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Efficacy of Botanical Extracts against Maize Weevil (*Sitophilus zeamais*) on Stored Maize at Vikenge Village in Mvomero District, Morogoro.

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Abstract

Maize (*Zea mays* L) is a staple food in Tanzania but is confronted by the challenges of maize weevils in storage structure. The objective of this study was to determine the efficacy of botanical leaf powders of affordable and available plant leaves on the control of maize weevils in stored maize grains. The efficacy of plant leaf powders was evaluated against stored maize weevils, *Sitophilus zeamais* at the Institute of Pest Management's laboratory at Sokoine University of Agriculture.

Treatments consisted of three weights of botanical leaf powders of 5 g per 200 g of maize grains, 10 g per 200 g of maize grains, and 20 g per 200 g of maize grains that were thoroughly mixed in sampling glass jars to obtain concentrations (w/w) while 200 g of untreated maize grains were used as control and actellic super dust at 0.11 g in 200 g of maize grains was used as standard. The experiment was laid down in a complete randomized design (CRD) to determine the optimum dose of botanical formulations that were recommended for protecting maize against weevils. The data were collected at weekly intervals for all nine weeks after application. The findings indicate that among the botanicals, the mean percentage mortality rate of *Sitophilus zeamais* in maize grains treated with a botanical leaf of *Artemisia abrotanum* was highest at a dosage of 20 g/200 g, recording an average of 76.22% for all eight weeks after application. *Strychnos spinosa* leaf powder is the second at 20 g/200 g of maize grains, recording an average mean percentage of 69.17%. Even though the death percentage rates of the remaining botanical leaf powders were smaller, there was still a significant difference ($p < 0.001$) with the untreated negative control.

Keywords: *Sitophilus zeamais*, *Strychnos spinosa*, *Artemisia abrotanum*, *Lantana camara*, Pesticidal plants, Negative control, Optimum dose

2.0 INTRODUCTION.

The maize weevil, *S. zeamais* Motschulsky, is recognized as one of the most damaging primary pests of stored

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maize and other grains, particularly in tropical and subtropical regions (Suleiman *et al.*, 2015) is present in all warm regions across the world.

Apart from attacking maize, it is also a pest of dried cassava, yam, common sorghum, and wheat. Both imago and grub feed internally on maize grains and an infestation can start in the field when the cob is still on the plant but most damage occurs in storage. According to statistics, 35% of stored maize grains suffer damage due to storage pests (Makundi, 2006). *Sitophilus zeamais* and *Prostephanus truncates* (Horn) being the most common culprits (Golob and Hodges, 1982). Despite the long-standing use of synthetic, their limitations in terms of cost, environment, and human health necessitate the investigation of the efficacy of locally available protectants. Therefore, the use of botanicals will aid in lowering post-harvest expenses and losses. In the past, the effectiveness of a certain control measure was the most crucial factor, but now, worker safety, environmental impact, and product quality are all top priorities. Botanical pesticides can significantly lower pollution, health hazards, and crop losses due to pests if they are used effectively (Kamatenesi-Mugisha *et al.*, 2008). The pesticidal properties of neem, pyrethrum, and tephrosia have been documented for controlling various insect pests in storage (Akhtar and Isman, 2004; Mbaiguinam *et al.*, 2006; Iloba and Ekrakene, 2006). For instance, the essential oil of *Artemisia annua* has been shown to repel *Tribolium castaneum* and *Callosobruchus maculatus* (Tripathi *et al.*, 2000). Therefore, the objective of this study was to assess the pesticidal activities of plant leaf powders of *Artemisia abrotanum*, *Lantana camara*, and *Strychnos spinosa* in stored maize grains at different application rates.

2.1 MATERIALS AND METHODS.

2.1.1 Materials.

2.1.1.1 Collection of experimental materials.

The untreated maize variety “Staha” was obtained from the Tanzania Agricultural Research Institute (TARI) at Kisongo Center in the Arusha region. The “Staha” variety was used for evaluating botanical storage pest susceptibility because it is particularly vulnerable to infestation (L) (Rugumamu, 2000). The fresh leaves of spiny monkey orange (*Strychnos spinosa* L), *Lantana* (*Lantana camara* L), and southern wood (*Artemisia abrotanum* L) were collected from Mgeta in Mvomero and Actellic super dust was purchased from Agro dealer in Morogoro. Furthermore, *S. zeamais* were obtained from infested grains from flour milling machines and godowns in Morogoro municipality.

2.1.1.2 Insect culture.

The mass production of *Sitophilus zeamais* followed the method described by Amadi *et al.* (2018). An initial population of unsexed adult *S. zeamais* was obtained from infested maize grains collected from farmers' storage facilities and godowns in the Morogoro region. The insect culture was established at the Pest Management Laboratory of Sokoine University of Agriculture in Morogoro region. The weevils were reared in plastic buckets fitted with perforated lids to ensure proper ventilation and prevent escape, and the buckets were kept in the laboratory. After a ten-day oviposition period, all adult weevils were removed using a sieve. The sieved grains were then placed in clean jars and left for one month to allow for progeny emergence. Juvenile *S. zeamais* that emerged were collected daily and transferred to fresh maize grains in glass jars covered with insect netting. These jars were kept under controlled environmental conditions (28 ± 2 °C and $50 \pm 5\%$ relative humidity) until a sufficient number of *S. zeamais* were obtained. Only unsexed adult weevils were selected for

the experiment. The mass production process adhered to the methodology outlined by Amadi *et al.* (2018).

2.1.1.3 Preparation of maize grains.

Untreated maize was sieved to remove any dirt, dust, or broken grains and manually graded with only larger grains selected and cleared of broken kernel and debris as suggested by Fukadu, Waktole, Dante, and Santiago (2012). No distinction was made between male and female weevils. Any prior infestation of pests in the grains was eliminated by putting the grain in an oven at 40 °C for 4 hrs (Bekele et al, 2002). Twenty kilograms of disinfested grain was randomly sampled and kept in a freezer at approximately -4 °C for two weeks to eliminate any prior sources of the weevil inoculum and eggs that might have already existed or protect it from any new infestations. For experimental purposes, the grain was removed from the freezer and allowed to acclimatize to ambient temperature and relative humidity, and then sun-dried.

2.1.1.4 Preparation of plant extract.

Fresh leaves of *Strychnos spinosa*, *Artemisia abrotanum*, and *Lantana camara* were shade-dried at ambient temperatures ranging from 27 to 30 °C for three days, with the drying time adjusted based on humidity levels. To preserve the active ingredients, the leaves were further oven-dried at 35 °C for 48 hours. Once dried, the leaves were individually ground into a fine powder using a grinder and sieved through a fine mesh with a pore size of 0.25 mm (Appendix 1) to obtain uniform powders. The powders were then mixed with maize grains at specific ratios based on weight-to-weight (w/w) measurements: 5 g, 10 g, and 20 g of plant powder per 200 g of maize grains.

2.1.1.5 Preparation of mixtures.

For all treatments, varying weights of botanical leaf powders were thoroughly mixed with 200 g of maize in sampling jars using a spatula to ensure uniform distribution of the biocontrol agent before introducing the pests. To initiate infestation, twenty randomly selected adult weevils of both sexes were taken from a laboratory culture and released into each sampling jar containing the treated maize. An untreated sampling jar served as the control and was covered with wire mesh, secured tightly with a rubber band to prevent weevil escape and allow aeration. The mixture of botanical leaf powders, maize grains, and weevils was gently shaken for two minutes and then left undisturbed under consistent conditions.

The quantities of leaf powders mixed with the maize grains were calculated based on the weight of powder per weight of grain (w/w). The synthetic chemical (Actellic Super Dust) was applied at the recommended dose rate of 50 g per 90 kg, as per the product instructions, and served as the standard, while untreated maize grains were used as the control.

2.1.2 Methods.

2.1.2.1 Experimental design.

The sampling glass jars were organized in a factorial layout with treatment combinations of 3x3 in a completely randomized design (CRD). Each treatment was replicated three times, and the jars were covered with wire mesh and securely sealed with rubber bands to prevent weevil escape while ensuring proper ventilation. The experiment had factor A with three levels of botanicals a1 (*Artemisia abrotanum*), botanical powder a2 (*Lantana camara*), botanical powder a3 (*Strychnos spinosa*) and factor B were the different levels of botanicals weight, b4 was untreated grains maize, b5 was maize treated with Actellic super dust at recommended dose rate

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of 50 g/90 kg, b1 was maize treated with botanical concentrations of 5 g in 200 g of maize grains, b2 was treated with botanical concentrations of 10 g in 200 g of maize grains and b3 was treated with botanical concentrations of 20 g in 200 g of maize grains (Appendix 2).

The allocation of treatment to experimental units in the laboratory was random to avoid any bias in the experiment resulting from the influence of another extraneous unknown factor that may affect the experiment (Appendix 3).

2.1.2.2 Data Collection.

The mortality count to evaluate the insecticidal activities of dried leaf powder of botanicals on stored maize grain was done in each treatment in a glass jar at an interval of every one week for eight weeks after maize grains were exposed to different botanical powder except in the control where no pesticides were applied.

After each week, the counting was done by pouring the content of each sampling jar on a small white tray and insects were sorted out of the mixture using a pin probe, the dead and living weevils were counted and recorded to obtain the adult weevils' mortality rate, live weevils were returned to their respective sampling glass jar, while dead weevils were discarded and the sampling jar containing the grains were then kept under the same condition for observation.

