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Effects of some insecticidal plants and their application rates on adult mortality and progeny development of Maize Weevil, *Sitophiluszeamais* (Motsch) in Stored Maize Grain

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Abstract

A study was conducted to evaluate the effects of some of insecticidal plants and their rate of application on adult parent mortality and progeny development 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. The experiment was laid out in a completely randomized design (CRD) in factorial arrangement and replicated four times. Data on parent mortality and progeny development were collected. Parent mortality was assessed at 3, 10, 17, 24 and 31 days after treatment (DAT). F_1 progeny was assessed from 35 to 75 DAT, but data analysis was done for counts after 45 to 65 DAT. The results showed that the F_1 progeny development was highly significantly ($P \leq 0.01$) affected by the botanicals, while the parent adult weevil mortality was highly significantly ($P \leq 0.01$) affected by the botanicals and rate of application. Among the tested botanicals, A. indica caused the highest adult mortality (100%) at variable durations and highly inhibited the F_1 progeny development (3.5) at 65 DAT. All of the botanicals showed insecticidal property but the degree of their efficiency varied with the rate of application and duration of storage. D. integrifolia and M. azedarachat 10% w/w resulted in highest cumulative parent weevil mortality (100%). The treatments of D. integrifolia and M. azedarach also resulted in low progeny emergence (7.25 and 6.5, respectively).

Keywords: Botanicals, *Dichrocephala integrifolia,* Adult mortality, Progeny development, Maize weevil.

Introduction

Maize (*Zea mays* L.) is the major staple food for more than 1.2 billion people in sub-Saharan Africa and Latin America[1] providing world's 20% and 15% of food calories and crop protein respectively[2]. According to the report from CIMMYT and IITA[3], 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[4].

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. In Ethiopia thirty or more arthropod species were found infesting maize in storage among which maize weevil, Angoumois grain moth, tropical warehouse moth, larger grain borer, Indian meal moth, flour beetles, and many others were the major insect pests. Some of these insects infest the ripening maize crop before harvest and at storage, and multiply further during storage[5].

The maize weevil, *Sitophilus zeamais* causes distinctive damage by making about 1 mm sized holes into the maize grain. The adult female then lay her eggs in the hole and it will be sealed with a gelatinous waxy secretions. 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[6,7] 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. About 100% seed damage was reported in grain samples from Bako area in farm stores after 6 to 8 months of storage[5].

The indiscriminate use of many synthetic insecticides, which is common practice among farmers, and its associated drawbacks including pest resistance, toxic residues in the stored product, application cost increase, safety in chemical handling, contamination of the environment and biodiversity erosion 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 grain damage during the storage is known practice in some developing countries like Ethiopia[8,9] with variety of botanical types used as per the indigenous knowledge of farmers. Although there is low implementation owing to low awareness amongst farmers, 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 the efficacy of some of the locally available plants and their effective doses in reducing the adult parent mortality and progeny development.

Materials and methods

Description of the Study Area: The experiment was done in National Maize Research Program laboratory of in Bako, West Shoa Zone, Oromia Region, Ethiopia from September 2012 to April 2013. The respective mean daily minimum, maximum and average air temperature and relative humidity of the laboratory at the experimental season were 21.7, 27.8, 24.7°C and 52.99, 68.25, 59.05% respectively.

Collection and Preparation of Experimental Materials: Maize grain BH-541 hybrid at 12-13% moisture content was used to rear the maize weevils. The seeds were cleaned from any dirt and damaged seeds and stored at -20 ± 2°C for 14 days to disinfest them from any infestations. The disinfested grains were placed in plastic bags and kept for another 14 days to acclimatize to experimental conditions as used by Girma[10].

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. To allow aeration and prevent escape, the jars were covered with muslin cloth and fixed with rubber band. The insects then allowed for one week to oviposit before they were sifted and moved to another set of grain kept for the same purpose. Starting from the commencement of progeny development in each jar, new emerged weevils were daily collected up to the stop of progeny emergence. F1 progeny of similar age (those emerged on similar day) were moved to another jar with fresh whole grain and kept at the experimental conditions[5].

