Persistence Evaluation of Some Insecticidal Plants and Application Rate to Maize Weevil Damage in Stored Maize Grain

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Abstract

A study was conducted to evaluate the persistence of insecticidal effects of some of botanicals and application on adult parent mortality of maize weevil in infested maize grain. Seven botanicals (Azadirachta indica (neem), Melia azedarach (melia), Parthenium hysterophorus (parthenium), Calpurnia aurea (calpurnia), Vernonia amygdalina (bitter leaf), Carica papaya (papaya) and Dichrocephala integrifolia) were tested each at three different rates viz, 2.5, 5 and 10% w/w. Malathion 5% dust at 0.05% as standard check and untreated check were included for comparison. Twenty unsexed adult weevils were re introduced to treated maize grains at 90 DAT and parent mortality was recorded at 93, 100, 107, 114, and 121 DAT. The experiment was laid out in a completely randomized design (CRD) in factorial arrangement and replicated four times. The result showed that A. indica, M. azedarach and D. integrifolia at all rates caused equal cumulative mortality (100%) with the synthetic insecticide, but the time required to totally kill the insects varied. All treatments caused significantly higher mortality than the untreated check after four months of storage.

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1. INTRODUCTION

Maize (Zea mays L.) is the most important cereal crop in Sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America (IITA, 2009). It provides 20% of the world’s food calories and 15% of all food crop protein (Meseret, 2011). According to the report from CIMMYT and IITA (2011), maize production is projected to double in the developing countries by the year 2050 and its global production surpasses all crops by 2025. In Ethiopia, out of 81.97% of land covered by cereals, 16.61% was maize, ranked second next to teff and it accounted for 24.5% of 87.29% yield obtained from cereals ranking first in production. This indicates that about 1,963,179.51 hectare of land was cultivated with maize and 49,861,254.95 quintal was produced with 25.4 qt/ha of yield (CSA, 2011).

Despite the worldwide continuous increase in the land coverage, production and demand for maize, there are multi-faceted production bottlenecks including arthropod pests in field and storage. More than 30 species of arthropods are recorded on stored maize in Ethiopia. The major insect pests of stored maize are the maize weevil (Sitophilus zeamais Motsch.), the Angoumois grain moth (Sitotroga cerealella Olivier), the larger grain borer (Prostephanus truncatus Horn), the tropical warehouse moth (Ephestia cautella Hubner), Indian meal moth (Plodia interpunctella Hubner), flour beetles (Tribolium spp.), and Cryptolestes spp. and etc. Some of these insects infest the ripening maize crop before harvest and at storage, and multiply further during storage (Abraham, 1991).

S. zeamais causes distinctive damage by making holes into the maize grain that is about 1 mm in size in which the adult female deposit eggs. The holes are sealed with a gelatinous waxy secretion. The eggs, larval and pupal stages of the insect take place within the grain after which the emerging adult weevil comes out of the grain via the holes, leaving visible hole on the grain (Rees, 2004; Sahaf et al., 2008) which invites infection and infestation by secondary pathogens and insects, respectively. Maize weevil damage results indirect food loss ready for consumption or cause cash loss. Maize weevil damage on maize grains also reduces the viability of the seeds as the larvae and adult consumes the embryo. Reports from Ethiopia indicate that post-harvest losses average 20 to 30% of grain dry weight in maize stored on farm due to the maize weevil. Grain damage levels of up to 100% have been reported in some grain samples from farm stores after 6 to 8 months of storage in the Bako area, West Shoa (Abraham, 1991).

The indiscriminate use of many synthetic insecticides, which is common practice among farmers, is associated with problems such as resistance of insect pests, food and food product contamination with toxic residues, increased cost of application, handling hazards, environmental contamination, biodiversity erosion and other negative impacts call for the development of alternative storage pest management. The use of locally available plants with insecticidal properties and inert materials to limit insect development and damage in stored grains is a common practice in developing countries (Firdisa and Abraham, 1999). In Ethiopia, farmers use different botanicals to protect their maize grain from insect infestation (Abraham, 2003), while the types of botanicals used vary from place to place. Although there is low implementation owing to low awareness amongst
farms, some studies made in the last decade have proved that there are certain botanicals which are reported to be effective at certain rates against the maize weevil on stored maize such as neem, melia, Mexican tea powder, datura, triplex and etc.

