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INSECTICIDAL POTENTIAL OF INDIGENOUS PLANTS LEAF POWDER AGAINST Rhyzopertha Dominica FAB. (Coleoptera: Bostrichidae) IN STORED MAIZE (Zea Mays) GRAINS IN NORTHEASTERN NIGERIA

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ABSTRACT

The study on the toxicity potential of plant leaf powders of Eucalyptus globulus, Citrus limon and Cassia occidentalis against maize weevil (Rhyzopertha dominica) infestation during storage was investigated in the Laboratory of the Department of Crop Protection, Faculty of Agriculture, Modibbo Adama University, Yola. The experiment was laid out in a Completely Randomized Design (CRD) with three replications and data collected were analyzed using General Linear Model Procedure of Statistical Analysis System (SAS, 2004) while, significance means will be compared using Duncan's Multiple Range Test (DMRT) at 5% probability level. Rhyzopertha dominica where exposed to four doses (0.2 g, 0.4 g, and 0.6 g) of these leaf powder per 50g of maize and a control treatment. Phytochemical analysis reveals the leaf powder of Eucalyptus globolus, Citrus limon, and Cassia occidentalis contain the following components (Saponin, Tanin, Steriod, Glycocide, Flavonoid, Tapinoid, Alkaloidand phenol). Though C. limon and C. occidentalis did not showed the presence of Tapinoid. The result of R. dominica mortality showed that at 3, 7, 14, and 21 days, highest mortality was observed on SAMMAZ 51 while SAMMAZ 15 had the lowest mortality. Mortality also of R. dominica on treated maize was highest at 0.6 g dosage, with effectiveness increasing over time. The Treated Maize exhibited less grain damage and weight loss compared to untreated controls. Germination percentage and palatability tests revealed no significant difference ($P < 0.05$) between treated and untreated maize among the tested plant powders. C. occidentalis demonstrated the highest efficiency in controlling R. dominica which can be recommended as effective botanical insecticides for the control of R. dominica in stored maize, these offer a promising eco-friendly alternative for post-harvest pest management.

KEYWORDS: Indigenous Plants; Rhyzopertha dominica; Leaf Powder; Zea mays; Insecticidal.

INTRODUCTION

Maize (Zea mays) is a cereal plant belonging to the grass family Poaceae and it is the most important cereal crop in Sub-Saharan Africa (SSA), which originated from Mexico and Central America (Schnable et al., 2009). It has several species that exist and consist of different colors, textures, and grain shapes and sizes. White, yellow and red maize are the most commonly cultivated types.

It's an important staple food for more than 1.2 billion people in Sub-Sahara Africa and Latin America, and more than 300 million Africans depend on it as the main stable food crop (IITA, 2022). It is one of the most cultivated cereal grains in West Africa most especially in Nigeria which produces about 7.7 million tonnes of maize grains annually, representing 0.9% of the world production (Amudalat, 2015; FAO, 2019).

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Unfortunately, more than 70% of the grains produced are stored in villages in traditional storage structures such as earthen pots, silos, gunny bags, steel drums, and baskets (Mobolade et. al., 2019).

However, maize storage is constrained by attack from insect pests which destroy approximately 20% to 50% of stored maize in most African countries (CABI, 2012). This stored maize grains is damaged by primary stored grain insect pests especially Rhyzopertha dominica (F.) (Coleoptera: Bostrichidae) (Rajashekar et al., 2012). The damage caused by R. dominica is direct, which affects the quantity, quality and germination of the grains (Doncho et al., 2020).