Seven botanicals were tested against *S. zeamais* (Table-1). Fruits of *A. indica* and *M. azedarach* were collected from Dire Dawa and Jigjiga, respectively. The leaves of *V. amygdalina* and *D. integrifolia* were collected 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 at room temperature. The dried samples were individually ground by wooden mortar and pestle and the powder were sieved by 0.25 mm size mesh to maintain plastic bag and store in the refrigerator adjusted to 13°C until used.

Table-1: Description of botanicals used.

Scientific name (Family)	Common name	Part used
Azadirachta indica A. Juss (Meliaceae)	Neem	Seed
Parthenium hysterophorus L. (Asteraceae)	Parthenium	leaf and stem
Melia azedarach L. (Meliaceae)	Melia	Seed
Calpurnia aurea Ait (Fabaceae)	Calpurnia	Leaf
Vernonia amygdalina Del (Compositae)	Bitter leaf	Leaf
Carica papaya L. (Caricaceae)	Papaya	Leaf
Dichrocephala integrifolia Kuntze (Asteraceae)	Not available	leaf and stem

Treatment Application: Two hundred grams of disinfested and conditioned maize grain was added into glass jars of 250ml 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. To allow aeration and prevent escape, the jars were covered with muslin cloth and fixed with rubber band. The experiment was laid out in completely randomized design (CRD) in four replications with factorial arrangement. The glass jars were maintained in the laboratory at room temperature. Daily temperature and RH of the experimental room were recorded up to the end of the experiment.

Data collection and analysis: Data on parent mortality and progeny development were collected. Parent mortality was assessed at 3, 10, 17, 24 and 31 days after treatment (DAT). The grain in each jar was carefully poured out on a white paper for inspection. Dead weevils were counted and removed, while those which were alive returned back into their respective jars. On 31 DAT, all weevils (dead and alive) were removed and counted. The grains under different treatments were retained under the same conditions of temperature and relative humidity to evaluate the F1 progeny development. The mortality data were corrected for control mortality using Abbott's formula mentioned by Semple[11].

$$PT = \frac{\text{PO} - \text{PC}}{100 - \text{PC}} \text{ X } 100$$

Where PT=corrected mortality; PO=observed mortality in treated jar and PC=control mortality (mortality in untreated jar).

As Abraham[5] reported, the mean time for development of *S. zeamais* was 42 days (ranged between 35 and 47) at the study site. Based on this information, starting 35 DAT the emerged progeny weevils were counted and recorded by sieving method at an interval of five days until the emergence ceased. The emerged and counted weevils were picked and transferred to another jar on each assessment day. The F_1 progeny was counted at 35 to 75 DAT and data analysis was done for counts after 45 to 65 DAT. Count data for adult mortality were converted to percentage, corrected mortality was computed and angular transformed. Counted F_1 progeny data were transformed by square root transformation method. The transformed data were then subjected to analysis of variance by using Gene Stat version 15 computer software program. Mean separation was done by using Tukey test at 0.05.

Results and discussion

Parent adult mortality: The percent adult mortality analysis at different dates after treatment indicated that botanicals and rates of application affected parent adult mortality highly and significantly (P≤0.01). All of the treatments caused higher parent adult mortality compared to the untreated check at each assessment dates. At three DAT the highest parent mortality (100%) was recorded in the treated check, while in the untreated check the rate of mortality was zero (Table-2). *Calpurnia aurea* and *P. hysterophorus* at 2.5% w/w caused the lowest parent mortality (3.45%) among the botanical treatments which was statistically higher than that of the untreated check. Even though *A. indica* 10% caused the highest percent of parent mortality (41.38%) as compared to other botanicals, its efficiency was much lower than the synthetic insecticide treatment. This could be due to the slow action of *A. indica* at early application. Adane and Abraham[12] reported the gradual action of botanicals such as leaf powder of *A. indica* and Persian lilac against *S. zeamais* and they recorded the maximum mortality at 28 days after treatment application. Fikremariam[13] also reported that one day after treatment application; all of the tested botanicals showed no significant difference over the untreated check except for a few treatments, unlike the seeds treated with Actellic 2% and malathion 5% dusts which showed 100% adult mortality.