Presently, we can confidently say that farmers and responsible bodies are not using these botanicals as the first option due to different reasons, like absence of firm recommendation, low confidence, lack of knowledge of botanical preparation, and unavailability of recommended plants in the area. Therefore, studies on alternative botanicals which can be conveniently utilized by farmers, need to be given due consideration for stored grain pest management. Current study, therefore, undertaken with the objective of evaluating persistence efficacy of some of the locally available plants and their effective doses in reducing the adult parent mortality after 3 months of application.

2. MATERIALS AND METHODS

2.1. Description of the Laboratory
The experiment was conducted in the laboratory of National Maize Research Program at Bako, West Shoa Zone of the Oromia Regional State from September 2012 to April 2013. Laboratory conditions during the experimental season indicated that the mean daily minimum, maximum and average air temperatures of the laboratory was 21.7, 27.8 and 24.7°C, respectively. The minimum, maximum and average relative humidity was 52.99, 68.25 and 59.05%, respectively.

2.2. Preparation of Experimental Materials
Whole grain of maize hybrid BH-541 at 12-13% moisture content was used to rear the maize weevils. The seeds were sieved to remove any dirt, dust or broken seeds and stored at -20 ± 2°C for two weeks to disinfest them from any infestations. The disinfested grains were placed in plastic bags and kept for two more weeks at the experimental conditions for acclimatization as used by Girma (2006).

Adults with known age were obtained by culturing 500 unsexed adult maize weevils in two liter plastic jars containing 500g of disinfested maize grains and maintained under laboratory conditions. The jars were covered with muslin cloth and fixed with rubber band to allow aeration and prevent possible escape of weevils. The insects were allowed for one week to oviposit before they were sifted and placed on another set of grain kept for the same purpose. Starting from the commencement of progeny development in each jar, new emerged weevils were removed daily until the progeny emergence ceased. Those emerged on the same day were transferred to fresh grain in other containers reserved with whole grain and kept at the experimental conditions (Abraham, 1991).

Seven botanicals were evaluated for their efficacy to maize weevil (Table 1). Fruits of A. indica and M. azedarach were collected from Dire Dawa and Jiggiga, respectively. The leaves of V. amygdalina and D. integrifolia were collected from the road side in Nekemte town; P. hysterophorus and C. papaya from Sasiga around Nekemte and C. aurea from Hareto near Shambu town. The plant parts were allowed to dry under shade around Nekemte and C. aurea from Hareto near Shambu town. The plant parts were allowed to dry under shade temperature. The dried samples were ground separately to fine powder using mortar and pestle and the powder passed through a 0.25 mm mesh sieve to obtain a fine dust. Prepared powders then separately maintained in a plastic bag and stored in the refrigerator at 13°C for future use.

Table 1. List of botanicals and their parts used

| No | Scientific name (Family) | Common name | Part used |
|----|--------------------------|-------------|----------|
| 1  | Azadirachta indica A. Juss (Meliaceae) | Neem | Seed |
| 2  | Parthenium hysterophorus L. (Asteraceae) | Parthenium | leaf and stem |
| 3  | Melia azedarach L. (Meliaceae) | Melia | Seed |
| 4  | Calpurnia aurea Ait (Fabaceae) | Calpurnia | Leaf |
| 5  | Vernonia amygdalina Del (Compositae) | Bitter leaf | Leaf |
| 6  | Carica papaya L. (Caricaceae) | Papaya | Leaf |
| 7  | Dichrocephala integrifolia Kuntze (Asteraceae) | Not available | leaf and stem |

2.3. Treatment Application
Two hundred grams of disinfested and conditioned maize grain was added into glass jars of 250 ml capacity. Three different rates of each botanical viz, 2.5%, 5% and 10% (w/w) were weighed and added onto the grain in each of the jars with lids allowing ventilation. Malathion 5% dust at 0.05% w/w and untreated controls were included for comparison. The jars were well shaken to ensure proper mixture of grains with botanical and insecticide dust.