The control of R. dominica is effectively achieved by the use of synthetic insecticides which are expensive for low-income farmers who are largely illiterates and thus misapply them (Medugu and Okrikata, 2021). Also, the indiscriminate use of these synthetic insecticides is of global concern due to its attendant hazards to man and the environment (Perez et. al., 2010; Okrikata and Anaso, 2019; Medugu, 2021). Therefore, alternative methods for control of this pest should be developed which must be effective, socially acceptable, ecologically reliable and economically feasible (Islam et. al., 2013; Thein et. al., 2013). Natural plant powders have proved to be effective against various stored grains insect pests especially R. dominica (Sagheer et al., 2013). Extracts of this plants contain volatile compounds that affect insect behavior and physiology through inhibiting reproduction, growth or development inhibitors, toxicants, repellent, deterrents and antifeedants (Khan et al., 2014; Trivedi et al., 2018). However, the efficacy and economic viability of plant products in pest management are well elucidated (Okrikata E, Oruonye, 2012; Okrikata et al., 2016).

To achieve food security, new methods are required to manage pests of stored maize grains, hence, the objective of this study was focused on the evaluation of insecticidal effects of three indigenous plant powder of Citrus limon, Cassia occidentalis, and Eucalyptus globulus in the control of R. dominica in stored maize grains.

MATERIALS AND METHODS

Study Site

The study was conducted in the Laboratory of the Department of Crop Protection, Modibbo Adama University, Yola, Adamawa State Nigeria, located on latitude $9^0$21'30"N and longitude $12^0$30, 30" E. It has a tropical climate with distinct dry and wet season. It has an average temperature and relative humidity of 20.5-40^0 C and 35-75%, respectively (Adebayo and Zemba, 2020).

SOURCE OF EXPERIMENTAL MATERIALS

Collection and preparation of plant materials, maize varieties and other materials

The fresh plant leaves of Citrus limon, Cassia occidentalis, and Eucalyptus globulus were collected from the University School Farm. The leaves were washed and shade-dried under room temperature in the Laboratory to avoid contamination for 5 days. Thereafter, the dried leaves were grounded into fine powder using electric blender Binatone model; BLGS585B and sieved with fine mesh and then stored in air tight plastic containers at room temperature prior bioassay.

A total of three (3) maize grains varieties were obtained from the Institute for Agricultural Research (IAR) Samaru, Zaria, Kaduna State, The maize grains were examined to remove any dirt and broken grains and thereafter sterilized thermally in a hot-air oven (Hot Air Circulated Oven; OV95c) at 60^oC for 1 hour to kill any pest and pathogen that might harbor inside the grains, and then allowed to equilibrate for 24 hours in the laboratory, while the experimental bottles was purchased in Jimeta modern market, were then washed and dried, and sterilized as above (Medugu, 2012). The above preparations were carried out prior to proximate analysis and bio-assays.

Phytochemical Analysis of Plant Leaf Powder

To achieve this, 5g of each plant leaf powder was weigh and placed into 100mls of conical flask. Distilled water was added to make up to volume (100mls). The conical flask was then covered and Shaked to ensure it is properly mixed. It was then filter using a paper filter. Each of the components present in the leaf powder was determined using the standard procedure to identify the constituent as described by Sofowora (1993).

Insect Culture

Adult parent stock of R. dominica population obtained from the Laboratory stock of the Department of Crop Protection, and used to establish new culture by rearing on a susceptible maize variety "SAMMAZ34" (Medugu et al., 2020) in two 1-litre transparent plastic bucket and routinely maintained to provide weevils of similar age for the study. Fifty (50) adult R. dominica per 500 g maize grains was placed in each bucket and then covered with muslin cloth fastened with rubber band to aid aeration and to prevent escape of the weevils. After ten days of oviposition, all parents R. dominica in each bucket were removed and placed on another fresh set of grains medium repeatedly until sufficient number of insects are obtained for the experiments. This set up was kept at Laboratory conditions on an open-air shelf. The Emerged F_1 progeny at 1-3 days old were then used for the experiment (Medugu, 2019).

Experimental Procedures

The treatments consist of Citrus lemon, Cassia occidentalis and Eucalyptus globulus leaf powder which consists of three dose rates each with an untreated control, each replicated three times.

