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| RESEARCH ARTICLE

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BIO-CONTROL OF RAW DIATOMACEOUS EARTH ALONE OR/IN COMBINATION WITH PERMETHRIN DUST AGAINST RHYZOPERTHA DOMINICA (COLEOPTERA: BOSTRYCHIDAE) ON STORED WHEAT (TRITICUMSPP)

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| ABSTRACT

Laboratory experiments was carried out to evaluate the efficacy of raw DE alone or/in combination with permethrin dust against R. dominica on wheat, to assess insect mortality caused by exposure to raw DE and/ or permethrin, effects on progeny production of exposed beetles and prevention of grain damage by the test insect. R. dominica was obtained from laboratory cultures which has been maintained in the laboratory for over year, where F_1 progeny was used for the experiment.

| KEYWORDS

Wheat .Diatomaceous earth .Rhyzoperthadominica .Mortality .Progeny

| ARTICLE INFORMATION

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ABSTRACT:-

Laboratory experiments was carried out to evaluate the efficacy of raw DE alone or/in combination with permethrin dust against R. dominica on wheat, to assess insect mortality caused by exposure to raw DE and/ or permethrin, effects on progeny production of exposed beetles and prevention of grain damage by the test insect. R. dominica was obtained from laboratory cultures which has been maintained in the laboratory for over year, where F_1 progeny was used for the experiment. The raw DE was tested at application rates of 0 (untreated control) 500, 750, 1000, 1500 mg raw DE/kg alone and with 2 and 5 mg active ingredient permethrin to each DE dose making a total of 12 treatment combinations. Each treatment combination and control, 50 g grain samples in three replicates were place in 250 ml capacity bottles, and thirty adults insects were placed into each replicate. Adult mortality, progeny production and percentage damage kernel by R. dominica were assessed. The result reveals that at higher dose rate of 1500 mg/kg of raw DE and with combination of permethrin gave appreciable adult mortality after 7 days of exposure interval, after continuous exposure to 14 days, complete 100% adult mortality was noticed at 1500 mg/kg dose rate. Progeny production was suppressed after 40 and 80 storage period. Greater than88% progeny suppression where recorded at the lowest dose rate of 500 mg/kg on raw DE and enhanced DE as the dose rate increases, complete progeny inhibition were noticed at the highest dose rate of 1500 mg/kg or 500 mg + 2 or 5 mg permethrin when compared with

untreated controls. The percentage damage kernel decreases at the dose rate of 1500 mg/kg with raw DE combined with 2 and 5 mg/kg were 1.3±1.0 and 0.0±0.0, respectively.

Introduction:-

Wheat Triticum spp is one of the most important cereal in the world. It is staple food for humans and livestock, it is of prime importance when compared to other cereals (Salman and Hamad, 2024).Wheattrading occupies major share in world market when compared to all other cereal crops combined it supersedes rice and maize in its source of protein and calories (Mostafa and Abotaleb, 2024). Wheat production, is hindered by numerous factors which cause quantitative and qualitative losses both before and after harvest (Susurluk and Bütüner, 2024). One of the primary factors contributing to these losses is pests (Mahroofet al., 2010).

Lesser grain borer, Rhyzopertha dominica (F.), is one of the destructive primary insect pests which infests wheat and many cereal grains at post-harvest levels (Naseem and Khan, 2011; Edde, 2012). It is usually a polyphagous and cosmopolitan insect pest all over the world (Majeed et al., 2015; Suleiman and Rugumamu, 2017). R. dominica infestations have been reported to have reduced grains to dust (Salmanet al., 2024).

R. dominicalarvae consume both germ and endosperm during their development in grain and provide more frass and the feeding on seed germ reduces germination rates and vigour of the grains and may be followed by secondary pests and fungi (Manivannanet al., 2024). This insect is capable of damaging grain, causing weight losses of up to 40% (Baliotaet al., 2024). Such damage can be quite serious economically (Cao et al., 2024). It is reported that R. dominica infestation on wheat grains resulted in substantial change in the nutritive contents such as calcium, phosphorus, zinc, iron, copper, manganese and total content of lipids, phospholipids, galactolipids, polar and non polar lipids and vitamin content of the wheat grains (Jood et al., 1996; Perišić et al., 2018; Milosavljevicet al., 2024), and reduction in the starch digestibility (Dhaliwal et al., 2010; Kerbelet al., 2024). Infestation of R. dominicaon wheat grains cause losses of 23 to 29% thiamine, 13 to 18% riboflavin and 4 to 14% niacin (Iqbal et al., 2024).