2.1.2.3 The determination of live and dead maize weevils (% mortality rate).

Visual inspection is the technique to determine the number of live and dead weevils (Schuler N.J *et al.*, 2014). The percentage of insect mortality rate was calculated by using the following equation (Jian 2019).

$$\% \text{ Mortality} = D/I \times 100$$

Where by

D = Total number of dead insect

I = Total number of inoculated weevils

2.1.2.4 Statistical analysis.

The data were analyzed using repeated measures analysis of variance (ANOVA) in GenStat for Windows, 17th Edition, with the Statistical Analysis System (SAS) software. Mean weevil mortality rates were compared using Fisher's least significant difference (LSD) test to evaluate differences between treatments at a significance level ($p \leq 0.05$). The results are presented in tables and charts. The statistical model applied was as follows:

Where by

$$Y_{ijk} = \mu + T_i + L_j + (T \times L)_{ij} + Error$$

Yijk = is the response variables

μ = is the general mean effect

Ti = is aith treatment effect

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L_j = is level(T x L) _{ij} = is the combination

2.2 DESCRIPTION OF STUDY LOCATION.

The study was conducted under laboratory conditions at the Institute of Pest Management at the Sokoine University of Agriculture (SUA) in Morogoro (Central Tanzania) at about 520 m altitude.

2.3 RESULTS AND DISCUSSION.

2.3.1 Results.

2.3.1.1 Maize weevil mortality on the first week after treatment.

A highly significant difference was observed among the treatments in terms of mortality during the first week after application (Table 2.1). Actellic Super Dust, used as the control, achieved the highest mean mortality percentage of 88.33% for maize weevils. When *Strychnos spinosa* and *Artemisia abrotanum* were applied at a rate of 20 g per 200 g of maize grains, the mean mortality percentages were 28.08% and 31.68%, respectively. The study revealed a significant increase in mortality rates for insects treated with 20 g of botanical products compared to the untreated control group. Actellic Super Dust recorded the highest mortality rates overall. Among the botanical treatments, *Artemisia abrotanum* was the most effective, producing significantly higher mortality rates than *Strychnos spinosa*. These findings underscore the potential of these treatments for effective pest management.

However, the mortality rates for most botanical treatments exhibited significant variation, except *Lantana camara* (5 g/200 g), *Lantana camara* (10 g/200 g), *Strychnos spinosa* (5 g/200 g), and *Strychnos spinosa* (10 g/200 g). The mean percentage mortality rates for these specific treatments were observed to be 5.64%, 5.86%, 7.97%, and 8.64%, respectively. In contrast, *Lantana camara* at an application rate of 20 g per 200 g demonstrated a much higher mean mortality rate of 18.25%. This highlights the varying efficacy of different botanical treatments.

Table 2.1: Mean mortality of weevil on the first week after application.

Treatments	Mean mortality percentage
CO	0.33a
LC (5 g)	5.64b
LC (10 g)	5.86b
LC (20 g)	18.25d
SS (5 g)	7.97b
SS (10 g)	8.64b
SS (20 g)	28.08e
AA (5 g)	10.76c
AA (10 g)	12.65c
AA (20 g)	31.68e
ASD	88.33f
LSD	2.279
CV%	1.8

Means in the same column followed by the same letter(s) are not statistically significantly different (P<0.05)

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following separation by Turkey's test ($n=3$), CV=Coefficient of variation, CO= Control, LC=*Lantana camara*, AA=*Artemisia abrotanum*, SS=*Strychnos spinosa*, ASD=Actelloc super dust, LSD=Least significant different.

In the untreated maize samples, which served as the negative control, the mean mortality rate recorded was 0.33%. This minimal mortality percentage can be attributed to the lack of any chemical treatment. In comparison, the samples treated with Actellic Super Dust showed the highest mortality rate, which was significantly greater ($p<0.05$) than those treated with various leaf powder application rates, as depicted in Fig. 2.1.

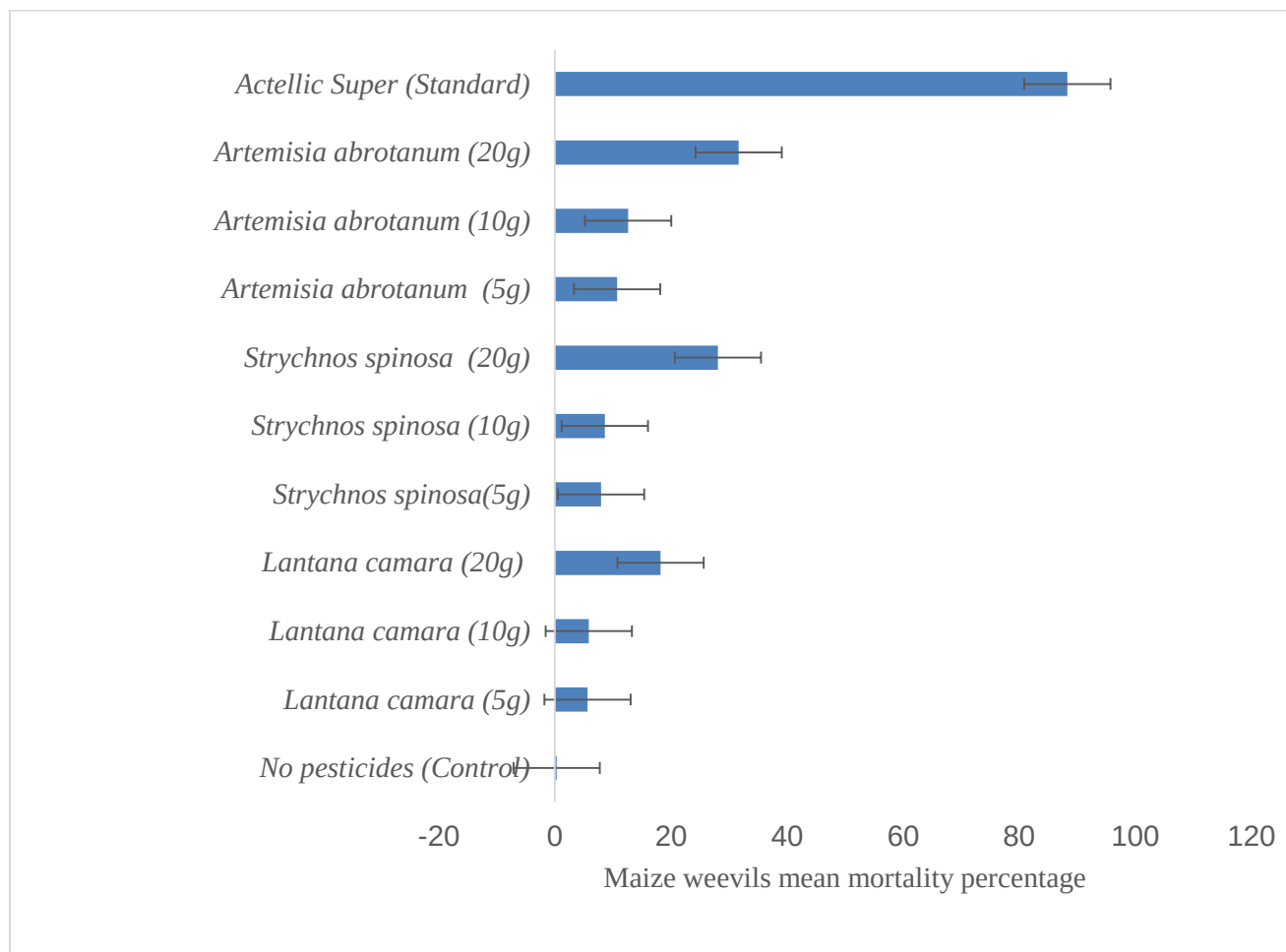


Figure 2.1: Mean mortality of *Sitophilus zeamais* in the first week.

2.3.1.2 Maize weevil mortality in the second week after treatment

During the second week of applying botanical pesticides, a highly significant difference in maize weevil mortality rates was observed across the various treatments. The mean mortality percentage for untreated maize grains was a mere 0.66%, whereas those treated with the synthetic pesticide Actellic super dust achieved an impressive mortality rate of 94.33%.

There were no significant differences were observed in the samples treated with *Lantana camara* at application

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rates of 5 g/200 g and 10 g/200 g, which yielded mean mortality rates of 13.67% and 9.96%, respectively. Additionally, treatments with *Strychnos spinosa* and *Artemisia abrotanum* at the application rate of 5 g/200 g yielded mean mortality rates of 14.98% and 15.87%, respectively (Table 2.2).

Table 2.2: Mean mortality of weevil on the second week after application

Treatments	Mean mortality percentage
CO	0.66a
LC (5 g)	13.67b
LC (10 g)	9.96b
LC (20 g)	25.68c
SS (5 g)	14.98b
SS (10 g)	14.29c
SS (20 g)	30.43d
AA (5 g)	15.87b
AA (10 g)	16.82c
AA (20 g)	38.36e
ASD	94.33f
LSD	3.403
CV%	2.1

Means in the same column followed by the same letter(s) are not statically significantly different ($P < 0.05$) following separation by Turkey's test ($n = 3$), CV=Coefficient of variation, CO= Control, LC=*Lantana camara*, AA=*Artemisia abrotanum*, SS=*Strychnos spinosa*, ASD=Actelloc super dust, LSD=Least significant different.

The results indicated that the highest mean percentage of mortality in adult *Sitophilus zeamais* was observed with the positive control, Actellic super dust. Among the various leaf powder concentrations tested, *Artemisia abrotanum* applied at a rate of 20 g per 200 g showed the highest mean percentage of maize weevil mortality. In contrast, *Lantana camara* applied at a rate of 10 g per 200 g exhibited the lowest mortality rate (Fig. 2.2). These findings suggest that the mortality of adult *Sitophilus zeamais* was highest when using Actellic super dust compared to different concentrations of leaf powders.