Two Lots of 150 g of each maize variety was placed in 500 ml capacity bottles and then treated with three dose rates each of 0.2 g, 0.4 g and 0.6 g of Eucalyptus globulus, Citrus lemon, and Cassia occidentalis leaf powder, respectively. Each lot is then capped and shaken manually for approximately 1 minute to achieve uniform distribution of the plant leaf powder in the entire grain mass, while control (0 g) had no treatment. Subsequently, three samples of 50 g of each treated and untreated maize was taken from each lot, and placed in 1 litre capacity bottles. In each bottle, ten (10) unsexed R. dominica adults were introduced, and the bottles covered with muslin cloth fitted with rubber band to allow gaseous exchange. This set-up was kept at laboratory condition of temperature and relative humidity of 20-31°C and 45-75%, respectively laid out in a split-split plot design with three replications.

Data Collection

Mortality of Rhyzopertha dominica

Adult mortality in both treated and untreated (control) bottles were assessed at 3, 7, 14 and 21 days after infestation (DAI) of beetle. To assess this, all adult insects were removed from each bottle and the dead and live insects counted and recorded. After 3, 7 and 14 DAI counts, live insects were returned to their respective bottles. On the 21 DAI counts, all dead and live insects were removed and grains were kept under same condition for observation of grain damage and weight loss. An insect is assumed dead when probed with a pin and there was no movement (Adedire et al., 2011).

Maize Grain Losses

At the 36 and 90 DAI, grains were taken from each bottle, the holes counted and recorded to assess the percentage grain damage (grains with number of adult exit holes) and the grain final weight was also taken to calculate the percentage weight loss due to beetle feeding.

Maize grain damage

Grain damage was expressed as a proportion of the total number of seeds sampled (Abebe et al., 2009):

$$\%\ \text{Grain damage} = \frac{\text{Total number of grains} - \text{Number of damaged grains}}{\text{Total number of grains}} \text{X } 100$$

Maize grain weight loss

The percentage weight loss was determined as describe by Samuel et al. (2010) thus;

$$\%\ \text{weight loss} = \frac{Wc - Wt}{Wc} \times 100 \quad (1)$$

where;

Wc = initial weight of sample before experiment

Wt = final weight of sample after experiment

Germination Percentage

The viability of treated and untreated grains was tested in the Laboratory of the Department of Crop Protection, Modibbo Adama University, Yola. To achieve this, ten grains were randomly collected from each treatment. The grains were placed on moist cotton wool in Petri dishes, labelled and left on a Laboratory bench exposed to sunlight for five days. This set up was replicates three times. At five days after planting, emerged seedlings were then counted and recorded, and percentage germination was calculated using the formular below (Yusuf et al. 2011).

$$\%\ \text{germination} = \frac{\text{Number of germinated seed}}{\text{Total number of seeds planted}} \times 100$$

Statistical Analysis

The data collected was analyzed to ascertain the significant differences between mean, while mean was compared using least significant differences (LSD) at $P < 0.05$ (Genstat, Software).

RESULTS

Phyto-chemical Analysis of Plant Leaf Powder

The result showed that the leaf powder of Eucalyptus globous, Citrus lemon, and Cassia occidentalis, contain all the listed component; Saponi, Tanin, Steriod, Glycocide, Flavonoid, Tapinoid, Alkaloid, Phenol. Though, Citrus lemon and Cassia Occidentalis did not showed the presence of Tapinoid.

Table 1: Phyto-chemical Analysis of Plant Leaf Powder

S/No	Components	Eucalyptus globulus	Citrus lemon	Cassia occidentalis
1	Saponi	+	+	+
2	Tanin	+	+	+
3	Steriod	+	+	+
4	Glycocide	+	+	+
5	Flavonoid	+	+	+
6	Tapinoid	+	-	-
7	Alkaloid	+	+	+
8	Phenol	+	+	+

Keys: **+** = presence of the compounds **-** = absence of the compound

Effects of plant leaf powder on mortality of Ryzopertha dominica at different concentration and time