R. dominica is indeed a notable pest in the realm of grain storage. This species presents a major risk to stored grains like corn, wheat, rice, and sorghum in numerous regions globally (Erturket al., 2024). Both adult and larvae of R. dominica contribute to the deterioration of stored grain quality as they feed (Arthur et al., 2012; Edde, 2012). The life cycle of R. dominica begins with adult females laying eggs shortly after mating (Hill, 2003; Mortazaviet al., 2024), each female can lay 300 to 500 eggs during her reproductive period (Deshwal et al., 2018). Once the eggs are hatch, the larvae begin their destructive feeding habits. They penetrate grains or consume flour and small particles that escape from holes created by adults (Cilgin and Kececi, 2024). Adult R. dominica also exacerbates the damage by entering grains to feed and continue developing (Mahmood et al., 2024). This continuous cycle of egg laying, larval feeding, and adult feeding allows R. dominica to potentially complete 3 to 4 generations per year under favorable conditions (Majeed et al., 2015; Javanmard et al., 2023).

Synthetic chemical insecticides have been employed for many years as a control method to manage pests, and their use persists today (Susurluk and Bütüner, 2024). However, recent European Union (EU) decisions have led to barred on use of chemical insecticides in agricultural production, particularly in stored productspest management (Deshwalet al., 2018). Some of the main reasons for these restrictions are the harmful effects insecticides on non-target organisms and the residues they leave on stored products (Wakilet al., 2024). This decision has increased the quest for alternative insect pest management methods over chemical control. However, findings have shown that the use of Diatomaceous earth which have little or no side effects as compared to the problems pose to the stored products using synthetic chemical insecticides. DEs acts as physical protectants against insect pests by inhibiting reproduction, growth or development through exoskeleton abrasion, cuticle piercing and absorption of fluid thereby dehydrating the insect pest (Majeed et al., 2015). Raw DEalone/or in combination with other formulations confer effective insect pest control in stored grains. DEs have been used as physical insecticides for thousands of years by earliest peoples and are presently used in modern grain storage facilities(Susurluk and Bütüner, 2024). The objectives of this study was evaluate insecticidalpotential of raw diatomaceous earth alone or in combination with permethrin dust in the management of R. dominica on stored wheat.

Material and Methods:-

The Experiment was conducted at the Entomology Laboratory of the Department of Crop Protection, Faculty of Agriculture, University of Maiduguri, Nigeria. Latitude 11^0 50' 42" N, 13^0 9' 36" E. Temperature and relative humidity during the study was measured using hygrometer. Temperature and relative humidity during the study were range from 34^{0c} and 65-75 % relative humidity.

Sources of Experimental Materials

The insects R. dominica was obtained from laboratory cultures which has been maintained for over a year. The wheat variety cetia was obtained from Lake Chad Research Institute, Maiduguri. The DE was supplied in a form of crude soft chalky rock. The rock was milled fine in the laboratory using a pestle and mortar and pass through a fine sieve (150µ) to obtain a powdery consistency. The fine powder was analyzed for $_P{}^H$ and tapped density in accordance with method describe by Korunic (1997). While mineral composition were analyzed in the Mineralogy Laboratory of the Department of Geology, University of Maiduguri by X-ray florescence method on Minimate (Panalytical Company, UK). The insecticide permethrin dust (0.6% a.i). Manufactured by Gongoni Company Limited Kano, Nigeria was obtained and used for the experiment.

Preparation of Wheat Grains

The wheat grains used for the experiment were cleaned, disinfested and placed in 2 kg plastic containerwith cover was used until commencement of experiments.

Insects Culturing Procedures

R. dominica was cultured on wheat. For this purpose 200 unsexed insects were placed on 500g wheat in 1 liter capacity jar and then the parents were removed after 15 days of feeding and oviposition. Parent insects were removed by emptying the content of the wheat on to plastic tray and removing the adult insects from the wheat and returning the grains and grain dust to the culture jar. The resulting F_1 progeny were used for test. The stocks were maintained under ambient laboratory conditions.

Grain Treatment.

The grain was treated at dose rate of 0 (untreated control) 500, 750, 1000, 1500mg raw DE/Kg, alone and with 2 and 5mg active ingredient (a.i) permethrin to each DE dose making a total of 12 treatment combinations. For each treatment combination 150g of wheat grain was placed in 1 liter capacity bottles and different levels of DE and /or permethrin dust were added. The bottles were closedwith their lids and shaken manually for 300 seconds (5 minutes) to acquire uniform distribution on the entire wheat grain. Same quantities of grain were kept untreated to serve as control.

