grain damage and weight loss were observed in all the treatments except the untreated check. Seed germination was significantly (P<0.05) lower in the untreated check compared to that of the other treatments among which no difference was observed (Table 3).

Significant (P<0.05) differences were observed in the different combinations of MTD and MTP with respect to the percentage of adult mortality when the treated grains were re-infested 3 months after treatment application (Fig.1). Significantly (P<0.05) lower rates of mortality were recorded in the untreated check at all dates considered. The rate of mortality increased with time after re-infestation (days after re-infestation, dari) in all of the treatments. Pure MTD and MTP treatments at recommended rates (T_1 and T_7) showed better persistence and resulted in complete control of the re-infested adults as early as 6 dari. The persistence of the combinations was observed to increase with the increase in the proportion of MTD in the mixture. This was indicated by the complete adult mortality obtained under T_5 and T_6 earlier at 12 dari, while similar effects were recorded six days later by T_2, T_3 and T_4 (Fig. 1).

Similarly, the pure MTD and MTP treatments and their various combinations significantly reduced progeny emergence from the re-infestation and thereby grain damage and weight loses compared to the untreated check (Table 4). Moreover, the pure treatments and their combination did not show significant variation among themselves with respect to seed germination at about five months after initial infestation. Germination of the untreated check, however, was significantly (P<0.05) reduced.

Economic analysis (costs of treatments) was done for the treatments used in the laboratory (200 g/jar) and converted to 1.5 t of maize seeds (Fig. 2). For the reason that the assumption is that each individual farmer can store an average of 1.5 t/year. The costs of treatments are in the increasing order from T_6, T_7, T_5, T_4, T_3 and T_1, respectively, which means the minimum cost was observed in the T_6 from combined treatments and the maximum were recorded in T_1 (pure treatment of MTP).

Table 2. Effect of different rates of malathion 5% D and Mexican tea powder combinations on maize weevil mortality at different days after infestation

Treatment	Percent weevil mortality			
	2 dai	4 dai	6 dai	12 dai
T_1	26.0(30.6) $\pm$ 3.0 ^{b}	74.0(59.4) $\pm$ 3.0 ^{a}	100.0(89.5) $\pm$ 0.0 ^{a}	100.0(89.5) $\pm$ 0.0 ^{a}
T_2	26.0(30.6) $\pm$ 2.0 ^{b}	30.0(33.6) $\pm$ 3.5 ^{c}	43.3(41.2) $\pm$ 4.4 ^{b}	100.0(89.5) $\pm$ 0.0 ^{a}
T_3	19.3(26.1) $\pm$ 0.6 ^{c}	30.0(33.6) $\pm$ 0.0 ^{c}	50.6(45.4) $\pm$ 0.6 ^{b}	100.0(89.5) $\pm$ 0.0 ^{a}
T_4	21.3(27.4) $\pm$ 3.5 ^{bc}	36.0(36.8) $\pm$ 1.1 ^{c}	42.6(40.7) $\pm$ 2.4 ^{b}	100.0(89.5) $\pm$ 0.0 ^{a}
T_5	46.0(42.7) $\pm$ 1.1 ^{a}	54.0(47.3) $\pm$ 1.1 ^{b}	100.0(89.5) $\pm$ 0.0 ^{a}	100.0 (89.5) $\pm$ 0.0^a
T_6	48.7(44.3) $\pm$ 0.6 ^{a}	51.3(45.7) $\pm$ 0.6 ^{b}	100.0(89.5) $\pm$ 0.0 ^{a}	100.0(89.5) $\pm$ 0.0 ^{a}
T_7	24.7(29.6) $\pm$ 4.3 ^{bc}	75.3(60.4) $\pm$ 4.4 ^{a}	100.0 (89.5) $\pm$ 0.0 ^{a}	100.0 (89.5) $\pm$ 0.0 ^{a}
T_8	0.0(0.4) $\pm$ 0.00 ^{d}	0.0(0.4) $\pm$ 0.0 ^{d}	1.3(4.1) $\pm$ 1.33 ^{c}	3.0(9.3) $\pm$ 0.6 ^{b}
CV %	8.69	5.38	4.33	0.81
Lsd	4.33	3.88	4.82	1.13

Means followed by the same letter (s) within a column are not significantly different from each other at 5% level of probability (Student-Newman-Keul's Range Test). ANOVA was conducted on transformed values. dai=days after infestation.
Figures in parenthesis are angular transformed value.

Table 3. Effects of malathion dust and MTP combinations on progeny emergence, grain damage, grain weight loss and seed germination after 3 months of treatment.