Table 2 showed the rate of mortality at different level of concentrations and time, from day 3, 7, 14 and 21, respectively. There is no significant difference ($p<0.05$) among the varieties across the mean mortality at all periods of the experiment. As at day 3, SAMMAZ 51 happens to have the highest mean mortality of 1.611 followed by SAMMAZ 29 with a mean of 1.556 and SAMMAZ 15 having the lowest mortality mean of 1.389. At day 7, SAMMAZ 29 has the lowest mean of 4.03 and SAMMAZ 51 has the highest mean mortality (4.44) while SAMMAZ 15 has mean mortality of 4.19. Ryzopertha dominica mortality at 14 days period showed that SAMMAZ 29 has the highest mean mortality of 5.69, followed by SAMMAZ 51 with mean score of 5.50, while SAMMAZ 15 has the lowest mortality of 5.47, though there is no significant different of Ryzopertha dominica mortality between the varieties.

Furthermore, there is no significant different of mortality and the varieties at day 21. However, SAMMAZ 29 has the highest mean mortality of 7.00 followed by SAMMAZ 51 with mean mortality of 6.72 while SAMMAZ 15 has the lowest mean mortality of 6.92. However, at 3 and 14 days of storage, SAMMAZ 15 had the lowest mortality of 1.389 and 5.47, respectively, and at 21 days, highest mortality was observed on SAMMAZ 29 with a mean of 7.00, followed by SAMMAZ 15, with mean of 6.92, and SAMMAZ 51 having mean of 6.72.

Mortality of Ryzopertha dominica by different plant leaf powder showed that at day 3, Eucalyptus globulus plant powder has the lowest mortality mean of 1.417 followed by Cassia occidentalis with mean of 1.528 and the highest mean mortality was recorded from Citrus limon with 1.611. Similarly, day 7 also showed that Cassia occidentalis has the highest mean mortality of 4.64 followed by Eucalyptus globulus with a mean mortality of 4.22, while Citrus limon has the lowest mortality of 3.81. The different plant powder used indicated highly significant differences ($p =0.05$). However, at 14 days of exposure period, the result showed high significant different ($p =0.05$) of Rhyzopertha dominica mortality between the different plant powders. Cassia occidentalis has the highest mortality mean of 6.39, followed by Eucalyptus globulus 5.47, while Citrus limon has lowest mortality mean of 4.81.

Among the plant powder Citrus limon has the lowest mortality mean of 6.56 and Cassia occidentalis has the highest mean of 7.47, followed by Eucalyptus globulus with moderate mean mortality of 6.61 at 21 days. Nevertheless, highly significance difference among the plant powder was observed.

Mortality of Ryzopertha dominica at different concentrations of plant leaf powder indicated that, 3 days period there is high significant different among the different concentrations, as concentration increases the mean mortality increases. The lowest mean mortality of 0.148 observed in the control (0.0 g), followed by 0.2 g (0.926) and 0.4g (1.889) while 0.6 g had the highest mean mortality of 3.111. This indicated that mortality increases with increase in concentration. The different concentration showed high significant difference ($p=0.05$). At day 7, the result showed that mortality increases with increase in concentrations from 0.2 g, 0.4 g and 06 g of 0.9613, 3.48, 5.56 and 6.89, respectively. Same trend was observed at 14 days period where mortality increases with increase in concentration. at 0.2 g, 0.4 g and 06 g of 4.81, 7.37, 8.30, respectively while, control 0.0 g has the lowest mean mortality of 1.74. concentration among plant powder used showed high significant different ($p<0.05$). Additionally, at 21 days, concentration level of 0.2 g, 0.4 g and 0.6 g, recorded 6.11, 8.78, and 9.70 of R. dominica mortality, while control (0.0 g) recorded the least mortality of 2.93. though, high level of significance was also observed.

The interaction between varieties and plant powder, varieties and concentration, plant powder and concentration, and varieties, plant powder and concentration are all non-significant (NS) at all the storage periods except at 14 days storage period where plant powder and concentration showed significant difference ($p=0.05$).