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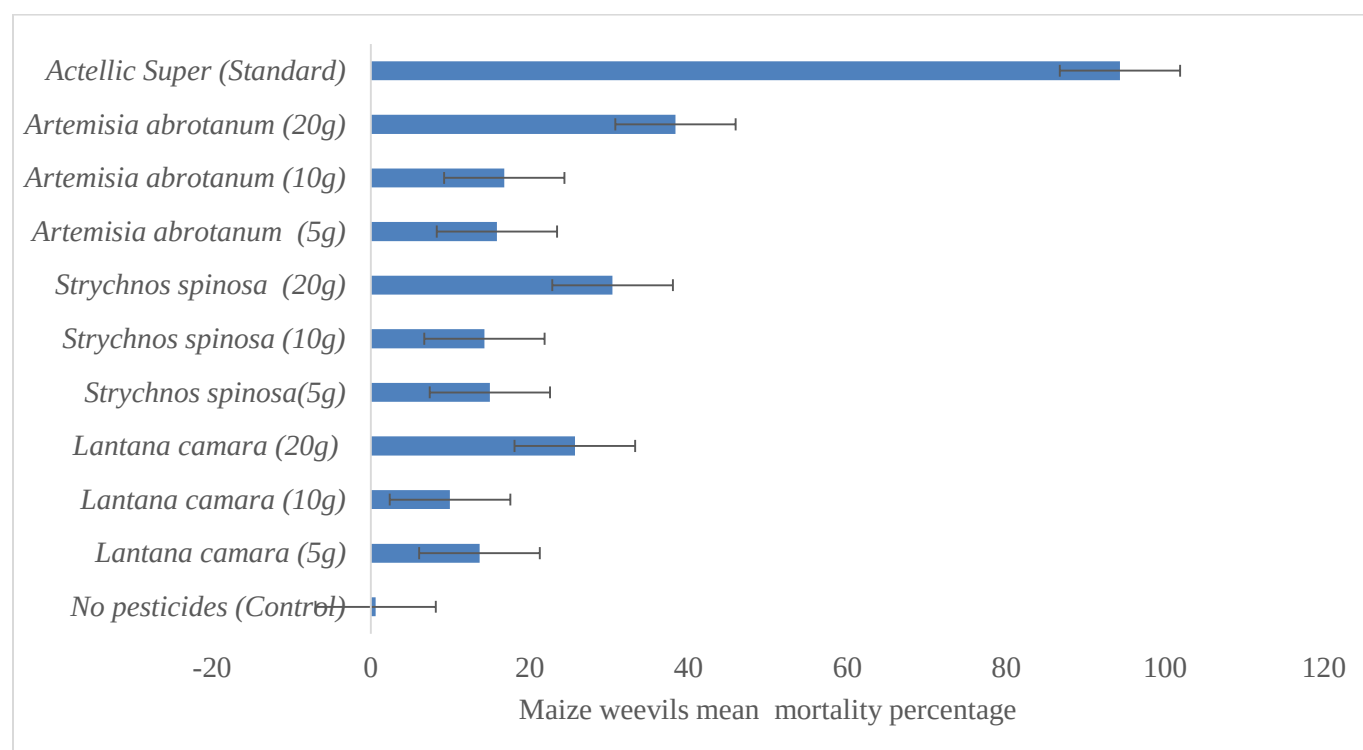


Figure 2.2: Mean mortality of *Sitophilus zeamais* in the second week.

2.3.1.3 Maize weevil mortality on the third week after treatment.

During the third week of application, the sample treated with synthetic pesticides (positive control) achieved a maize weevil mortality rate of 97.33%, with only 2.67% surviving. The mean mortality rates for *Artemisia abrotanum* and *Strychnos spinosa*, at an application rate of 20 g per 200 g, were 64.98% and 54.76%, respectively. Although *Artemisia abrotanum* showed a higher mortality percentage than *Strychnos spinosa*, the difference was not statistically significant. Both treatments, however, were significantly different from the other botanical samples.

The following botanical leaf powders did not show significant differences in mortality rates: *Lantana camara* at 5 g (13.97%), *Lantana camara* at 10 g (14.49%), *Strychnos spinosa* at 5 g (14.49%), and *Strychnos spinosa* at 10 g (16.85%). In contrast, the untreated sample had a mean percentage mortality of 0%, which was significantly different from all other samples. Among the botanical treatments, *Lantana camara* had the lowest mortality rates against maize weevils (Table 2.3).

Table 2.3: Mean mortality of weevil on the third week after application.

Treatments	Mean mortality percentage
CO	0.00a
LC (5 g)	13.97b
LC (10 g)	14.49b
LC (20 g)	34.88d
SS(5 g)	14.49b
SS (10 g)	16.85b
SS (20 g)	54.76e

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AA (5 g)	19.96c
AA (10 g)	19.96c
AA (20 g)	64.98e
ASD	97.33f
LSD	5.433
CV%	3.4

Means in the same column followed by the same letter(s) are not statically significantly different ($P < 0.05$) following separation by Turkey's test ($n = 3$), CV=Coefficient of variation, CO= Control, LC=*Lantana camara*, AA=*Artemisia abrotanum*, SS=*Strychnos spinosa*, ASD=Actelloc super dust, LSD=Least significant different.

Actellic Super Dust recorded the highest mortality rate, while the untreated control sample showed the lowest. In the second week, the mortality rates for *Artemisia abrotanum* at application rates of 5 g and 10 g per 200 g of maize grains were comparable and not significantly different. Similarly, *Lantana camara* at 10 g per 200 g of maize grains and *Strychnos spinosa* at 5 g per 200 g of maize grains exhibited mortality rates that were not significantly different from those of *Lantana camara* at 5 g per 200 g and *Strychnos spinosa* at 10 g per 200 g of maize grains (Fig. 2.3).

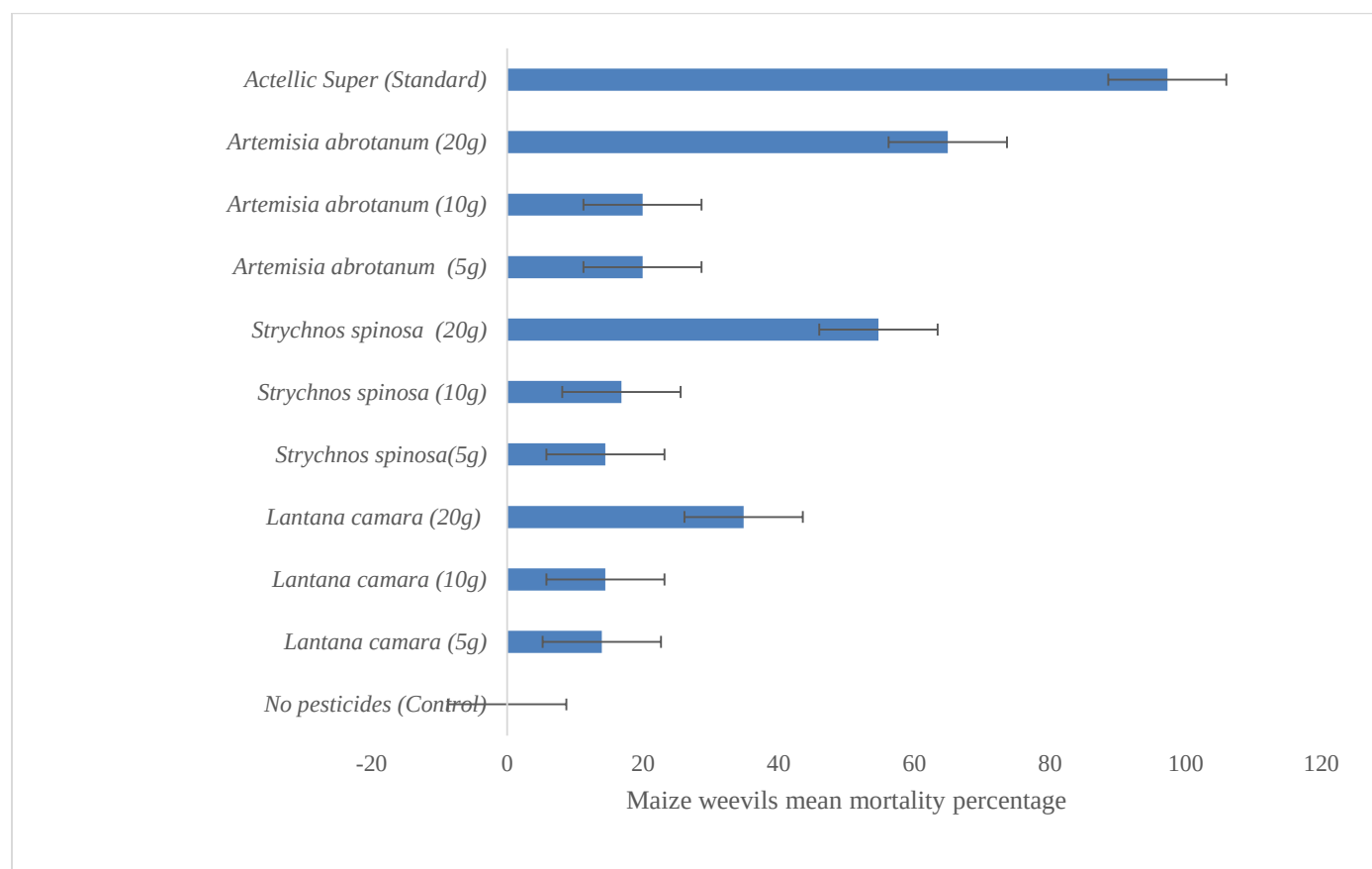


Figure 2.3: Mean mortality of *Sitophilus zeamais* in the third week.

2.3.1.4 Maize weevil Mortality in the fourth week after treatment.

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In the fourth week after treating maize with various botanical leaf powders at different concentrations, notable differences were observed in the mean percentage mortality rates among the treatments (see Table 2.4). The negative control (untreated sample) exhibited a mortality rate of 0%, whereas the positive control (Actellic super dust) achieved a 100% mortality rate for maize weevils. This indicates that all *Sitophilus zeamais* were effectively eliminated.

