Evaluation of selected botanicals for the management of maize weevil (*Sitophilus zeamais*) on maize (*Zea mays* L.) grain under laboratory condition in Gabilay District, Somaliland

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**ABSTRACT**

One of the most reliable crops in the research region is maize. However, a variety of post-harvest insect pests like *Sitophilus zeamais* and Angoumois grain moths pose a hazard to the cultivation and storage of maize. Hence, a laboratory experiment was conducted in Gabilay District Somaliland in 2021 to assess selected botanicals effectiveness against maize weevil. The treatments of consisted of six botanicals namely neem seed, neem leaves, garlic, lantana, ginger, and pepper tree leaves at 50 g/kg of each were evaluated. Malathion 5% dust at 0.05 g/kg as standard check and the control/untreated check/were included for comparison. The Experiment was designed in a Completely Randomized Design and replicated three times, All the botanical powders were more effective than the control by causing high insect mortality, by lowering grain damage, weight loss, and emergence of F1 progeny. Neem seed and Garlic showed 100% adult mortality, which had a similar effect to Malathion 5% dust. Neem seeds produced the lowest F1 offspring, followed by garlic. Neem seeds and garlic had the least amount of seed damage among the botanicals (0%) and (4%), respectively. The control/untreated check resulted in the most seed damage (45%). Similarly, the highest weight loss among the botanicals was recorded on the control check, Ginger and Pepper tree 11%, 5%, and 4% respectively. The ability of seeds to germinate was unaffected by the botanicals. A conclusion, neem seed and garlic leaves are the most effective treatment against maize weevil.

1. **Introduction**

One of the grains that are most widely grown worldwide is maize (*Zea mays* L.). Because of its extremely high yield potential, it is frequently referred to as the “queen of cereals” (Nand, 2015). After rice and wheat, maize is one of the three most significant cereal crops that belong to the Gramineae family (Lyon, 2000). For a huge portion of the world, including Africa, Latin America, and Asia, maize is a staple grain (Yaouba et al., 2012). Around 75 million tons of maize was produced in Africa in 2018, accounting for 7.5% of global maize production. In Africa, maize accounts for roughly 24% of arable land, with an average output of two tons per hectare per year (FAO, 2019). In Somaliland, maize production ranked the second in production of all cereal crops next to sorghum, which is concentrated in the western part of the country, particularly the Gabilay region. This crop can be cultivated once a year under rain feed conditions in different parts of the country, especially the western part (Mukhtar, 2020).

The maize weevil, the primary storage insect pest of maize, poses a significant difficulty during the postharvest phase of maize grain (Nwosu, 2018; Ileke et al., 2020). Although this weevil starts its infestation in the field, the majority of the damage is done during storage (Demissie et al., 2008). Various control approaches and strategies have been developed, and more are still being worked on, to help reduce significant losses during storage. Artificial chemical control techniques have effectively stopped the destructive activities of insects and other storage pests. These techniques include fumigating stored goods with carbon disulfide or phosphine or dusting with Malathion, carbaryl, pirimiphos-methyl, or permethrin (Ileke and Oni, 2011).

On suppress storage pests, synthetic insecticides have been applied to grains on a large scale (Rajashekar et al., 2012). However, there is a widespread worry regarding environmental risks, chemical residues on food, the emergence of pesticide resistance, and related expenses (Cherry et al., 2005). Currently, the utilization of medicinal plant material as grain protectors is receiving attention (Longe, 2010).

As a fast-growing tree, neem (*Azadirachta indica*) originated in the India and is now found throughout Asia, Africa, and Central America. It is among the most researched and promising species worldwide. In a study...
conducted by Koul (2004), the volatile compound diallyl disulfide isolated from neem proved to be toxic, fumigant, and an effective deterrent to stored seed pests. These pests included Sitophilus zeamais, Sitophilus oryzae, and Tribolium castaneum. The lantana shrimp (Lantana Camara L.) has colourful flowers and is often referred to as red-flowered sage, wild sage, or white sage (Saxena and Tripathi, 1981). Lantana Camara leaves has been shown to be insecticidal (Dua et al., 2010). As a highly invasive shrub, it provides homes with protection against pest insects and thickets of insects (Daisy, 2014).