Interaction between plant powders and concentration on mortality of Rhyzopertha dominica

The result in Table 3 shows the mean mortality of Rhyzopertha dominica when treated with different plant powder at various concentrations of 0.0 g, 0.2 g, 0.4 g, 0.6 g. The control 0.0 represent the baseline mortality rate without any plant powder applications with a mean mortality of 1.67 Eucalyptus globulus, 2.00 Cassia occidentalis and 1.56 Citrus lemon. At 0.2 g, Eucalyptus globulus had mean mortality of 4.56; Cassia occidentalis had the highest of 5.44, while Citrus lemon had the lowest of 4.44 at 0.4 g, Eucalyptus globulus had 7.11, Cassi occidentalis had the highest mortality of 9.22, while Citric lemon had the lowest mortality of 5.78. Furthermore, at 0.6 g, Eucalyptus globulus had 8.56, Cassia occidentalis had the highest mortality of 8.89, and Citrus lemon with lowest mortality of 7.44. It can be noted that Cassia occidentalis had the highest mortality of 9.22 at all the concentrations. However, Cassia occidentalis recorded the highest mean mortality (2.00, 5.44, 9.22 and 8.78 at all levels, respectively) as compared to Eucalyptus globulus and Citric limon. While, Citric limon has the lowest mean mortality at all concentration levels, followed by Eucalyptus globulus of 1.67, 4.56, 7.11 and 8.56 respectively.

Table 2: Effects of varieties, plant powder and concentration on mortality of Rhyzopertha dominica for 3, 7, 14 and 21 days storage period.

	Mortality (days)			
Treatment	**3d**	**7d**	**14d**	**21d**
Varieties (V)				
SAMMAZ 15	1.389	4.19	5.47	6.92
SAMMAZ 29	1.556	4.03	5.69	7.00
SAMMAZ 51	1.611	4.44	5.50	6.72
P≤F	0.008	0.296	0.826	0.505
LSD	0.099	0.636	1.063	0.620
Plant powder (p)				
E. globulus	1.417	4.22	5.47	6.61
C. occidentalis	1.528	4.64	6.39	7.47
C. limon	1.611	3.81	4.81	6.56
P≤F	0.680	0.004	<.001	<.001
LSD	0.476	0.424	0.438	0.268
Concentrations (C)				
0.0	0.148	0.96	1.74	2.93
0.2	0.926	3.48	4.81	6.11
0.4	1.889	5.56	7.37	8.78
0.6	3.111	6.89	8.30	9.70
P≤F	<.001	<.001	<.001	<.001
LSD	0.4383	0.647	0.629	0.639

V = Variety; P = Plant powder; C = Concentration; NS = Not significant; ***** = significance

Table 3: Interaction between plant powders and concentration on mortality of Rhyzopertha dominica

	Concentration (g)			
Plant powder	**0.0**	**0.2**	**0.4**	**0.6**
Eucalyptus globulus	1.67	4.56	7.11	8.56
Cassia occidentalis	2.00	5.44	9.22	8.89
Citrus lemon	1.56	4.44	5.78	7.44

Effects of plant powder and concentration on grain damage, weight loss and percent germination of Maize grains after three months storage period.

Table 4 showed the effectiveness of plant powder for the control of R. dominica in stored maize grains at 36 and 90 days storage periods and percentage germination performance after 90 days. The damage and weight loss were compared across the mean of different plant powder and concentrations at both 36 and 90 days which all indicated non-significant difference (P<0.005).