There were no significant differences in maize weevil mortality rates among the various treatments. The mean mortality rates were as follows: *Lantana camara* at 5 g/200 g resulted in 18.54% mortality; *Lantana camara* at 10 g/200 g was 19.87% mortality; *Strychnos spinosa* at 5 g/200 g was 17.97% mortality; and *Strychnos spinosa* at 10 g/200 g resulted in 18.97% mortality. Furthermore, there was no significant difference in mortality rates observed between *Lantana camara* at 20 g/200 g, *Artemisia abrotanum* at 5 g/200 g, and *Artemisia abrotanum* at 10 g/200 g.

Artemisia abrotanum at 20 g/200 g recorded the highest mortality rate among the botanical treatments, with 76.76%. This was followed by *Strychnos spinosa* at 20 g/200 g, which resulted in a mortality of 69.35%. The lowest percentage was observed in *Strychnos spinosa* at 5 g/200 g, with a mortality rate of 17.97% (see Fig. 2.4).

Table 2.4: Mean mortality of weevil on the fourth week after application.

Treatments	Mean mortality percentage
CO	0.00a
LC (5 g)	18.54b
LC (10 g)	19.87b
LC (20 g)	36.26c
SS(5 g)	17.97b
SS (10 g)	18.97b
SS (20 g)	69.35d
AA (5 g)	23.97c
AA (10 g)	32.36c
AA (20 g)	76.76e
ASD	100.00f
LSD	6.024
CV%	2.8

Means in the same column followed by the same letter(s) are not statically significantly different ($P < 0.05$) following separation by Turkey's test ($n = 3$), CV=Coefficient of variation, CO= Control, LC=*Lantana camara*, AA=*Artemisia abrotanum*, SS=*Strychnos spinosa*, ASD=Actelloc super dust, LSD=Least significant different.

The graph shows that the mortality rate of adult *Sitophilus zeamais* when treated with *Artemisia abrotanum* at a concentration of 20 g per 200 g, was significantly higher compared to other dosage levels. This treatment was more effective than all dosages tested, except for Actellic super dust (Fig. 2.4).

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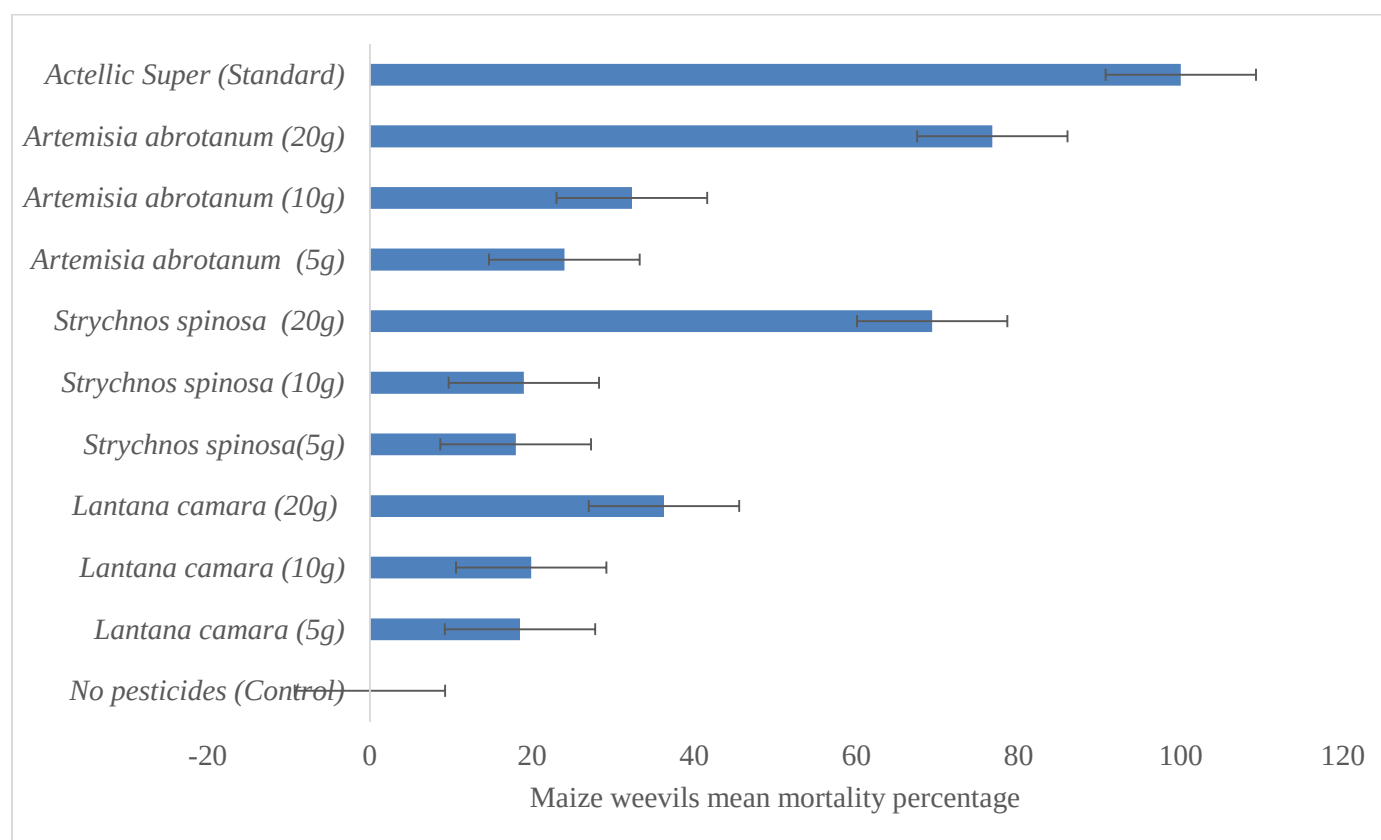


Figure 2.4: Mean mortality of *Sitophilus zeamais* in the fourth week.

2.3.1.5 Maize weevil Mortality in the fifth week after treatment.

The results after the fifth week of treatment indicate that there were no significant differences in effectiveness between *Lantana camara* and *Strychnos spinosa* when applied at rates of 5 g /200 g of maize and 10 g/200 g of maize. Similarly, no significant difference was observed for *Artemisia abrotanum* at application rates of 5 g/200 g and 10 g/200 g of maize grain (Table 2.5).

All weevils in the sample treated with Actellic super dust were eliminated, achieving a mean mortality rate of 100%. This was not significantly different from the sample treated with *Artemisia abrotanum* (20 g/200 g), which had a mean mortality of 98.63%. While Actellic Super Dust showed a higher mortality score compared to *Artemisia abrotanum*, it was followed by *Strychnosa spinosa* (20 g/200 g), which recorded a mean mortality rate of 92.53%.

In contrast, the negative control (untreated) sample showed no mean mortality, registering a rate of 0%, and thus significantly differed from the other treatment groups.

Table 2.5: Mean mortality of weevil on the fifth week after application.

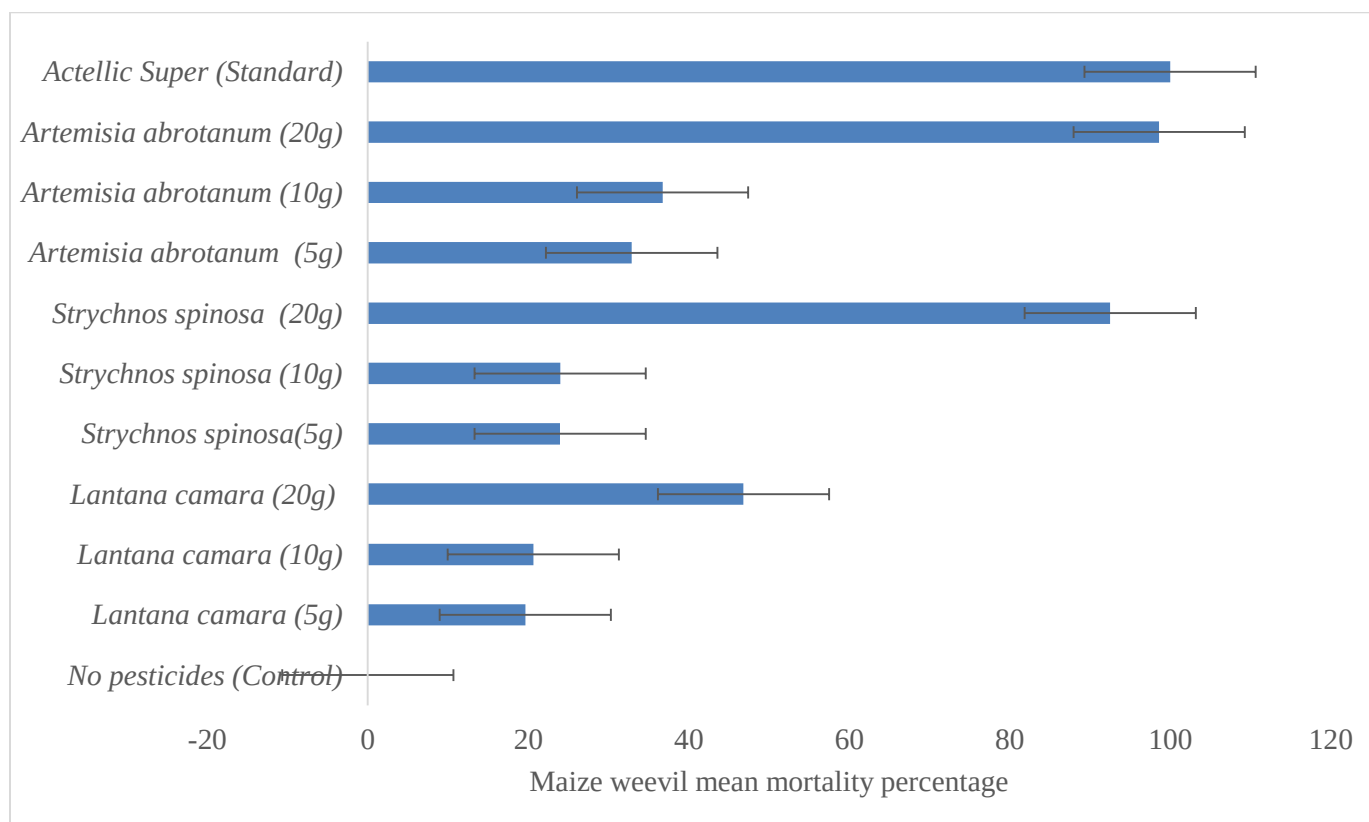
Treatments	Mean mortality percentage
CO	0.00a
LC (10 g)	19.64b
LC (20 g)	20.64b