Bioassay Procedures.

Each treatment combinations and control, 50g wheat grain samples in three replicates was placed in 250ml capacity bottles, and thirty (30) adult insects were placed in each treatments replicate. Adult mortalities were observed after 7 and 14 days exposure and each bottle was emptied on to a tray, live and dead insects were recorded and dead insect were removed from the bottles, and the live insects were returned into the bottles and recounted after 14 days of exposure, at this time both the live and dead insects were removed from each treatment bottles.

The grain and the grain dust were returned to their appropriate bottles and kept on the laboratory shelf at the same conditions, for additional 40 and 80 days intervals for adult progenies emergence of F_1 and F_2, respectively.

Experimental Design and Data Analysis

The experiment was laid in split-split-plot design. Insect specie was assigned to the main plot, while exposure period and dose rate were assigned to the sub-plot and sub-subplot, respectively. Data on adult mortality was expressed in percentage and the data were corrected for mortality in control using the Abbott's formula (Abbott, 1925):

$$P_T = (Po\text{-}Pc/100 - Pc)\ 100$$

Where, P_T - Corrected mortality;

Po - Observed mortality;

Pc - Mortality in control

Data on progeny and grain damage were log ($\log_{x+1}$) transformed and subjected to ANOVA with number of progeny and percent grain damage as response to variables and dose rate as main effects. For comparison of treatment means, the Tukey-Kramers' HSD test at P≤0.05, was used.

Results:-

Effect of raw and enhanced DE on mortality of R. dominica and adults after 7 days of exposure.

The results obtained shown that DE and permethrin alone or in combination can cause high mortality in R. dominica. Significant differences (p<0.05) in adult mortality were observed among different dose rates of both DE alone and in combination with permethrin. Increased with increase in dose rate in all cases causes adult mortality of the test insect. Raw DE at a rate of 500 mg /kg gave 65.7±4.7 mortality of R.dominica after 7 days of exposure, while as the dose rate increases, the rate of mortality also increases. At 1500mg/ kg mortality was 81.1±3.1of R.dominica, also at 7 days of exposure (Table 1). As raw DE combined with 2 mg/kg permethrin result in increased beetle mortality. A combination of 2 mg/kg permethrin and 500 mg/kg of raw DE after seven days of exposure resulted in mortality rates of 66.7±3.9 of R. dominica. However, as the DE dose rate increases, the mortality also increases, thus at application dose rate of 1500 mg/kg 87.3±3.0 mortality was achieved. Moreover, as the raw DE combined with additional 5mg/ kg permethrin, after seven (7) days of exposure the mortality at the lowest dose rate of 500 mg/kg was 78.9±4.1. As the dose rate increases mortality rate also increased; at 1500 mg/ kg of raw DE and 5 mg/kg permethrin 100%mortality was observed (Table 1)

Table 1: Effect of raw and enhanced DE on mortality of R. dominica and adults after 7 days of exposure.

Dose rate (mg/kg)	Mortality (SE±)
0.0	2.0 ± 0.6^{b}
500	65.7 ± 4.7^{a}
750	69.6 ± 4.3^{a}
1000	75.7 ± 4.0^{a}
1500	81.1 ± 3.1^{a}
F	78.7
P	< 0.0001
0.0	1.1 ± 0.6^{c}
500+2mg(Perm)	66.7 ± 3.9^{b}
750+2mg(Perm)	71.1 ± 1.0^{b}
1000+2mg(Perm)	80.1 ± 0.9^{ab}
1500+2mg(Perm)	87.3 ± 3.0^{a}
2mg (permethrin)	93.8 ± 6.2^{a}
F	105
P	<0.0001
0.0	3.3 ± 0.0^{c}
500+5mg(Perm)	78.9 ± 4.1^{b}
750+5mg(Perm)	87.8 ± 3.3^{ab}
1000+5mg(Perm)	90.0 ± 5.8^{ab}
1500+5mg(Perm)	$100.\ 0\pm0.0^{a}$
5mg (permethrin)	96.7 ± 3.3^{a}
F	110
P	<0.0001

Mean within columns and within treatment group followed by the same letter(s) are not significantly different (p>0.05) from each other: Tukey-kramer HSD test.