Grain damage due to activities Rhyzopertha dominica on different maize varieties at 36 and 90 days storage period

At 36 days of storage, SAMMAZ 51 exhibited the highest mean grain damage of 11.69 due to the activities of Rhyzopertha dominica, while SAMMAZ 15 had the lowest mean damage of 8.75, followed by SAMMAZ 29 with a mean damage of 9.75. After 90 days of storage, SAMMAZ 51 continued to show the highest susceptibility with a mean grain damage of 19.69, while SAMMAZ 29 had the lowest mean damage of 14.31 followed closely by SAMMAZ 15 with a mean damage of 14.61 (Table 4). Among the plant powder, after 36 and 90 days storage period, Citrus lemon had the highest grain damage of 10.92 and 17.81, respectively followed by Eucalyptus globulus 9.94 and 16.08, respectively. While Cassia occidentalis had lowest grain damage of 9.33 and 14.72 at 36 and 90 days storage periods, respectively. It was observed that as the level of concentration increases the level of damage decreases. At 0.0 g, 0.2 g, 0.4 g, 0.6 g, all the maize varieties recorded mean damage of 16.19, 11.00, 7.52, 5.56 and 26.19, 17.85, 12.04 and 12.04 at 36 and 90 days storage periods, respectively (plate iv). At day 36- and 90-days storage period, interaction showed that there is non-significant difference between varieties and plant powder, varieties and concentration, plant powder and concentration, varieties, plant powder and concentration.

Weight loss due to activities of Rhyzopertha dominica on different maize varieties at different storage period

The result on weight loss showed that there is significant difference (p<0.05) at 36 and 90 days of storage period. SAMMAZ 15 had the highest grain weight loss of 48.15 and 45.76 at 36 and 90 days, respectively followed by SAMMAZ 29 with 47.70 and 45.59, respectively. While moderate grain weight loss was recorded on SAMMAZ 51 of 47.07 and 43.61, respectively. Nevertheless, at 36 and 90 days storage period, highest grain weight loss was recorded by Citric lemon from initial 50 g cowpea grains to 47.29 g and 44.39 g, respectively, followed by Eucalyptus globulus of 47.60 g and 44.98 g at day 36 and 90, respectively. While low weight loss was recorded by Cassia occidentalis of 48.03 and 45.60 g at 36 and 90 days storage periods, respectively (Table 4). Furthermore, different weight loss was observed at different concentration (0.0, 0.02, 0.4, and 0.6 g). The result showed highest weight losses of 48.98 at 0.6 g followed by 48.50, 47.65 and 46.78, 44.25 at 0.4 and 0.2, respectively, while the lowest weight loss was recorded in the control of 45.43 and 40.97 at 36 and 90 days storage periods, respectively. At the end of the 90 days, interaction showed that there is no significant difference (p<0.005) between all the different concentration levels.

Percentage germination of maize varieties after 90 days of storage period

The result indicated that after 90 days storage period, SAMMAZ 51 recorded lowest germination percentage of 6.53 while SAMMAZ 29 had the highest germination percentage of 7.44, followed by SAMMAZ 15 with 7.14. On the other hand, maize variety treated with Citric limon had the lowest germination percentage of 6.83, while Cassia occidentalis had the highest germination percentage of 7.39, followed by Eucalyptus globulus of 6.89. However, as the concentration increases germination also increases. Therefore, control (0.0 g) had the lowest germination percentage of 6.19 followed by 0.2 g (6.81). While highest germination was recorded at 0.6 g concentration followed by 0.4 g (7.15). The interaction indicated that there is non-significant difference (p<0.005) between varieties and plant powder, varieties and concentration, plant powder and concentration, and varieties, plant powder and concentration (Table 4).

Table 5: Effects of varieties, plant powder and concentration on grain damage, weight loss and percent germination after three months storage period