Adult weevils of 1 to 3 days old were thoroughly mixed and randomly picked for use. Thirty unsexed adult maize weevils were introduced into each glass jar and the jars were covered with muslin cloth and fixed by rubber band to allow sufficient ventilation and to prevent escape of the weevils. The experiment was laid out in completely randomized design (CRD) in four replications arranged factorially. The glass jars were maintained in the laboratory at room temperature. Temperature and relative humidity of the room were recorded daily until the end of the experiment.
2.4. Data Collection and Analysis
Treated jars were previously used for data collection for other studies and grains remaining in each jar, 20 unsexed adult weevils from the laboratory stock were re introduced at 90 DAT. Adult mortality was recorded at 3, 10, 17, 24 and 31 days after introduction (i.e. 93, 100, 107, 114, and 121 DAT). On the 31st day all of the insects were removed and counted as the same procedure employed in the preceded experiment. Count data for adult mortality were converted to percentage, corrected mortality was computed and angular transformed. The transformed data were then subjected to analysis of variance by using GeneStat version 15 computer software program. Mean separation was done by using Tukey test at 0.05.

3. RESULT AND DISCUSSION
The botanicals and their rates of application had significantly different persistence and affected the mortality of adult weevils when introduced at 90 DAT.
Following 93 DAT, the highest adult mortality (92.37%) was on grains treated with malathion and the lowest mortality (8.82%) on C. aurea 2.5% (Table 2). No mortality was observed on untreated grains. Meliaazedarach and A. indica, both at 10% w/w, caused relatively higher mortalities than the other botanical treatments. C. aurea, V. amygdalina and P. hysterophorus at 2.5% and 5% rates caused less mortality, but significantly more effective than the untreated check.
A. indica at 10% w/w was as effective as the synthetic insecticide (malathion) at 100 DAT and both of them caused 100% adult mortality (Table 3). Some of the treatments did not show significant differences when applied at 2.5% and 5% w/w. Dicrhocephala integrifolia and M. azedarach at 10% w/w caused relatively higher mortality than the rest treatments.

Table 2. Effects of botanicals and rates on percent of adult weevil mortality at 93 DAT

| Treatments         | Percent adult weevil mortality |
|--------------------|--------------------------------|
|                    | 2.5 (%) | 5 (%) | 10 (%) |
| C. aurea           | (8.82)  | (11.32)| (17.63)|
| D. integrifolia    | (26.51) | (38.03)| (59.47)|
| V. amygdalina      | (11.45) | (10.07)| (22.70)|
| M. azedarach       | (30.33) | (27.83)| (53.16)|
| A. indica          | (40.46) | (44.21)| (64.54)|
| C. papaya          | (20.33) | (24.08)| (26.51)|
| P. hysterophorus   | (8.88)  | (10.13)| (16.45)|
| Malathion          | (92.37) | (92.37)| (92.37)|
| Untreated check    | (0.00)  | (0.00) | (0.00) |

| LSD (5%) | 3.90 |
| CV (%)   | 8.70 |

Values in parentheses are untransformed means; mean separation was done with angular transformed values; means followed by the same letter(s) are not significantly different from each other at 5% level of significance by Tukey.

At 107 DAT, A. indica at 2.5 and 5%, D. integrifolia at 10% and M. azedarach at 10% resulted in 100% mortality while the mortality caused in the untreated check was 0% (Table 4). All of the treatments caused significantly higher mortality than the untreated check and D. integrifolia at 5% w/w caused relatively higher mortality than the rest botanical treatments.
Following 114 DAT the highest (100%) mortality was observed in D. integrifolia at 2.5% and 5% w/w while the mortality recorded in the untreated check was 0% (Table 5). All of the other treatments also caused significantly higher mortality than the untreated check. The increase in efficacy of D. integrifolia as the rate increase in the present study is similar with the result of Pone et al. (2013) who reported that the ethanolic leaf extract of D. integrifolia inhibited embryonation, egg hatch and larval survival of gastro-intestinal nematode parasite of mice (Heligmosomoides bakeri) at various concentrations when compared with the control and the extract with higher concentrations showed more activity than the extract with lower concentration.
Table 3. Effects of botanicals and rates on percent of adult weevil mortality at 100 DAT