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SS (5 g)	46.82d
SS (10 g)	23.96b
SS (20 g)	23.98b
AA (5 g)	92.53e
AA (10 g)	32.89c
AA (20 g)	36.74c
ASD	98.63f
LSD	100.00f
CV%	4.456

Means in the same column followed by the same letter(s) are not statically significantly different ($P < 0.05$) following separation by Turkey's test ($n = 3$), CV=Coefficient of variation, CO= Control, LC=Lantana camara, AA=Artemisia abrotanum, SS=Strychnos spinosa, ASD=Actelloc super dust, LSD=Least significant different.

The mortality of *Sitophilus zeamais* was evaluated using varying dosages of leaf powders from *Lantana camara* and *Strychnos spinosa*. For *Lantana camara*, no significant differences in mortality were observed between the 5 g and 10 g application rates ($p < 0.05$). Similarly, for *Strychnos spinosa*, the mortality rates at 5 g and 10 g were not significantly different, although *Strychnos spinosa* exhibited greater efficacy compared to other treatments. In the case of *Artemisia abrotanum*, no significant differences were found between the 5 g and 10 g application rates per 200 g of maize grains. However, the 10 g application of *Artemisia abrotanum* resulted in the highest mortality rate (Fig. 2.5).



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Figure 2.5: Mean mortality of *Sitophilus zeamais* in the fifth week.**2.3.1.6 Maize weevil mortality on the sixth week after treatment.**

During the sixth week of this study, significant differences were observed in some of the samples following treatments with botanicals. There was no significant difference in the mean mortality percentage of maize weevils between the positive control (Actellic Super Dust), which achieved a mean mortality of 100%, and *Artemisia abrotanum* (20 g/200 g), with a mortality rate of 99.34%. The mean maize weevil mortality percentage for *Strychnos spinosa* (20 g/200 g) was 92.27%, while *Lantana camara* (5 g/200 g) had a much lower mortality rate of 25.81%.

Additionally, the mean maize weevil mortality percentages for several treatments were not significantly different from one another. Specifically, *Lantana camara* (20 g/200 g) recorded a mortality rate of 58.92%, *Strychnos spinosa* (10 g/200 g) was at 48.09%, *Artemisia abrotanum* (5 g/200 g) had a mortality rate of 50.86%, and *Artemisia abrotanum* (10 g/200 g) was at 55.97%. There was also no significant difference between *Lantana camara* (10 g/200 g), which scored 37.97%, and *Strychnos spinosa* (5 g/200 g), which had a mortality rate of 39.86% (Table 2.6).

Table 2.6: Mean mortality of weevil on the sixth week after application.

Treatments	Mean mortality percentage
CO	0.00a
LC (5 g)	25.81b
LC (10 g)	37.97c
LC (20 g)	58.92d
SS (5 g)	39.86c
SS (10 g)	48.09d
SS (20 g)	92.27e
AA (5 g)	50.86d
AA (10 g)	55.97d
AA (20 g)	99.34f
ASD	100.00f
LSD	4.152
CV%	3.3

Means in the same column followed by the same letter(s) are not statically significantly different ($P < 0.05$) following separation by Turkey's test ($n = 3$), CV=Coefficient of variation, CO= Control, LC=*Lantana camara*, AA=*Artemisia abrotanum*, SS=*Strychnos spinosa*, ASD=Actelloc super dust, LSD=Least significant different.

The sample treated with Actellic super dust resulted in a greater number of adult weevils killed compared to the leaf powder of *Artemisia abrotanum* when applied at 20 g per 200 g of maize grains (Fig. 2.6)

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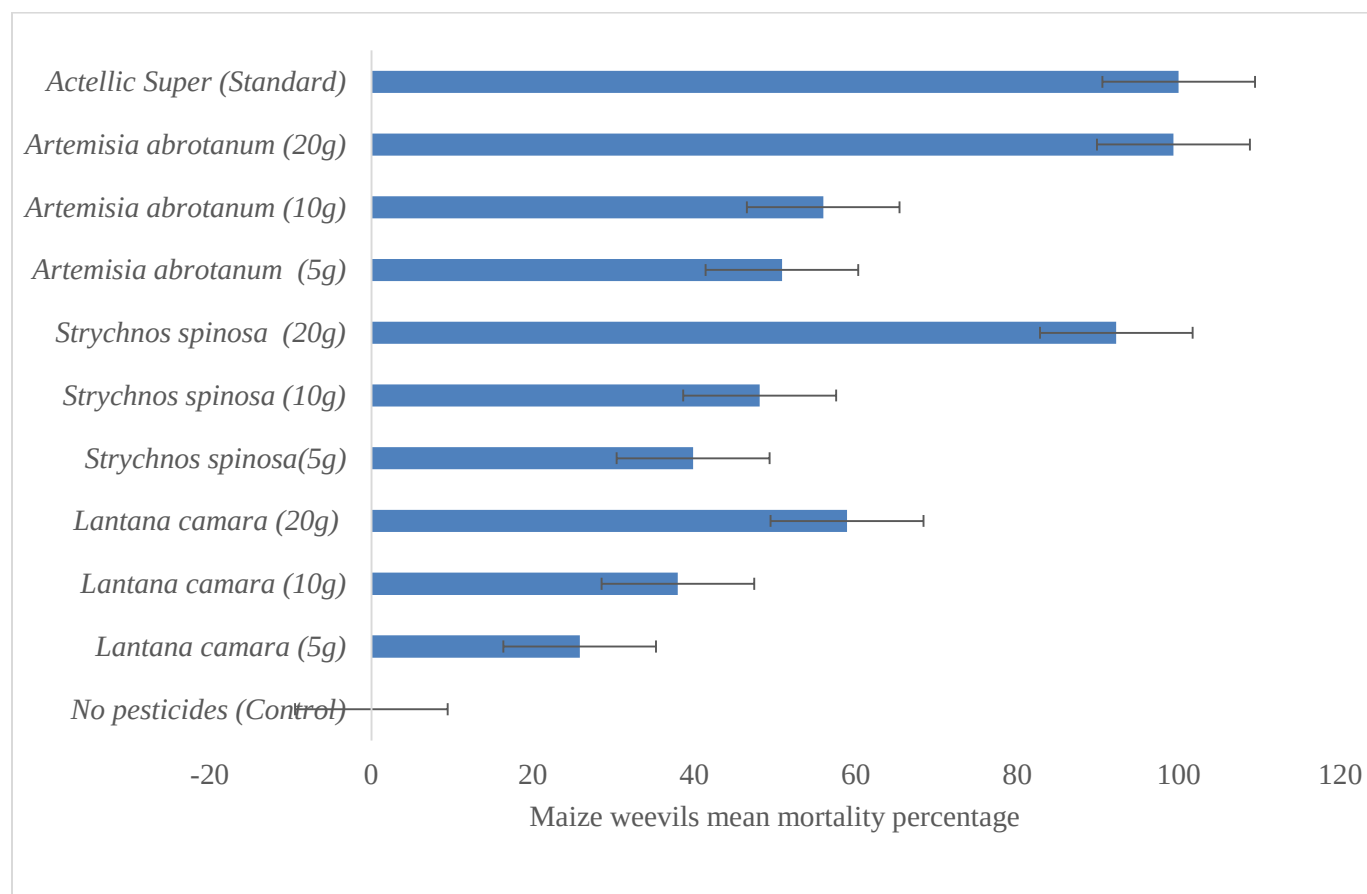


Figure 2.6: Mean mortality of *Sitophilus zeamais* in the sixth week.

2.3.1.7 Maize weevil mortality on the seventh week after treatment.

The mean mortality rate of *Sitophilus zeamais* after seven weeks of treatment revealed highly significant differences across the various treatments. The synthetic pesticide (Actellic super dust), used as the control, achieved a mean mortality percentage of 100%. This result was not significantly different from that of *Artemisia abrotanum* (20 g/200 g), which also reached a mean mortality of 100%. Subsequently, *Strychnos spinosa* (20 g/200 g) recorded a mean mortality rate of 92.34%. There were no significant differences in mean mortality percentages among *Lantana camara* (5 g/200 g), *Lantana camara* (10 g/200 g), *Strychnos spinosa* (5 g/200 g), and *Strychnos spinosa* (10 g/200 g). Additionally, there were no significant differences between *Artemisia abrotanum* (5 g/200 g) and *Artemisia abrotanum* (10 g/200 g), with mean mortalities of 60.76% and 63.08%, respectively (see Table 2.7). It is worth noting that no mean weevil mortality percentage was observed for untreated maize grains.

Table 2.7: Mean mortality of weevil on the seventh week after application.