In the absence of improved storage structures and storage practices, the maize weevil is the most prevalent problem in the storage of maize products, which results in significant nutritional and economic losses for farmers (20%–40%) (Hared, 2014). Therefore, it was important to study the evaluations of botanicals against maize weevil as management option in Somaliland at the Gabilay District.

2. Material and methods

2.1. An explanation of the research area

The investigation was conducted in Somaliland’s Gabilay District, where maize and botanicals are collected for the laboratory experiment. Gabilay is located in a valley in the Galgodon (Ogo) highlands, and sites where maize and botanicals are collected for the laboratory experiment. The investigation was conducted in Somaliland’s Gabilay District, where maize and botanicals are collected for the laboratory experiment. Gabilay is located in a valley in the Galgodon (Ogo) highlands, and sites where maize and botanicals are collected for the laboratory experiment. Gabilay is located in a valley in the Galgodon (Ogo) highlands, and sites where maize and botanicals are collected for the laboratory experiment. Gabilay is located in a valley in the Galgodon (Ogo) highlands, and sites where maize and botanicals are collected for the laboratory experiment. The investigation was conducted in Somaliland’s Gabilay District, where maize and botanicals are collected for the laboratory experiment. Gabilay is located in a valley in the Galgodon (Ogo) highlands, and sites where maize and botanicals are collected for the laboratory experiment.

2.2. Treatments and experimental design

The total treatments of the experiment were eight, which consist of six botanicals, the standard check (Malathion Dust 5%), and the control were included as comparisons. The botanicals were namely neem seed (Azadirachta indica), neem leaf (Azadirachta indica), lantana leaf (Lantana camara), garlic leaf (Allium sativum) peppercorn tree leaf (schinus molle), and ginger rhizome (Zingiber officinalis). The experiment had a factorial layout and a Completely Randomized Design (CRD) that was repeated three times.

2.3. Collection and preparation of plant materials

2.3.1. Botanicals like lantana, neem, and pepper tree were collected around the experimental site, while garlic and ginger were purchased from the market

The plant products were then cleaned with distilled water and dried after a further two weeks in the shade. The dried leaves and seeds were ground with a mortar and pestle, then sieved. In order to prevent loss of quality, polythene bags were used to store and seal the powders at room temperature (Chayengia et al., 2010).

2.4. Rearing of maize weevil

In order to obtain the same kind of age group, quantity of adults, and quantity of weevils for the experiment, a culture of maize weevils was developed. At a local market, we purchased about fifty kilograms of maize infested with weevils. During rearing, the weevil was maintained at 26 °C and about 71% relative humidity. Health grains were stored in a freezer at 20 °C for two weeks to disinfest pests after being discarded if they had visible damage. Moreover, for adaptation grains were stored for two additional weeks under experimental conditions (Goftishu and Belete, 2014). Adult unsexed maize weevils were cultured on infested grains in plastic jars on disinfested grains. There were 300 adult weevils infesting each jar containing 2 kg of maize grains. The jars were covered with muslin cloth to keep weevils from escaping. After one week, all parent weevils were counted and discarded. The experiment was conducted using newly emerged adult weevils (Alemnew, 2017).

2.5. A botanical approach to maize weevil control

A 1-L plastic jar was filled with approximately 200 g of maize, and 50 g/kg of each botanical was mixed in with the grains (Abebe, 2005; Abdi, 2011; Alemnew, 2017). A standard check was performed using 0.05 g/kg of malathion 5% dust, along with a control check. Thirty mature maize weevils, unsexed, were placed in each jar. Glass jars were covered with muslin cloth and fastened with rubber bands to prevent weevils from escaping (Alemnew, 2017).

2.6. Data collected

2.6.1. Effect of botanicals on parent adult mortality and F1 progeny

The data on the number of dead and alive parent adult weevils’ were recorded at the intervals of 1, 5, 10, 15, 21, and 28 days after infestation with the weevils. The live adults were kept for treatment while the dead adults were counted and discarded. After 28 days, all weevils, dead and alive, were thrown away. Using nylon mesh roofs on jars containing maize grains, the F1 progeny were assessed. Observation and removal of F1 progeny weevils were carried out for 58 days after they emerged. For four weeks, each F1 adult was counted once per week to eliminate generation overlap. Evans (1985) reported that most F1 offspring emerge during this time period.