| Treatments      | Percent adult weevil mortality | Rates (% w/w) |
|-----------------|--------------------------------|---------------|
|                 | 2.5                            | 5             | 10            |
| C. aurea        | (18.95) 25.41<sup>k</sup>      | (23.95) 28.94<sup>ij</sup> | (36.58) 37.08<sup>hi</sup> |
| D. integrifolia | (54.34) 47.51<sup>efg</sup>    | (77.37) 62.02<sup>cd</sup>  | (94.93) 76.99<sup>b</sup>  |
| V. amygdalina   | (24.21) 29.27<sup>ij</sup>     | (21.45) 27.44<sup>ij</sup>  | (46.71) 43.09<sup>h</sup>   |
| M. azedarach    | (61.97) 51.97<sup>dce</sup>    | (56.97) 49.02<sup>ef</sup>  | (94.93) 76.99<sup>b</sup>   |
| A. indica       | (87.37) 69.27<sup>b</sup>      | (87.24) 69.35<sup>bc</sup> | (100.00) 90.00<sup>a</sup>  |
| C. papaya       | (41.97) 40.30<sup>fg</sup>     | (49.47) 44.69<sup>eh</sup>  | (54.34) 47.51<sup>efg</sup> |
| P. hysterophorus| (19.08) 25.65<sup>i</sup>      | (21.58) 27.64<sup>ij</sup>  | (34.21) 35.76<sup>hi</sup>  |
| Malathion       | (100.00) 90.00<sup>b</sup>     | (100.00) 90.00<sup>b</sup>  | (100.00) 90.00<sup>a</sup>  |
| Untreated check | (0.00) 0.00<sup>k</sup>        | (0.00) 0.00<sup>k</sup>     | (0.00) 0.00<sup>k</sup>     |
| LSD (5%)        | 5.53                           |               |               |
| CV (%)          | 8.30                           |               |               |

Values in the parentheses are untransformed means; mean separation was done with angular transformed values; means followed by the same letter(s) are not significantly different from each other at 5% level of significance by Tukey.

At 121 DAT, significantly the highest adult mortality was observed in M. azedarach at 2.5% and 5% w/w, while there were no dead weevils recorded in the untreated check (Table 6). The efficacy of each treatment was increased in increase with rate of application and duration. This might be due to the fact that botanicals have long persistence effect. Tigist (2004) also suggested that natural pesticides could have direct or delayed insecticidal effects. The delayed effect is inhibition of reproduction and development by hampering oviposition, larval penetration into the seed and adult emergence. Generally, the present result suggests that all of the tested botanicals remained effective against the maize weevil at least for four months.

Table 4. Effects of botanicals and rates on percent of adult weevil mortality at 107 DAT

| Treatments      | Percent adult weevil mortality | Rates (% w/w) |
|-----------------|--------------------------------|---------------|
|                 | 2.5                            | 5             | 10            |
| C. aurea        | (34.14) 35.65<sup>g</sup>      | (34.08) 35.57<sup>g</sup>  | (69.54) 56.59<sup>ed</sup> |
| D. integrifolia | (75.92) 60.64<sup>c</sup>      | (94.93) 76.99<sup>b</sup>  | (100.00) 90.00<sup>a</sup> |
| V. amygdalina   | (41.91) 40.31<sup>fg</sup>     | (40.39) 39.40<sup>fg</sup>  | (63.16) 52.69<sup>de</sup> |
| M. azedarach    | (75.92) 60.64<sup>c</sup>      | (67.11) 55.04<sup>cd</sup>  | (100.00) 90.00<sup>a</sup> |
| A. indica       | (100.00) 90.00<sup>a</sup>     | (100.00) 90.00<sup>a</sup>  | nd            |
| C. papaya       | (52.11) 46.26<sup>ef</sup>     | (58.36) 49.85<sup>de</sup>  | (67.11) 55.12<sup>ed</sup> |
| P. hysterophorus| (34.21) 35.78<sup>g</sup>      | (43.09) 41.02<sup>fg</sup>  | (49.47) 44.69<sup>ef</sup> |
| Malathion       | (100.00) 90.00<sup>b</sup>     | (100.00) 90.00<sup>b</sup>  | (100.00) 90.00<sup>a</sup> |
| Untreated check | (0.00) 0.00<sup>k</sup>        | (0.00) 0.00<sup>k</sup>     | (0.00) 0.00<sup>k</sup>     |
| LSD (5%)        | 4.51                           |               |               |
| CV (%)          | 5.7                            |               |               |

Values in parentheses are untransformed means; mean separation was done with angular transformed values; means followed by the same letter(s) are not significantly different from each other at 5% level of significance (Tukey). nd:-- indicates no data was recorded since all the weevils dead previously.