Treatment	GD 36 days	WL 36 days	GD 90 days	WL 90days	% germination
Varieties (V)					
SAMMAZ 15	8.75	48.15	14.61	45.76	7.14
SAMMAZ 29	9.75	47.70	14.31	45.59	7.44
SAMMAZ 51	11.69	47.07	19.69	43.61	6.53
P≤F	0.014	0.004	0.021	0.018	0.218
LSD	1.513	0.397	3.477	1.299	1.214
Plant powder (P)					
E. globulus	9.94	47.60	16.08	44.98	6.89
C. occidentalis	9.33	48.03	14.72	45.60	7.39
C. limon	10.92	47.29	17.81	44.39	6.83
P≤F	0.274	0.089	0.042	0.037	0.408
LSD	2.048	0.657	2.332	0.896	0.959
Concentrations (C)					
0.0	16.19	45.43	26.19	40.97	6.19
0.2	11.00	47.65	17.85	44.25	6.81
0.4	7.52	48.50	12.04	46.78	7.15
0.6	5.56	48.98	12.04	46.78	8.00
P≤F	<.001	<.001	<.001	<.001	<.001
LSD	0.706	1.869	2.372	1.134	0.789
Interactions					
VXP	NS	NS	NS	NS	NS
VXC	NS	NS	NS	NS	NS
PXC	NS	NS	NS	NS	NS
VXPXC	NS	NS	NS	NS	NS

GD = Grain damage; WL = Weight loss V = Varieties; C = Concentration; P = plant powder

DISCUSSION

Phyto-chemical Analysis of Plant Leaf Powder

The result obtained from the qualitative analysis of the plant leaf powder used in the study indicate that Eucalyptus globulus had the following compounds; saponin, tannin, steroid, glycocide, flavonoid, tapinoid, alkaloid and phenol. While Citrus lemon (limon) and Cassia occidentalis had the following compound; saponin, tannin, steroid, glycocide, flavonoid, alkaloid and phenol. It can be noted that all the plant leaf powder possesses the entire compound tested except for Citric lemon and Cassia occidentalis where terpenoid was absent. The compound extracted from Citrus lemon and Cassia occidentalis and Eucalyptus globulus is similar with the finding of Ehigbai et al, (2016), Verma et al (2010), Barbosa et al (2016), respectively. The result above indicate that all the plant leaf powder used in the study has insecticidal properties as stated by Sarwar, M. (2015) that, the most potent bioactive compounds responsible for insecticide properties in botanicals are alkaloids, non-proteic amino acids, steroids, phenols, flavonoids, glycosids, glucosinolates, quinones, tanins, terpenoids, salanine, meliantrol, azadiractin, piretrolone, cinerolone and jasmolone acting as contact poisons, ingestion or stomach poisons, feeding deterrences, repellents and confusants, leading to finally death of the insects.

However, at each storage period, the three maize varieties exhibited different levels of mortality against Rhyzopertha dominica. As storage duration increases from day 3 to 21, the mortality of Rhyzopertha dominica generally increases for all the varieties. This finding indicated that the various mortality exhibited on the varieties is depending on the storage duration. This is in agreement with the findings of Chougourou et al (2016) who reported that mortality rates increased proportionally with duration of exposure time. At day 3 and 7 also, the mortality exerted on SAMMAZ 51 was high compare to day 14 and 21, this may be due to the active compound present in the leaf powder that degraded over time. As stated by Lengai et al. (2020) that botanical pesticides are easily broken down by detoxifying enzymes and disintegrate quickly in plant systems, the air, and moisture due to their easy breakdown properties. Therefore, due to their rapid breakdown, botanical pesticides show less persistence in the environment and are less toxic to non-target creatures. Insecticides can kill pests when a lethal amount is administered, but to fully understand their impact, sub-lethal effects must also be considered. Because pesticides naturally break down after being applied to crops, insects are frequently exposed to sub-lethal amounts of the chemicals (Desneux et al., 2007; Mostafiz et al., 2020).

The differences observed in mortality from the three varieties of maize at day 3 up to 21 days, the highest mortality which was observed in SAMMAZ 29 at 21 days could be due to the characteristics possess by the different variety that either favour the survival or less favourable to Rhyzopertha dominica leading to mortality. The physical factors such as antibiosis or hardiness as a result of biochemical compounds are toxic to insects which lead to subsequent death of the weevils (Siwale et al 2009).