2.6.2. Protection of grain from F1 progeny

In order to evaluate which treatments were most effective at protecting grain from F1 descendants, different treatments were applied. According to the techniques utilized by (El-Ghar et al., 1987) as in Eq. (1), the formula of percentage reduction in adult emergence or inhibition rate (% IR) was used to determine which treatment inhibited the emergence of F1 progenies.

\[
\text{Percentage protection} = \frac{\text{Total F1 progeny in control} - \text{Total F1 progeny in treatment}}{\text{Total F1 progeny in control}} \times 100 \tag{1}
\]

2.6.3. Grain weight loss assessment

About 100 grains were taken at random from each jar in order to calculate the weight loss percentage. Count and weigh methods were used to count and weigh damaged grains and undamaged grains. Then, the percentage weight loss was computed using Eq. (2) (Adams, 1976).

\[
\text{Weight loss} (%) = \frac{(W_u \times Nd) - (W_u - Nu)}{W_u \times (Nd + Nu)} \times 100 \tag{2}
\]

\(W_u = \text{Weight of the undamaged grain}\)
\(Nu = \text{Number of undamaged grain}\)
\(WD = \text{Weight of the damaged grain}\)
\(Nd = \text{Number of damaged grain}\)

2.6.4. Grain damage assessment

In order to measure grain damage, one hundred grains from each treatment were randomly selected and their damaged and undamaged percentages were recorded. The percentage of insect damaged grains was computed using Eq. (3) developed by (Fekadu et al., 2006; Wambugu et al., 2009).

\[
\text{Insect damaged grain (%) = } \frac{\text{Number of insect damage}}{\text{Total number of grains}} \times 100 \tag{3}
\]

2.6.5. Germination test

The experiment was concluded with a germination test. Prior to twenty grains from each treatment, one hundred grains were randomly chosen in each treatment and control group were tested for germination.
The percentage germination was calculated using the formula developed by Abebe (2009) as in Eq. (4).

\[
\text{Viability index} (\%) = \frac{NG \times 100}{TG}
\]

where \( NG \) = number of seeds germinated, \( TG \) = total number of seeds tested in each Petri dish (Uke et al., 2011)

### 2.7. Data analysis

The statistical analysis system’s general linear model approach was used to analyze the experimental data (SAS JMP statistical discovery v10). Turkish’s Studentized Range Test (HSD) was used to differentiate significant means (\( P < 0.05 \)) for botanicals at a 5% significant level. The reaction of several botanicals was examined using one-way analysis of variance (ANOVA). Each replication’s adult weevil mortality data was represented as a proportion of the total number of adult weevils injected. Using Abbott’s correction equation (Eq. (5)), mortality statistics were adjusted for control mortality (Abbott, 1925).

\[
(\% \text{ CM}) = \left( \frac{(\%T - \%C)}{(100 - \%C)} \right) \times 100
\]

where: CM = corrected mortality, T = mortality in treated seed and C = mortality in untreated seed. By reporting the results as back-transformed data, data transformations were used to normalize the distribution.

### 3. Result and discussions

#### 3.1. Effect of botanicals on parent adult weevil mortality

After one day of treatment of application, Malathion 5% Dust revealed 100% of adult mortality, while garlic, neem, and lantana leaves presented less than 10%, of mortality. All other botanicals did not show any adult mortality of *Sitophilus zeamais* (Table 1). Based on the results, these botanicals had no or little effect on adult rice weevil mortality after one day of application of treatment. It has been reported by Sori (2014) that 24 h after treating maize seeds with neem oil (0.11% per 0.5 kg seed), the results were not significantly different from those in a control treatment.

After five days of treatment application, neem seeds and garlic leaves showed the highest adult mortality among the botanicals, while neem, lantana, and pepper tree leaves showed less percentage of adult mortality respectively. There is no significant difference between ginger and the control five days after treatment application (Table 1). Similar trend was observed ten days after treatment application. After ten days of treatment application, neem seed caused 90% adult mortality while garlic rhizome, neem, lantana, ginger, and pepper tree leaves presented 86.66%, 39.53%, 16.65%, 10%, and 9.99% adult mortality respectively. The control check showed the lowest adult mortality after ten days of treatment application (Table 1). Katamsadan et al. (2015) reported 100% mortality of maize weevils when treated with neem seed powder after seven days of treatment application in 40 g kg-1 of maize seeds. It also showed the efficacy of neem seed powder and citrus peel powder exposure was time-dependent.