Table 5. Effects of botanicals and rates on percent of parent adult mortality at 114 DAT

| Treatments      | Percent adult weevil mortality | Rates (% w/w) |
|-----------------|--------------------------------|---------------|
|                 | 2.5                            | 5             | 10            |
| C. aurea        | (49.34) 44.62<sup>hi</sup>     | (44.21) 41.65<sup>f</sup>  | (87.30) 69.23<sup>bd</sup> |
| D. integrifolia | (100.00) 90.00<sup>a</sup>     | (100.00) 90.00<sup>a</sup>  | nd            |
| V. amygdalina   | (59.61) 50.59<sup>ghi</sup>    | (59.34) 50.52<sup>hi</sup>  | (78.36) 62.47<sup>cde</sup> |
| M. azedarach    | (89.87) 71.44<sup>bc</sup>     | (94.93) 76.99<sup>b</sup>   | _             |
| A. indica       | (57.17) 49.25<sup>ghi</sup>    | (67.24) 55.25<sup>fg</sup>  | (77.24) 61.77<sup>def</sup> |
| C. papaya       | (49.34) 44.62<sup>hi</sup>     | (64.61) 53.53<sup>eh</sup>  | (63.42) 52.88<sup>fg</sup>  |
| P. hysterophorus| (19.08) 25.65<sup>i</sup>      | (21.58) 27.64<sup>ij</sup>  | (34.21) 35.76<sup>hi</sup>  |
| Malathion       | (100.00) 90.00<sup>b</sup>     | (100.00) 90.00<sup>b</sup>  | (100.00) 90.00<sup>a</sup>  |
| Untreated check | (0.00) 0.00<sup>k</sup>        | (0.00) 0.00<sup>k</sup>     | (0.00) 0.00<sup>k</sup>     |
| LSD (5%)        | 4.75                           |               |               |
| CV (%)          | 5.7                            |               |               |
Values in parentheses are untransformed means; mean separation was done with angular transformed values; means followed by the same letter(s) are not significantly different from each other at 5% level of significance (Tukey). nd:- indicates that no data was recorded since all the weevils dead previously.

Table 6. Effects of botanicals and rates on percent of parent adult mortality at 121 DAT

| Treatments     | Percent adult weevil mortality |
|----------------|--------------------------------|
|                | 2.5 (Rates (% w/w)) 5 10       |
| C. aurea       | (64.54) 53.56f (54.35) 47.51f  |
| D. integrifolia| — nd —                        |
| V. amygdalina  | (78.55) 62.56e (85.99) 68.69cde|
| M. azedarach   | (100.00) 90.00a (100.00) 90.00a|
| A. indica      | — —                          |
| C. papaya      | (65.99) 54.50f (79.87) 63.63g  |
| P. hysterophorus| (65.79) 54.22f (83.62) 66.29de|
| Malathion      | — —                          |
| Untreated check | (0.00) 0.00f (0.00) 0.00f     |

LSD (5%) 4.15  
CV (%) 4.3  

Values in parentheses are untransformed means; mean separation was done with angular transformed values; means followed by the same letter(s) are not significantly different from each other at 5% level of significance (Tukey). nd:- indicates that no data was recorded since all the weevils dead previously.

4. SUMMARY AND CONCLUSIONS

Plants with insecticidal properties are locally available; however, farmers lack adequate know-how about their benefits. Unlike synthetic chemicals, botanicals do not affect the environment, have no residual effects and are inexpensive. In this study, all the tested botanicals showed insecticidal properties with varying degrees and were significantly different from the untreated check.

Significant differences in the percentage of damaged grains and grain weight losses were noted among the botanicals. Among the botanical treatments the highest level of seed damage was recorded in C. aurea at 2.5% and the highest level of grain weight loss was recorded in grains treated with C. aurea and V. amygdalina both at 2.5, 5 and 10% w/w, while there was no seed damage and weight loss recorded in grains treated with A. indica at all rates. Generally, percentage of damaged grains and grain weight losses were lower in all botanical treatments than in the untreated check. On the other hand, the botanicals did not negatively affect the seed germination.

Although this study showed existence of the potentials of some botanicals in controlling the maize weevil on maize grain, further research is needed to determine the active ingredients and mode of action of the botanicals, and it is essential that trials be also carried out to investigate the responses which would be observed under real farm conditions, such as fluctuating ambient climatic conditions, continuous disturbance of grain by the family itself and a complex of insect pest species and also the effects of store design and structure since this laboratory based and short duration study may not be enough for the final recommendation. It is also important to investigate how long these botanicals can further remain active in reducing F1 progeny development, seed damage, weight loss and retaining viability.

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