Azadirachta indica 10% treatment caused complete mortality (100%) while the untreated check did not caused any mortality at 10 DAT (Table-3). *Calpurnia aurea*, *V. amygdalina* and *P. hysterophorus* at 2.5% and 5% w/w caused less mortality, but significantly effective than the untreated check. The efficiency of *A. indica* at the rate of 10% increased by 58.62% at 10 DAT as compared to 3 DAT and this result is in line with the report of Fikremariam[13] who found that the efficacy of *A. indica* leaf and seed powders increased through time and high mortality was recorded after seven days of application.

Following 17 DAT, the highest mortality (100%) was recorded in the grains treated with *A. indica* at 5% and *M. azedarach* at 10% w/w (Table-4). At the lowest rates all of the botanicals except *A, indica*, *M. azedarach* and *D. integrifolia* caused less mortality, but significantly higher than 0% mortality recorded in the untreated check. *Azadirachta indica* 2.5% and *D. integrifolia* 10% caused the second highest mortality as compared with that of all botanicals with the exception of *M. azedarach* at 10% w/w.

Table-2: Effects of botanicals and their rates on percent adult weevil mortality at 3 DAT.

Treatments on Botanicals	Percent adult weevil mortality		
	Rates (% w/w)		
	2.5	5	10
C. aurea	(3.45) 9.16^{k}	(5.17) 12.72^{ijk}	(9.48) 17.75^{hij}
D. integrifolia	(15.52) 23.17^{fgh}	(23.28) 28.81^{def}	(37.93) 38.01^{bc}
V. amygdalina	(5.17) 12.72^{ijk}	(4.31) 11.83^{jk}	(12.93) 21.04^{gh}
M. azedarach	(18.10) 25.16^{efg}	(16.38) 23.85^{fgh}	(33.62) 35.42^{bcd}
A. indica	(25.00) 29.99^{def}	(27.59) 31.66^{cde}	(41.38) 40.03^{b}
C. papaya	(11.21) 19.32^{ghi}	(13.79) 21.72^{gh}	(15.52) 23.17^{fgh}
P. hysterophorus	(3.45) 9.16^{k}	(4.31) 11.83^{jk}	(8.62) 16.99^{hij}
Malathion	(100.00) 90.00^{a}	(100.00) 90.00^{a}	(100.00) 90.00^{a}
Untreated check	(0.0) 0.0^{l}	(0.0) 0.0^{l}	(0.0) 0.0^{l}
LSD (5%)	3.65		
CV (%)	9.50		

Values in parentheses are untransformed corrected mortality means; mean separation was done with angular transformed values; the superscript letters indicate similarity of the means; means with similar letter(s) have no significant difference at 5% (Tukey).

Girma[10] reported that neem seed powder at 2% w/w was as effective as pirimiphos-methyl at 15 DAT in terms of adult mortality. Similarly to the present result, the effectiveness of *M. azedarach* has been reported by many authors. Saljoqi *et al.*[14] found that *M. azedarach* showed repellent and lethal effects against the rice weevil and its ethanol extract was the most effective from all of the tested plants. Solomon[15] and Fikeremariam[13] also tested the seed powder of *M. azedarach* and it was significantly caused adult death, reduced F1 progeny development and reduced grain weight loss than control treatment. However, it was also reported that the melia leaf extract was not effective against the maize weevil[16].

Table-3: Effects of botanicals and their rates on percent adult weevil mortality at 10 DAT.

Treatments on Botanicals	Percent adult weevil mortality		
	Rates (% w/w)		
	2.5	5	10
C. aurea	(7.11) 13.30^{i}	(10.71) 18.52^{ghi}	(19.64) 26.08^{fgh}
D. integrifolia	(32.14) 34.51^{ef}	(52.68) 46.54^{cd}	(87.50) 69.47^{b}
V. amygdalina	(10.71) 18.52^{ghi}	(8.93) 17.18^{hi}	(26.79) 31.13^{ef}
M. azedarach	(37.50) 37.75^{de}	(56.25) 48.59^{c}	(83.04) 65.88^{b}
A. indica	(80.36) 3.75^{b}	(91.07) 73.53^{b}	(100.00) 90.00^{a}
C. papaya	(23.21) 28.51^{efg}	(28.57) 32.22^{ef}	(32.14) 34.51^{ef}
P. hysterophorus	(7.14) 13.30^{i}	(8.93) 17.18^{hi}	(17.86) 24.89^{fgh}
Malathion	ND	_	_
Untreated check	(0.0) 0.0^{j}	(0.0) 0.0^{j}	(0.0) 0.0^{j}
LSD (5%)	5.55		
CV (%)	9.90		

Values in parentheses are untransformed corrected mortality means; mean separation was done with angular transformed values; the superscript letters indicate similarity of the means; means with similar letter(s) have no significant difference at 5% (Tukey); nd: denotes that no data was recorded since all of the weevils were dead previously.