All treatments significantly increased adult weevil mortality after the fifteenth day of treatment application (Table 1). There was 100% mortality among adults from neem seed powder and garlic leaves. The rest of the botanicals like neem, lantana, ginger rhizome, and pepper tree leaves showed 53.33%, 29.98%, 23.33%, and 19.99% adult mortality, which was significant compared to the control check. A minimum number of adult mortality was recorded from the control, followed by pepper tree, ginger, and lantana leaves 20 days after treatment application (Table 1).

The largest mortality rate was recorded from the neem leaves, and the largest mortality rate was from the pepper tree, ginger, and lantana leaves (Table 1). These findings are similar to Temitope (2014), who reported that Weevil mortality increased as exposure time increased even at lower dosages of neem seed powder used. The trend was the same four weeks after weevil exposure to the treatments.

After twenty-eight days of treatment, the application of lantana, neem, and ginger showed 63.30%, 59.33%, and 49.33% adult mortality respectively. While there is no significant difference between pepper tree leaves and the control check sample (Table 1), Tesfaye et al. (2021) reported that garlic (53.33%) and neem seed powder (50.70%) were significantly more effective in killing rice weevils after 28 days of treatment application. Sorghum weevil populations were most effectively controlled by neem seed powder in a study by Bhandari et al. (2015). Overall, adult mortality increased as exposure time increased to all the botanical treatments. According to Suleiman et al. (2012), the length of exposure has a clear correlation with the increase in mortality associated with *C. sinensis* treatment. However, neem seed and garlic were more effective than other botanicals in decreasing adult mortality. Mortality over twenty-eight days following treatment showed that neem seed and garlic were effective as malathion 5%, while neem leaf and lantana caused mortality above 50%, and ginger and pepper tree produced mortality below 50%. It may be that the plant powders that lead to the mortality of adults are fumigators and repellents. These powders are consumed in lethal doses from the plant powders that are sprayed on grain, leading to stomach poisoning. Likewise, Danga et al. (2015) stated that the active ingredient in neem seed oil caused high mortality of weevils. Due to their easy penetration into the cuticle, botanicals proved to be highly toxic to rice weevils (UshaRani et al., 2014).

#### 3.2. Effect of botanicals on the emergence of F1 progeny and percentage protection

A significant difference was found in “percent protection” in F1 emergence among the treatments (\( P < 0.05 \)). The grains were almost totally protected from F1 progeny by Malathion 5% dust and neem seed powder. This was followed by garlic rhizomes which had the lowest number of F1 progeny emergence among the other botanicals. A high number of F1 progeny emerged from the controls, pepper tree, ginger, lantana, and neem leaves respectively (Table 2). In a similar way to Malathion dust 5%, neem seeds effectively protected maize grains. During this period, treatments with garlic, neem, lantana, ginger rhizome, and pepper tree leaves protected the maize grains more than the control (Table 2). Natural pesticides may have immediate or delayed insecticidal effects (Shiferaw, 2004). An adult pest cannot reproduce, penetrate, or emerge from a larval state during a complete cycle of development due to the delayed effect. This can be measured once it has completed its life cycle of development. Treatments that suppress F1

| Treatment          | Day 1 | Day 5 | Day 10 | Day 15 | Day 20 | Day 28 |
|--------------------|------|------|-------|-------|-------|-------|
| Neem seed          | 0.0d | 83.3b| 90.0b | 100.0a| –     | –     |
| Neem leaf          | 6.6c | 16.6d| 39.3d | 52.3b | 55.3b | 59.3c |
| Garlic             | 10.0b| 76.6c| 86.6c | 100.0a| –     | –     |
| Ginger             | 0.0d | 00.0g| 10.0f | 23.3d | 36.3c | 49.3d |
| Pepper tree        | 0.0d | 6.6f | 9.9f | 19.9e | 26.6d | 39.9e |
| Lantana            | 6.6c | 9.9e | 16.6e | 29.9c | 36.6c | 63.3b |
| Malathion          | 100.0a| –   | –     | –     | –     | –     |
| Control            | 0.0d | 00.0g| 00.0g | 0.0f  | 0.0e  | 0.0e  |
| SE                 | 0.17 | 0.12 | 0.12 | 0.12  | 0.12  | 0.24  |
| DMRT               | 0.49 | 0.35 | 0.35 | 0.35  | 0.35  | 0.35  |
| Sign. difference   | *    | *    | *    | *     | *     | *     |