Treatment	Number of progeny weevils emerged	Damaged grain (%)	Grain weight loss (%)	Seed Germination (%)
T_1	0.00(0.71) ± 0.0 [b]	0.00(0.71) ± 0.0 [b]	0.00(0.71) ± 0.0 [b]	97.00 ± 0.58 [a]
T_2	0.00(0.71) ± 0.0 [b]	0.00(0.71) ± 0.0 [b]	0.00 (0.71)± 0.0 [b]	96.33 ± 0.33 [a]
T_3	0.00(0.71) ± 0.0 [b]	0.00(0.71) ± 0.0 [b]	0.00 (0.71)± 0.0 [b]	96.67 ± 0.33 [a]
T_4	0.00(0.71) ± 0.0 [b]	0.00(0.71) ± 0.0 [b]	0.00(0.71) ± 0.0 [b]	97.00 ± 0.58 [a]
T_5	0.00(0.71) ± 0.0 [b]	0.00(0.71) ± 0.0 [b]	0.00(0.71) ± 0.0 [b]	96.67 ± 0.88 [a]
T_6	0.00(0.71) ± 0.0 [b]	0.00(0.71) ± 0.0 [b]	0.00(0.71) ± 0.0 [b]	96.67 ± 0.33 [a]
T_7	0.00(0.71) ± 0.0 [b]	0.00 (0.71)± 0.0 [b]	0.00(0.71) ± 0.0 [b]	96.33 ± 0.88 [a]
T_8	69.00(8.34) ± 0.6 [a]	13.32(3.71) ± 0.2 [a]	2.34(1.68) ± 0.02 [a]	92.33 ± 0.33 [b]
CV %	1.28	1.49	0.53	0.90
Lsd	0.030	0.020	0.010	0.863

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 parentheses are square root transformed.