A complete suppression of the adult weevils by *D. integrifolia* was observed when used at the rate of 10%, and at 5%, relatively high mortality was recorded by *D. integrifolia* (76.14%) and *M. azedarach* (76.97%) as compared with the other botanicals. It was reported that *D. integrifolia*is culturally used to treat blindness and anthrax in animals[17] and the leaves are used on wounds and cuts[18]. Although the report is being locked on its insecticidal property, the screening study of the phytochemical extracts of this plant showed alkaloid was one of the chemicals detected[19]. The chemical effect of the plant was tested on different strains of bacteria. Compounds such as carotenoids, flavonoids, phytosterols, alkaloid, and tannins are assumed to be reasons for its observed antimicrobial activities even though its efficiency was lower than that of the standard antibiotics (ciprofloxacin) through the study.

Generally, *D. integrifolia* exhibited its phytochemical effect on *E. coli*, *S. aureus* and *S. typhi*, backing the traditional usage of the plant in local community. Another study also indicated the nematicidal effect of *D. integrifolia*on *Heligmosomoidesbakeri*, the gastro intestinal parasite of mice[20]. The present result also showed that the plant has insecticidal property on *S. zeamais* which varied with the rate of application and duration of storage.

Table-4: Effects of botanicals and their rates on percent adult weevil mortality at 17 DAT.

Treatments on Botanicals	Percent adult weevil mortality		
	Rates (% w/w)		
	2.5	5	10
C. aurea	(17.86) 23.80^{i}	(27.68) 31.25^{f-i}	(45.54) 42.43^{def}
D. integrifolia	(50.00) 45.00^{cde}	(61.61) 51.78^{cd}	(93.75) 75.65^{b}
V. amygdalina	(20.54) 26.63^{hi}	(22.32) 27.74^{ghi}	(41.96) 40.32^{def}
M. azedarach	(45.54) 42.43^{def}	(66.96) 54.92^{c}	(100.00) 90.00^{a}
A. indica	(95.54) 77.95^{b}	(100.00) 90.00^{a}	$\_^{nd}$
C. papaya	(32.14) 34.49^{e-i}	(35.71) 36.68^{e-h}	(39.29) 38.76^{efg}
P. hysterophorus	(16.96) 24.08^{i}	(29.79) 31.00^{f-i}	(33.93) 35.53^{e-i}
Malathion	_	_	_
Untreated check	(0.0) 0.0^{j}	(0.0) 0.0^{j}	(0.0) 0.0^{j}
LSD (5%)	6.21		
CV (%)	9.30		

Values in parentheses are untransformed corrected mortality means; mean separation was done with angular transformed values; the superscript letters indicate similarity of the means; means with similar letter(s) have no significant difference at 5% (Tukey); nd: denotes that no data was recorded since all of the weevils were dead previously.

At 31 DAT, the highest mortality (87.77% and 84.34%) was caused by *D. integrifolia* and *M. azedarach* at 5% w/w, respectively (Table-6).

The synthetic insecticide, *A. indica* at all rates, *M. azedarach* and *D. integrifolia* at 10% w/w were killed all of the adult weevils introduced to the grains before they reached 31 DAT. *Calpurnia aurea* at 2.5 and 5% caused less mortality, but significantly higher than the untreated check. Traditionally farmers use *C. aurea* to wash animals to disinfest them from ticks. *C. aurea* was reported to have insecticidal activities[21-23]. Its water extract at 10% found to reduce the tick movements and suggested to be used when there is no solvent available other than water[24].

Table-5: Effects of botanicals and their rates on percent adult weevil mortality at 24 DAT.