Means followed by the same letter within the column are not significantly different: DMRT, \( P < 0.05 \); CV = coefficient variation.
progeny may be synergistic due to increased adult mortality, larvicidal and ovicidal properties of botanical formulations, and chemical disruption of insect feeding. The potential of botanicals to reduce the production of F1 progeny in storage insect pests has been demonstrated in a number of studies (Dejene, 2002; Shaheen, 2006). Danga et al. (2015) reported that the active ingredient in neem seed caused high mortality in weevils and significantly reduced progeny emergence.

### 3.3. Evaluation of grain damage and weight loss

In terms of grain weight loss and grain damage, treatments differed significantly (P < 0.05) (Table 3). Amongst plant products, the lowest percentage of grain weight loss was observed from neem seed and garlic leaves. High weight loss was recorded from ginger, while the remaining botanicals like pepper tree, lantana, and neem leaves showed a lower grain weight loss compared to the control (Table 3).

Malathion 5% dust and neem seed completely protected the grains from grain damage significantly, low seed damage was recorded from garlic rhizome compared to other botanical treatments like ginger, pepper tree, lantana, and neem leaves, while the highest grain damage level was recorded from ginger other than the control (Table 3). The dissimilarity of grain damage and weight loss caused by rice weevil might be due to variation of botanicals having different toxic ingredients. Numerous abiotic and biotic factors, in addition to the moisture content of the seed, storage conditions, and pests, can affect grainlity (Amruta et al., 2015). Among untreated samples and neem seed powder treatments, Abraham Tadesse (2003) found substantial differences between the neem seed powder treatments and the untreated samples. Neem seed powder had the lowest percentage of sorghum seeds that were damaged and the maximum germination rates, according to Kudachi and Balikai, 2009.

### 3.4. Seed germination percentage

In terms of seed germination, there was no significant difference (P < 0.05) between the treatments. (Table 4). Neem seed, neem leaves, lantana, ginger, garlic, and pepper tree treatments all showed (100%) seed germination, which was comparable to Malathion 5% dust treatments. The lowest percentage of seed germination was shown on the untreated check (Table 4). There was no significant difference between treated and untreated seeds in an investigation on the effect of botanicals on germination ability (G./Silassie and Getu, 2009).

### 4. Conclusions and recommendations

The botanical powders used in the study had the advantage to be used as protectants against *Sitophilus zeamais* in the storage. During the study, all tested plant parts either seed or leaf part showed insecticidal activities which had a varying degree and were significantly different from the control. Results after 28 days revealed that all plant parts were significantly different from the control in F1 progeny, seed damage, and seed weight loss. Neem seed treatment displayed a correspondent effect to the synthetic insecticides used despite its gradual killing effect. Neem seed powder and Garlic rhizome were botanicals that cause the highest number of adult mortality, F1 progeny protection, grain damage, and grain weight loss, while other botanicals lantana, pepper tree, neem leaves, and ginger rhizome showed a better control compared to the control. As a whole, as the exposure period to the botanical treatments increased, so did the rate of adult rice weevil mortality. All botanicals inhibited F1 progeny emergence likewise, plant products reduced grain damage and weight loss. The ability of grains to germinate was unaffected by the botanicals. Neem seed and garlic rhizome were found to be the most effective among the other treatments. All treated grains gave 98–100% germination. Overall, the botanicals in the current experiment neem seed and garlic can be used for the management of *Sitophilus zeamais* in the study area.

### Declarations

**Author contribution statement**

Jamaal Barre: Conceived and designed the experiment; Performed the experiment; Wrote the paper.
Abaynew Jemal Jenber: Conceived and designed the experiment; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

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**Data availability statement**
Data will be made available on request.

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The authors declare no conflict of interest.

**Additional information**
No additional information is available for this paper.

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