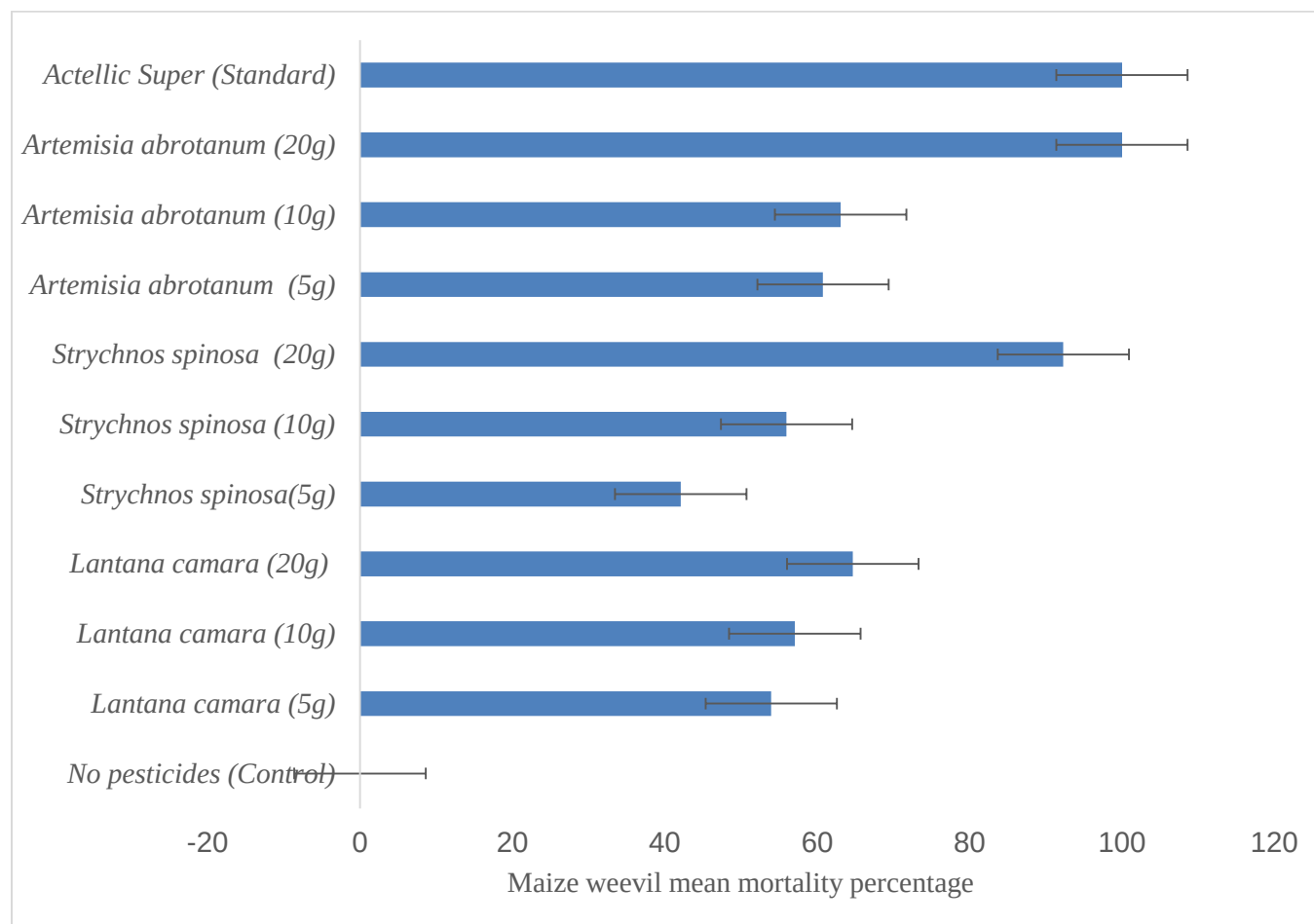
Treatments	Mean mortality percentage
CO	0.00a
LC (5 g)	53.96b
LC (10 g)	57.06b
LC (20 g)	64.67d
SS (5 g)	42.09b

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SS (10 g)	55.97b
SS (20 g)	92.34e
AA (5 g)	60.76c
AA (10 g)	63.08c
AA (20 g)	100.00f
ASD	100.00f
LSD	3.264
CV%	1.2

Means in the same column followed by the same letter(s) are not statically significantly different ($P < 0.05$) following separation by Turkey's test ($n = 3$), CV=Coefficient of variation, CO= Control, LC=*Lantana camara*, AA=*Artemisia abrotanum*, SS=*Strychnos spinosa*, ASD=Actelloc super dust, LSD=Least significant different.

The graph shows that all *Sitophilus zeamais* were killed on the seventh day when treated with 20 g of *Artemisia abrotanum* per 200 g of maize grains. This treatment was compared to the recommended dosage of synthetic pesticides (Actellic super dust). Maize treated with 20 g of *Strychnos spinosa* per 200 g of maize recorded the second-best results, while the untreated maize showed the lowest efficacy, with no *Sitophilus zeamais* fatalities observed (Fig. 2.7).



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Figure 2.7: Mean mortality of *Sitophilus zeamais* in the seventh week.**2.3.1.8 Maize weevil mortality on the eighth week after treatment.**

In the eighth week of the study, the results indicated no significant differences in mean mortality rates among *Lantana camara* (20 g/200 g), *Strychnos spinosa* (10 g/200 g), and *Artemisia abrotanum* (10 g/200 g), with mean mortality percentages of 78.25%, 63.87%, and 65.86% respectively. Additionally, there were no significant differences observed between *Lantana camara* (10 g/200 g), which had a mean mortality of 60.76%, *Strychnos spinosa* (5 g/200 g), with a mean mortality of 60.97%, and *Artemisia abrotanum* (5 g/200 g), which recorded a mean mortality of 62.74%. The mean mortality percentage for the synthetic pesticides used as a control was 100%, which was not significantly different from that of *Artemisia abrotanum* (20 g/200 g), which also achieved a mean mortality of 100%. *Strychnos spinosa* (20 g/200 g) had a mean mortality of 93.65%. There was no observed mean mortality percentage for untreated maize grains (Table 2.8).

Table 2.8: Mean mortality of weevil on the eighth week after application.

Treatments	Mean mortality percentage
CO	0.00a
LC (5 g)	58.08b
LC(10 g)	60.76c
LC(20 g)	78.25d
SS (5 g)	60.97c
SS(10 g)	63.87d
SS (20 g)	93.65e
AA (5 g)	62.74c
AA (10 g)	65.86d
AA (20 g)	100.00f
ASD	100.00f
LSD	2.963
CV	3.25

Means in the same column followed by the same letter(s) are not statically significantly different ($P < 0.05$) following separation by Turkey's test ($n = 3$), CV=Coefficient of variation, CO= Control, LC=*Lantana camara*, AA=*Artemisia abrotanum*, SS=*Strychnos spinosa*, ASD=Actelloc super dust, LSD=Least significant different.

The highest graph illustrates the effectiveness of synthetic pesticides and *Artemisia abrotanum* at a dosage of 20 grams per 200 grams of maize, where all *Sitophilus zeamais* (maize weevils) in the stored maize were eliminated. This was followed by the application of *Strychnos spinosa*, also at a dosage of 20 grams per 200 grams of maize. In the control group (untreated), no maize weevils were killed (Fig. 2.8).

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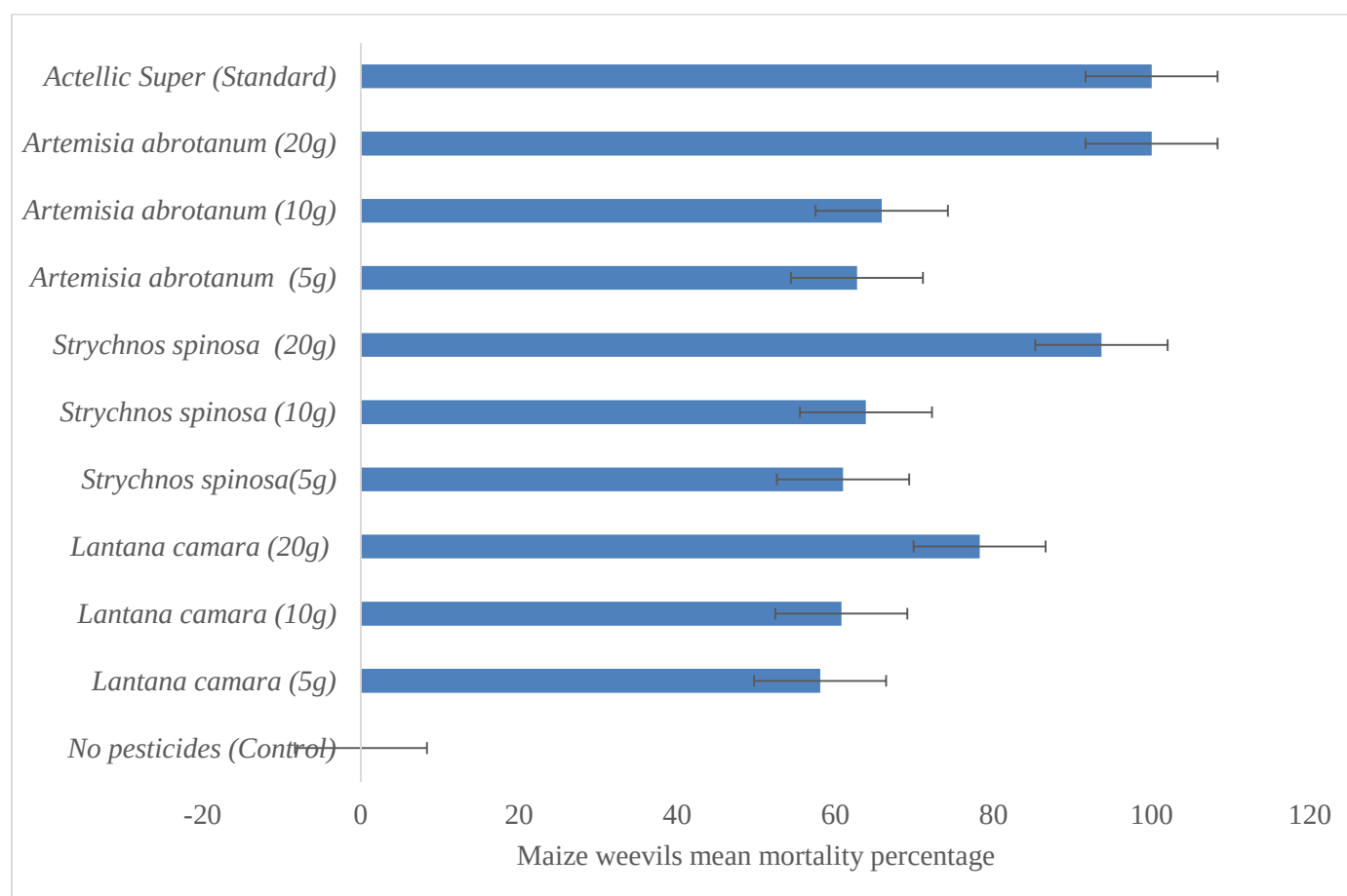


Figure 2.8: Mean mortality of *Sitophilus zeamais* in the eighth week.