Treatments on Botanicals	Percent adult weevil mortality		
	Rates (% w/w)		
	2.5	5	10
C. aurea	(22.97) 28.47^{f}	(31.07) 33.50^{def}	(60.99) 51.45^{bc}
D. integrifolia	(53.97) 47.42^{bcd}	(76.14) 61.65^{b}	(100) 90^{a}
V. amygdalina	(26.48) 30.86^{ef}	(30.17) 33.18^{def}	(48.80) 44.28^{cde}
M. azedarach	(51.26) 45.73^{cd}	(76.97) 61.37^{b}	ND
A. indica	(100) 90^{a}	–	–
C. papaya	(35.34) 36.45^{def}	(45.10) 42.19^{c-f}	(51.35) 45.79^{cd}
P. hysterophorus	(22.97) 28.47^{f}	(40.64) 39.52^{c-f}	(45.01) 42.12^{cdef}
Malathion	–	–	–
Untreated check	(2.59) 4.69^{g}	(2.59) 4.69^{g}	(2.59) 4.69^{g}
LSD (5%)	7.65		
CV (%)	10.40		

Values in parentheses are untransformed corrected mortality means; mean separation was done with angular transformed values; the superscript letters indicate similarity of the means; means with similar letter(s) have no significant difference at 5% (Tukey); nd: denotes that no data was recorded since all of the weevils were dead previously.

The study showed that *V. amygdalina*, *C. papaya* and *P. hysterophorus* were less active than the other botanicals especially at the lowest rate. However, they caused significantly higher mortality than the untreated check. Asawalam and Hasanali[25] assessed the bioactivity of the essential oil extracted from *V. amygdalina* against *S. zeamais* in maize grain and found that it significantly reduced progeny development and evoked a high repellent action. Eucalyptol was found to be the highest component in *V. amygdalina* oil. The insecticidal activity of its leaf powder was also compared to chemical insecticide against the larvae of *Collosobruchus maculatus* and *S. zeamais* and provided substantial control[26].

Table-6: Effects of botanicals and their rates on percent adult weevil mortality at 31 DAT.

Treatments on Botanicals	Percent adult weevil mortality		
	Rates (% w/w)		
	2.5	5	10
C. aurea	(24.79) 29.48^{e}	(29.19) 31.98^{de}	(59.48) 50.53^{bc}
D. integrifolia	(66.41) 55.78^{ab}	(87.77) 70.11^{a}	ND
V. amygdalina	(25.00) 29.96^{e}	(34.20) 35.54^{cde}	(53.37) 46.95^{bcd}
M. azedarach	(50.27) 45.16^{bcd}	(84.34) 66.82^{a}	–
A. indica	–	–	–
C. papaya	(36.06) 36.90^{cde}	(47.18) 43.39^{b-e}	(57.21) 49.19^{bc}
P. hysterophorus	(25.00) 29.65^{e}	(45.26) 42.23^{b-e}	(53.85) 47.28^{bc}
Malathion	–	–	–
Untreated check	(2.59) 4.69^{f}	(2.59) 4.69^{f}	(2.59) 4.69^{f}
LSD (5%)	7.79		
CV (%)	10.4		

Values in parentheses are untransformed corrected mortality means; mean separation was done with angular transformed values; the superscript letters indicate similarity of the means; means with similar letter(s) have no significant difference at 5% (Tukey); nd: denotes that no data was recorded since all of the weevils were dead previously.

Mulungu *et al.*[27] evaluated different plant products on maize weevil and found that *C. papaya* leaf powder effectively reduced the insect population, which is in line with the present results. Similarly, the number of damaged seeds and grain weight loss were relatively less in the grains treated with *C. papaya* leaf powders than the untreated check. It was reported that *P. hysterophorus* has insecticidal property and contain the toxin sesquiterpene lactones[28,29]. In addition, Parthenin and other phenolic acids viz, chlorogenic acid, anisic acid, parahydroxybenzoic acid and caffeic acid, which are lethal to animals including human being, were found in *P. hysterophorus*[30]. The extract from parthenium was found to be repellent against *Tribolium castaneum*[31].

In a field study by Melanie *et. al.*[32] shade dried *P. hysterophorus* leaf water extracts were tested against *Lipaphis erysimi* on *Brassica juncea*. The population density of *L. erysimi* was reduced down to 29% of the initial in festation three days after extract application.

Araya[33] also tested different botanicals, including *P. hysterophorus* on *Zabrotes subfasciatus* in stored common bean, and found that *P. hysterophorus* showed less efficiency to control the insect than the other treatments. The disparity of the studies could be due to the plant part used and processed.