Mortality rate increases as storage period increases, but extend of the increase varies depending on the concentration of the plant powder across all the treatment (Eucalyptus globulus, Cassia occidentalis and Citric lemon). Day 3 indicate non-significance difference, while day 7, 14, and 21 showed highly significance difference $p<0.005$ among the plant powder. Although all the plant powder exert mortality on R. dominica and Citric limon happens to be more effective at 3 days (early) of storage. Cassia occidentalis recorded higher mortality followed by Eucalyptus globule plant powder from day 7, 14, and 21, respectively. This therefore, indicated that treatments have a greater effect on Rhyzopertha dominica over long duration both at steady and different concentration. This is in agreement with the study carried out by Waleed et al., (2021) who revealed that Cassia occidentalis gave significantly higher mortality percentage than the control throughout the experimental period. Additionally, the lethal effects of these extracts were dose and time dependent. At 3 days, the mortality increases from 0.148 at 0.0 g concentration to 3.111 at 0.6 concentrations, indicating a clear concentration dependent effect. At 7 days, the mortality increases from 0.96 at 0.0 g (control) concentration to 6.89 at 0.6 g concentration. Which likewise show a strong concentration dependent effect. The p. value suggests higher concentration of the plant powder results in high mortality rate across all storage periods. However, at 7, 14, and 21 days, the p. value shows mortality rate less than <0.001, indicating extremely high efficacy in controlling R. dominica. The findings therefore reveals that, the concentration of the plant powder has a significant impact on the mortality of R. dominica, and higher concentration is more effective in controlling the insect, leading to higher mortality rates especially over longer storage periods. This is in agreement with the findings of (Waleed et al., 2021). However Citrus lemon is able to offer significant level of protection against R. dominica which is similar with the findings of Adusei Mensah et al., (2014) who reported highest toxic effect was recorded for Citrus medica followed by Citrus lemon.

The result in table 3 indicated that there is a significant interaction between the plant powders and their concentrations on the mortality of R. dominica. This indicated the effects of the plant powders on mortality of the insect are not the same across the different concentration tested. Therefore, the mortality of R. dominica therefore increases with increasing concentration for all the three-plant powder, but the magnitude of effect differs between the plant powders which is in line with the finding of Negbenebor (2021), this demonstrates the interaction between the plant powder type and concentration on the insecticidal activity against R. dominica. The mortality therefore may be due to the type of plant powder used, concentration and time period, which is in agreement with the findings of Fouad et al. (2020) who demonstrated that mortality of C. maculatus adults varied according to plant species, concentrations of plant powder and time period of exposure. The results are also in concordance with previous studies that reported the insecticidal toxicity of L. inermis leaves that successfully control cowpea weevil (Jose and Adesina, 2014; Suleiman and Suleiman, 2014; Chudasama et al., 2015).

CONCLUSION

The various plant leaf powder of Cassia occidentalis, Eucalyptus globulus and Citric limon used in this study contained important bio-pesticidal properties making all the three-plant leaf powder effective in the control of R. dominica. This study will enable one to device a strategic means of managing this cosmopolitan pest of maize as well as other cereals and storage products. The use of maize varieties with proven resistance can aid in reducing the cost of management of Rhyzopertha dominica. Many reviewers have proven that in the past plant parts (leafs, roots, stems, and fruits) have been used as botanical pesticide in the control of storage pest. There is also need for further studies to achieve a long term and sustainable pest management strategies so as to diversify various plant materials for pest control.

Cassia occidentalis shows highly level of mortality of Rhyzopertha dominica among all the plant leaf powders used although considerable mortality was recorded on Eucalyptus globulus and Citric lemon leaf powder at all the storage periods. As concentration of plant powder increase the rate of R. dominica mortality also increases at different time intervals.

Rhyzopertha dominica is a cosmopolitan pest of stored products, and the level of damage they caused is very serious. The study showed that R. dominica can be control by the use of Cassia occidentalis, which is readily available, low risk and easy to handle and should be encouraged since it does not have negative effect on palatability.

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