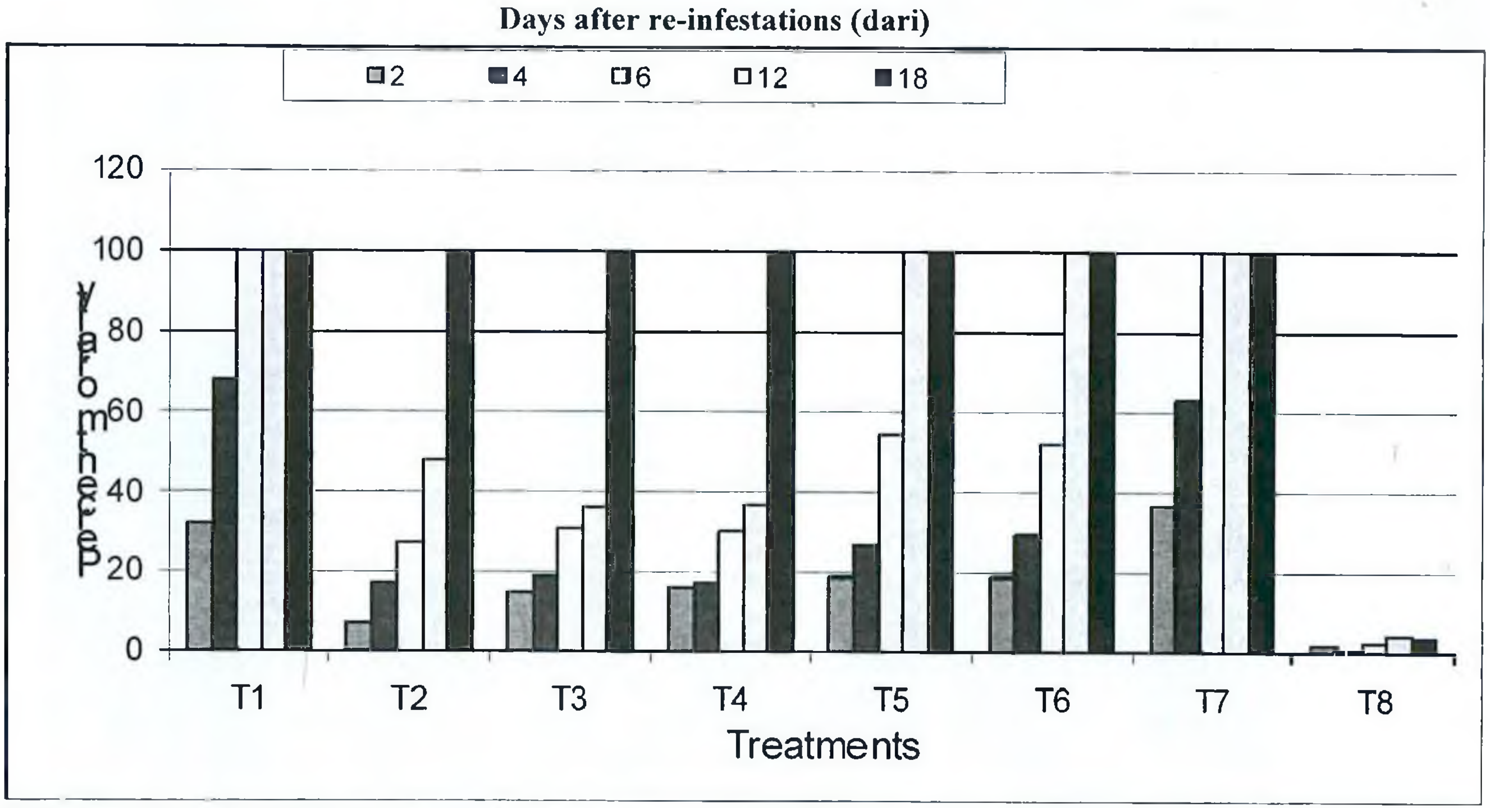

Figure 1. The rate of mortality of weevils re-infesting maize grains 3 months treatment with different combination of malathion dust and Mexican tea leaf powder.

Table 4. Residual effects of combinations of different rates of malathion 5% dust and Mexican tea leaf powder on grain and weevils re-infested three months after treatment.

Treatment (code)	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	1.67(1.46) ± 0.33 [c]	0.05(0.74) ± 0.03 [bc]	0.008(0.71) ± 0.00 [c]	89.67 ± 1.20 [a]
T_2	2.67(1.77) ± 0.33 [b]	0.16(0.80) ± 0.15 [bc]	0.033(0.73) ± 0.00 [b]	89.67 ± 0.88 [a]
T_3	3.00(1.85) ± 0.58 [b]	0.32(0.88) ± 0.28 [b]	0.050(0.74) ± 0.00 [b]	89.33 ± 0.88 [a]
T_4	2.67(1.77) ± 0.33 [b]	0.09(0.76) ± 0.06 [bc]	0.053(0.74) ± 0.00 [b]	90.00 ± 0.57 [a]
T_5	2.33(1.67) ± 0.33 [bc]	0.03(0.73) ± 0.01 [bc]	0.050(0.74) ± 0.01 [b]	89.33 ± 1.15 [a]
T_6	2.33(1.67) ± 0.33 [bc]	0.14(0.79) ± 0.12 [bc]	0.043(0.73) ± 0.01 [b]	90.33 ± 1.20 [a]
T_7	0.00(0.71) ± 0.00 [d]	0.00(0.71) ± 0.00 [c]	0.000(0.71) ± 0.00 [c]	89.33 ± 1.20 [a]
T_8	131.33(11.48) ± 1.76 [a]	25.05(5.05) ± 0.11 [a]	3.373(1.96) ± 0.06 [a]	49.33 ± 2.40 [b]
CV %	6.47	7.57	1.16	2.35
Lsd	0.280	0.160	0.017	2.006

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). dari=days after re-infestation, dai= days after infestation, Values in the parentheses are square root transformed.