Progeny development: The results of progeny development indicated that the effects of the botanicals were highly significant ($P \leq 0.01$), while the interaction effects of botanicals and rates were not significant.

There was no F_1 progeny developed in malathion 5% treatment and significantly highest number of F_1 progenies (59.6) emerged from the untreated check at 65 DAT (Table-7). Relatively low number of F_1 progenies emerged from *A. indica* treatment (3.5), *D. integrifolia* (7.3) and *M. azedarach* (6.5).

The significant reduction in parent weevil survival and progeny emergence in the *A. indica* treatment is in agreement with the study which found that neem seed powder at 2.5 or 5% when mixed with the maize grain reduced oviposition by *S. oryzae* and stopped its postembryonic development[28].

Abraham[9] also reported that neem seed powder at 2% w/w and above suppressed progeny emergence in maize weevil and in another study the leaf powders of neem, pepper tree, melia, Mexican marigold and lantana showed significant differences in terms of the number of F_1 progeny of the bean bruchid, *Zabrotes subfaciatus*[34].

It was also found that finely crushed and sieved seeds of *M. azedarach* mixed with grain at 1 % to 2% ratio or leaf powder mixed at 4 to 8% ratio provided a good protection to grain stock from the Angoumois grain moth (*Sitotroga Cerealella*) for over 135 days[35]. Similarly, it was also reported that treatment with leaf of wild oil nut, croton and seed of *M. azedarach* protected the maize seeds by 92.2, 86.7 and 85.5%, respectively[13].

This study indicated that all of the botanicals also reduced the F_1 progeny emergence. Likewise, Adane and Abraham[12] reported that the number of emerged F_1 progenies were significantly different in grains treated with 17 plant species that were tested for their efficacy against the maize weevil.

The marked differences in adult mortality and progeny emergence between each treatment showed that there is significant effect of the tested botanicals on adult development and subsequent effect on the F_1 progeny emergence due to the ovicidal and larvicidal properties.

Table-7: Effects of botanicals and their rates on F1 progeny development at 65 DAT.

Treatments	F_1 Progeny development
	65 DAT
C. aurea	(17.33) 4.18^b
D. integrifolia	(7.25) 2.60^c
V. amygdalina	(15.17) 3.84^b
M. azedarach	(6.50) 2.54^c
A. indica	(3.50) 1.82^c
C. papaya	(19.42) 4.39^b
P. hysterophorus	(17.83) 4.24^b
Malathion	(0.00) 0.71^d
Untreated check	(59.58) 7.73^a
LSD (5%)	0.57
Rate (%)	
2.5	(17.08) 3.69
5.0	(15.89) 3.57
10.0	(15.89) 3.42
LSD (5%)	NS
CV (%)	19.60

Values in parentheses are untransformed means; mean separation was done with square root transformed values ($\sqrt{X+0.5}$); the superscript letters indicate similarity of the means; means with similar letter(s) have no significant difference at 5% (Tukey); NS: denotes non-significant.

Ofuya[36] suggested that inhibition of oviposition by adult bruchids resulted in fewer eggs in addition tolarval mortality. According to another study, groundnut stored with kernel powder of the neem seed at 5% w/w was resulted in reduced progeny emergence of *Caryedon serratus* comparably to that of the treated check[37]. Araya[33] reported different levels of protection by different plants, but the leaf powder of *P. hysterophorus* resulted in non-significant difference with control check. However, other studies showed the efficiency of its leaf and seed powder to reduce the F_1 progeny emergence in some cereal storage insects[38-40].

Conclusion

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.

Observations at various dates showed that all botanicals were significantly different from the untreated check in causing parent weevil mortality. Despite their gradual killing, 31 days after exposition, *A. indica* at all rates, *M. azedarach* and *D. integrifolia* at 10% w/w were equally effective with the synthetic insecticide. F_1 progeny emergence in all treatments was significantly lower than that of the untreated check. Moreover, higher F_1 progeny of weevils were noted in the grains treated with *C. aurea*, *V. amygdalina*, *C. papaya* and *P. hysterophorus* after different durations, but significantly lower than the untreated check.

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 F_1 progeny development, seed damage, weight loss and retaining viability.

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