2.3.1.9 Summary of Findings.

Table 2.9 Effect of leaf powders of botanical on mortality of *Sitophilus zeamais* within the duration of treatment application.

g of powder/ 200 g of maize	Sitophilus zeamais mortality							
	1st WAT	2nd WAT	3rd WAT	4th WAT	5th WAT	6th WAT	7th WAT	8th WAT
No pesticides (Control)	0.33a	0.66a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a
Lantana camara (5g)	5.64b	13.67b	13.97b	18.54b	19.64b	25.81b	53.96b	58.08b
Lantana camara (10g)	5.86b	9.96b	14.49b	19.87b	20.64b	37.97c	57.06b	60.76c
Lantana camara (20g)	18.25d	25.68c	34.88d	36.26c	46.82d	58.92d	64.67d	78.25d
Strychnos spinosa(5g)	7.97b	14.98b	14.49b	17.97b	23.96b	39.86c	42.09b	60.97c
Strychnos spinosa (10g)	8.64b	14.29c	16.85b	18.97b	23.98b	48.09d	55.97b	63.87d
Strychnos spinosa (20g)	28.08e	30.43d	54.76e	69.35d	92.53e	92.27e	92.3e	93.65e
Artemisia abrotanum (5g)	10.76c	15.87b	19.96c	23.97c	32.89c	50.86d	60.76c	62.74c
Artemisia abrotanum (10g)	12.65c	16.82c	19.96c	32.3c	36.74c	55.97d	63.08c	65.86d
Artemisia abrotanum (20g)	31.68e	38.36e	64.98e	76.76e	98.63f	99.34f	100f	100f

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<i>Actellic Super</i> (Standard)	88.33f	94.33f	97.333f	100f	100f	100f	100f	100f
LSD	2.279	3.403	5.433	6.024	4.456	4.152	3.264	2.963
CV%	1.8	2.1	3.4	2.8	4	3.3	1.2	3.25

2.3.1.9.1 Mean mortality of *Sitophilus zeamais*.

The summary of the mean mortality percentages over eight weeks shows that Actellic super dust achieved a minimum mean mortality percentage of 88.33% and a maximum of 100%. The study demonstrated that Actellic super dust effectively killed weevils within the first week of application and maintained its efficacy for the entire eight-week period, resulting in the complete elimination of the weevils.

In contrast, *Artemisia abrotanum*, applied at a rate of 20 g/200 g of maize grains, recorded a mean mortality percentage ranging from 31.68% to 100% while the mortality rate for *Strychnos spinosa* at the same concentration was the lowest 28.08% while the highest was 93.65%. Similarly, *Strychnos spinosa* at 20 g/200 g showed a significant increase in mean mortality percentage during the fifth week after application. However, this percentage was significantly different from those observed with Actellic super dust and *Artemisia abrotanum*. (Table 2.9.)

The study demonstrated that the mean mortality percentage of *Sitophilus zeamais* was significantly influenced by the varying application dosages of leaf powders of *Artemisia abrotanum*, *Strychnos spinosa*, and *Lantana camara* for eight weeks. As the application dose of these leaf powders increased, the mean mortality percentage of the weevils also rose it indicates that the damage of maize grains decreased proportionally to the rising dose of powdered leaf of botanicals since the feeding activities are highly influenced by the number of weevils in the maize grains. Thus the highest dose of 20 g showed a higher mortality percentage than the other botanical leaf powders.

Specifically, the effects of the different dosages were as follows: *Artemisia abrotanum* at 5 g per 200 g was less effective than *Lantana camara* at 10 g per 200 g, and *Lantana camara* at 10 g per 200 g was less effective than *Lantana camara* at 20 g per 200 g. This trend was similarly observed with *Strychnos spinosa* and *Artemisia abrotanum*, where the mortality rates increased from the lowest dose of 5 g per 200 g to the highest dose of 20 g per 200 g. (Fig 2.9-2.11).

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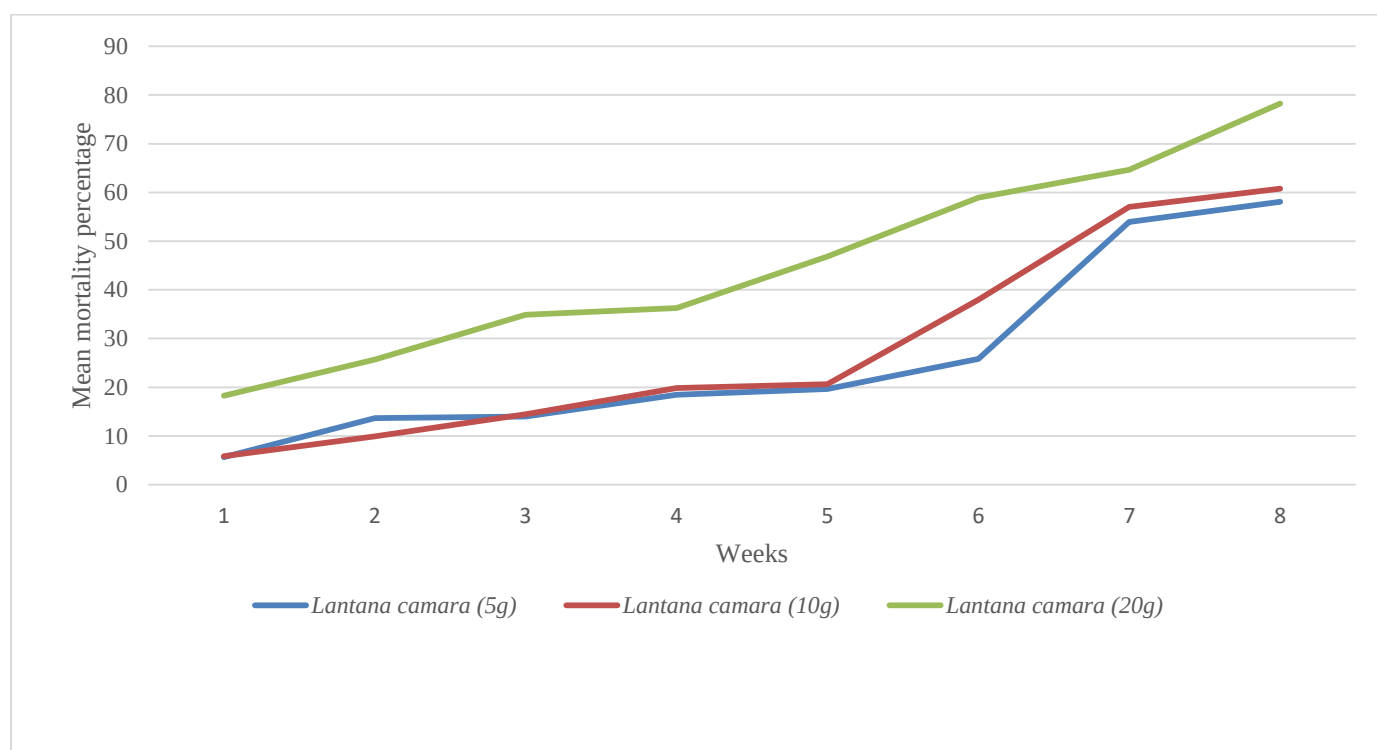


Figure 2.9: Effect of difference application dose of *Lantana camara* on mortality rate.