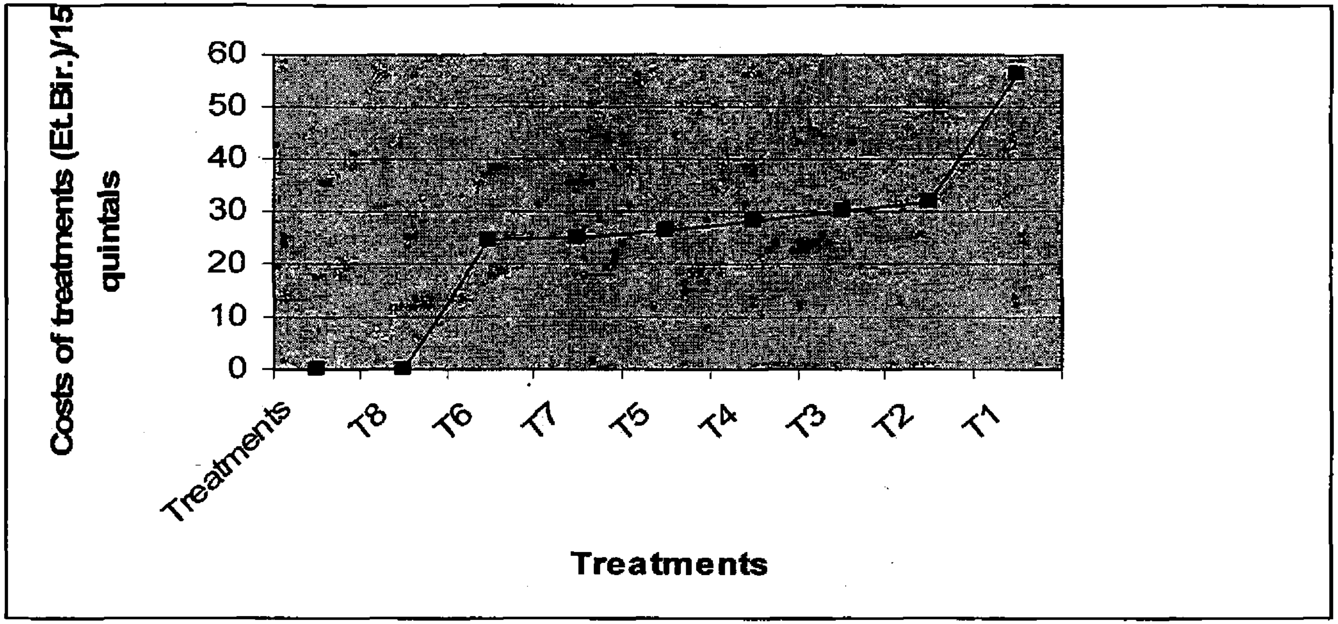

Figure 2:- The costs (Et.Birr) of each treatment /1.5 t of maize seed converted from the costs of treatments used for 200g/Jar in the laboratory.

Discussions and Conclusion

The combination of malathion dust and Mexican tea powder provided effective control of weevils as the synthetic insecticide for up to 5 months. This finding is in agreement with numerous works on combinations of different materials against storage pests. For example, Stather and Credland (2003) studied the combinations of diatomaceous earth with plant extracts, insecticides and entomopathogenic fungi and found that the combination of diatomaceous earth 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 ppm. A reduced level of the combinations provided adequate protection of maize from maize weevil for more than six months. Ulrich and Mewis (2000) 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 *Tribolium castaneum* and *S. oryzae* for more than three months.

The result of this study showed that the efficacy and persistence of the combinations improved as the proportion of MTD in the mixture increases. However, the treatments with lower proportion of MTD in the combination gave complete control of the pest about a week latter compared to those with higher doses of MTD in the mixture. Fabiane and Sonia (2005) also reported that mixing diatomaceous earth with deltamethrin, the mortality of *S. zeamais* was affected by the dosages and by the exposure time. Dead insects were registered in the first day after application. The same study also reported that treatments using diatomaceous earth combined with low dosages of deltamethrin dust provided an efficient control of *S. zeamais* for more than six moths. According to Barbosa *et al.* (1994), the efficacy of diatomaceous earth was improved when it was mixed with pirimiphos-methyl and deltamethrin against *Prostephanus truncatus* (Horn). Treatments using high rates of diatomaceous earth combinations with low dosages of powder deltamethrin represent an efficient control measure against *S. zeamais* in stored corn because insect mortality is faster than in treatments using diatomaceous earth alone and residues of active ingredients were much lower than using the insecticide in high dosage. Bridgeman (2000) also obtained satisfactory results when diatomaceous earth was combined with fumigation.

According to Kassis and Sawasan (2002), methoprene would be an effective alternative to synthetic pyrethroid for control of *Rhyzopertha dominica* and could be used in rotation program as part of resistance management strategy. Mixtures of methoprene (as Apex 5E) in combination with pirimiphos-methyl or carbophos (malathion) were developed for the control of the rice weevil, the grain borer (*Rhyzopertha dominica*), flour beetle and meal beetle (Kogteva and Zakladnolg, 2001). According to Arthur (2002), combinations of insecticidal pyrazole ethiprol, applied at the rates of 7.5, 10 ppm with deltamethrin, piperonyl butoxide and chlorpyrifos-methyl resulted in dead weevils after one week and no progeny weevils emerged.

In addition, Obeng-Ofori (1995) reported that oils and insecticide mixtures also completely inhibited the development of the eggs, early and late larval stages of *S. zeamais* compared to the treatments with oil or pirimiphos-methyl alone in which only the eggs and early larval instars were killed.

The current study showed that use of reduced rates of mixtures of the synthetic insecticide malathion dust and Mexican tea leaf powder controlled the maize weevil, as effective as synthetic insecticide at recommended rate. Therefore, using combination at reduced rate of malathion helps to reduced the amount of the pesticide to be used which minimizes the costs of control and treatment residue. Moreover, the combination could be applied in rotation with MTD and MTP as an integrated management of the pest to handle development of resistance. On the other hand, economic analysis (cost of treatments) showed that the least cost was obtained in T_6 from combined treatments and the maximum cost was recorded in T_1 (pure MTP). Even though all combined treatments showed similar effects in controlling the maize weevils after five months of storage time, treatment six (T_6) is the least cost and can be used by the farmers to over come the problem of weevils on stored maize (Fig. 2).

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