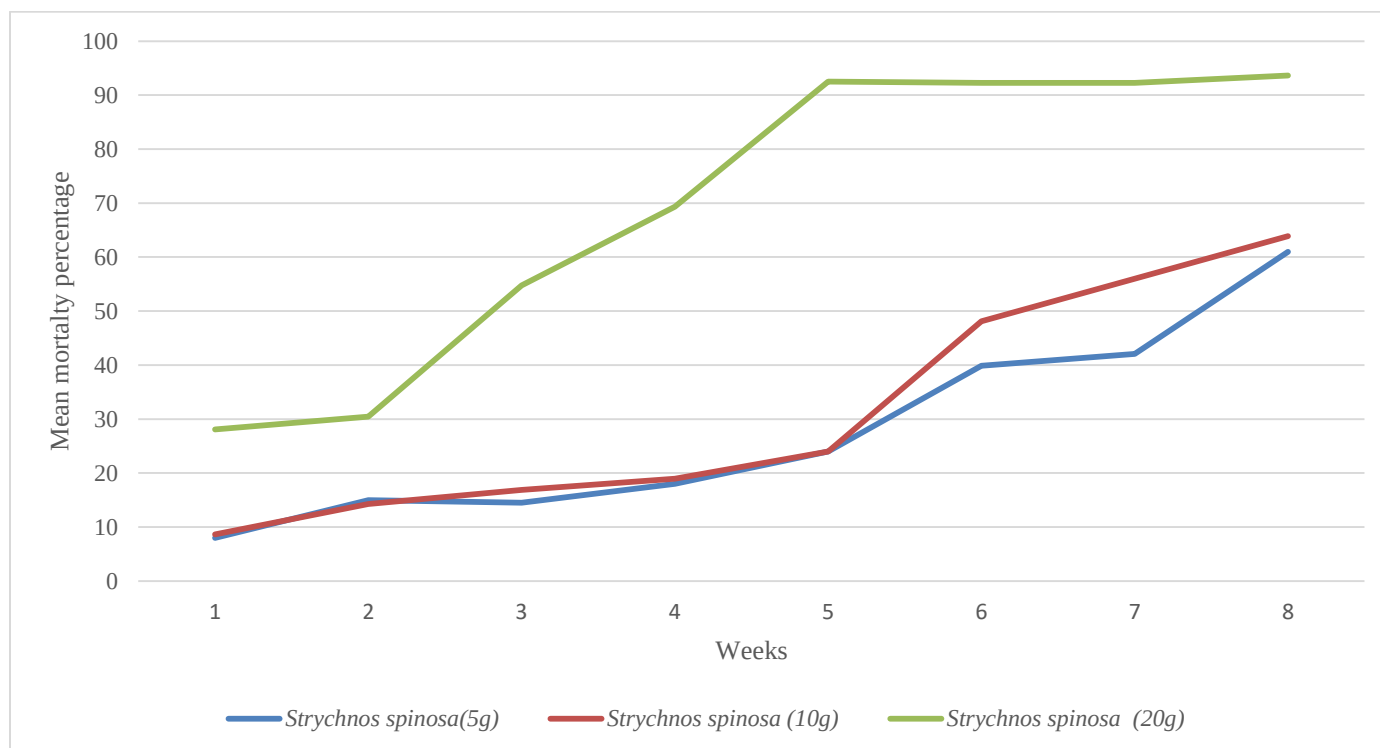


Figure 2.10: Effect of difference application dose of *Strychnos spinosa* on mortality rate.

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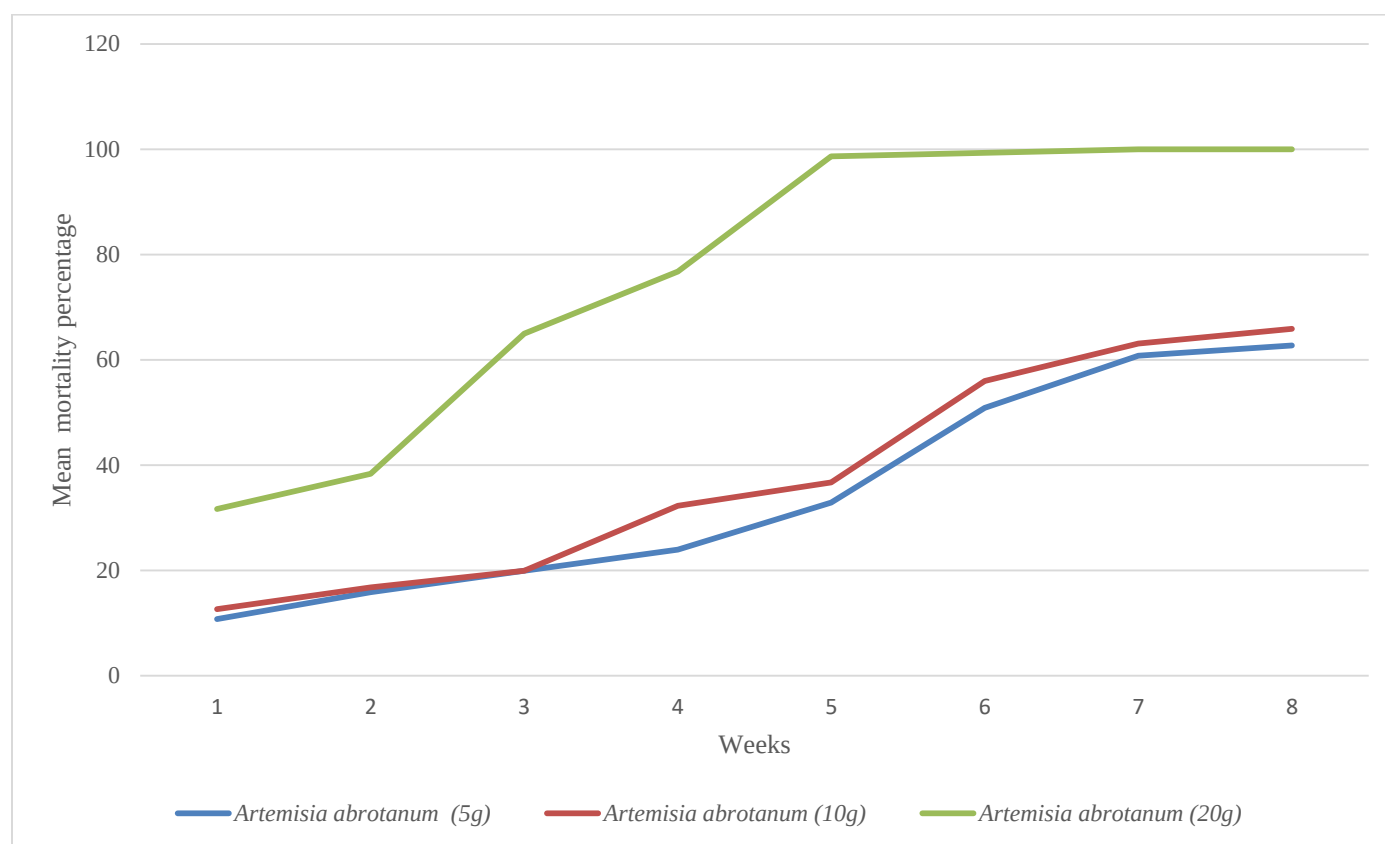


Figure 2.11: Effect of difference application dose of *Lantana camara* on mortality rate.

2.3.2 Discussion.

The present laboratory study on the effectiveness of *Lantana camara*, *Strychnos spinosa*, and *Artemisia abrotanum* leaf powder concentrations indicated that all botanical powders tested were less effective in the control of weevils when compared with that of the standard insecticides (actellic super dust) performed better than leaf powders of those botanicals when treated with 200 g of maize grain at application rates of 5 g, 10 g, and 20 g, however, greatest effectiveness of the botanical pesticides was observed at 20 g *Artemisia abrotanum* followed by *Strychnos spinosa*. *Strychnos spinosa*, when applied at a concentration of 20 g per 200 g of maize grains, recorded an average mortality rate of 69.17%. In contrast, *Sitophilus zeamais* treated with 20 g of *Artemisia abrotanum* leaf powder per 200 g of maize grains exhibited the highest average mortality rate of 76.22% overall eight weeks following application. The mortality rates were significantly lower for *Lantana camara* when used at concentrations of 5 g, 10 g, and 20 g per 200 g of maize, as well as for *Strychnos spinosa* at 5 g and 10 g per 200 g, and *Artemisia abrotanum* at 5 g and 10 g per 200 g. According to Table 2.9, the mortality rate of *S. zeamais* was notably low in the positive control group (untreated). Consequently, small-scale farmers can utilize any of these plant leaf powders in various concentrations as effective alternatives to chemical pesticides for treating their maize.

It was observed that the performance of the botanical pesticide increased with increasing doses of application, such that the higher the botanical weight per 200 g of maize grains, the better performance in reducing the incidence of weevil attack hence protecting the grains. This agrees with the work of Ukpa *et al.*, (2017) and

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Amadi *et al.*, (2018) who reported that higher dosages work effectively in the control of *Sitophilus zeamais*. Therefore; the effectiveness of those botanical leaf powders can be improved by increasing the dosage to maintain their efficacy. All botanical products tested performed well in controlling *Sitophilus zeamais* in stored maize grains as compared to the control (untreated) application. The untreated maize had the lowest mortality rates in all weeks since it offers free movement of the weevils leading to high chances of mating, resulting in an increasing weevil population. The high build-up of weevils in the untreated maize results in high feeding rates that lead to the highest weight loss and damaged maize seeds compared to all the other treatments. Weevils are capable of causing 80-100% weight loss and can also cause secondary effects such as fungal infection leading to further weight loss if grains are left untreated for long periods. (Duke, J.A, 2001).

The study demonstrated that all the botanical leaf powders tested exhibited insecticidal properties by significantly reducing the population of maize weevils in the samples, although their effectiveness varied. According to Aktar *et al.* (2004), the impact of different plant materials on insects can depend on factors such as chemical composition and the susceptibility of the insect species. The findings of this study align with previous research that has demonstrated the effectiveness of local botanical products and other accessible materials in protecting stored maize grains against weevils. For example, studies have shown the use of maize cob ashes at varying concentrations to control maize weevils (Gadzirayi *et al.*, 2006).

2.4 CONCLUSION AND RECOMMENDATIONS.

Through that observation, *Artemisia abrotanum* leaf powder at an application rate of 20 g in 200 g of maize grains showed potential in controlling the weevils because of the high mean mortality rate of *Sitophilus zeamais* and therefore can be used as a good alternative to synthetic pesticides than other botanicals in the control of maize grains as the plant is locally available in the village and therefore easily available to the small scale farmers in Vikenge village throughout the season and is a suitable material in that location, however, regular re-application of the botanical powder is necessary to maintain high efficacy, as the effectiveness of botanicals diminishes over time during the study.

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Conflicts of Interest: The author(s) declare(s) that there is no conflict of interest regarding this work.

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