Effect of raw and enhanced DE on mortality of R. dominica adults after 14 days of exposure.

R. dominicamortality after 14 days exposure showed significant differences among the different doses of the raw DE and enhanced DE on wheat. After14 days of exposure interval to raw DE, high mortality rate of >80% was observed at the lowest dose rate of 500 mg/kg. At the highest dose rate of 1500 mg/kg of raw DE 97.8±8% mortality was recorded, combination of 2 mg/kg permethrin, mortality rate at the least dose rate of 500 mg/kg was increased to 91.1±4.5. Increase in dose rate to 1500 mg/kg complete adult mortality was obtained against the test insects. Furthermore, addition of 5 mg/kg permethrin to raw DE, further increases the adult mortality to 94.7±5.3. At 1500 mg/kg and 5 mg/kg permethrin, complete adult mortality was recorded. However, there was no significant differences in mortality level when 2 and 5 mg/kg permethrin was used alone or added to 1000 and 1500 mg/kg of raw DE (Table 2).

Table 2: Mean Mortality (%±SE) of R. dominica adults exposed for 14 days on wheat treated with raw and enhanced DE.

Dose rate (mg/kg)	Mortality (SE±)
0.0	3.3±0.2[b]
500	90.0±5.8[a]
750	93.3±1.2[a]
1000	94.4±5.6[a]
1500	97.8±2.2[a]
F	116
P	<0.0001
0.0	2.2±0.6[b]
500+2mg(Perm)	91.1±4.5[a]
750+2mg(Perm)	96.7±3.3[a]
1000+2mg(Perm)	97.8±2.2[a]
1500+2mg(Perm)	100.0±0.0[a]
2mg (permethrin)	100.0±0.0[a]
F	245
P	<0.0001
0.0	4.0±1.7[b]
500+5mg(Perm)	94.7±5.3[a]
750+5mg(Perm)	96.7±3.3[a]
1000+5mg(Perm)	100. 0±0.0[a]
1500+5mg(Perm)	100. 0±0.0[a]
5mg (permethrin)	100. 0±0.0[a]
F	210
P	<0.0001

Mean within columns and within treatment group followed by the same letter(s) are not significantly different (p>0.05) from each other: Tukey-kramer HSD test.

Effect of raw and enhanced DE on progeny production and percent progeny inhibition of R. dominica adults on treated wheat: The effect of raw and enhanced DE on progeny production, percentage of dead adult progeny and percentage progeny inhibition of R. dominica was shown in Table 3. The results reveals that there were significant differences (p<0.05) among all dose rates and storage periods on numbers of progenies production and inhibition rate of R. dominica.After 40 days storage period there were only very few 2.5% F_1 adult progeny were emerged, when compared with untreated control 113.7%. On raw DE alone treated grain the percentage of dead adult progeny ranged from 69.3±0.5% to 77.6±1.4%, while progeny inhibition ranged from 94.1% to 98.2%. After 80 days of storage period only 2.0% adult progeny emerged were as in the untreated control with 202.7±4.4 adults developed. At the highest dose rate 1500 mg/kg only 0.4±0.4% adult progeny were recorded. At all dose rates progeny inhibition was >98% compared to the untreated control. Similarly, combination of raw DE with 2 mg/kg permethrin only 2.3% adult progeny were emerged when compared with untreated control being 93.7±6.4% and inhibited 93.6% of F_1 adult progeny at least dose rate of 500 mg/kg, at 1500mg/ kg only 1.2% adult were developed and inhibited 98.9%. Also after 80 days of storage, at the lowest application dose rate only 1.9 adults were recorded when compared to 192.7±7.1 in the untreated control while F_1 adult progeny inhibition was 98.2%. At 1500 mg/kg no adult progenies was observed after 80 days of storage. Moreso, after addition of 5mg/kg permethrin, the mean number of F_1 progeny emerged at the least dose rate of

500 mg/kg was only 1.9% and adult progeny inhibition rate was 98.4%, at1500 mg/kg DEcombinedwith permethrin dose no F_1 adult progeny were recorded. After 80 days of storage period at the least dose rate of 500 mg/kg only very few 2.0% adult progeny were emerged whereas 202.7±4.4 F_2 were emerged in the untreated control. Also, at the highest dose rate of 1500mg/ kg combined with 2 and 5 mg/kg permethrin and 2 and 5mg/kg alone of permethrin dose no adult progenies were developed (Table, 3).

Table: 3 Mean numbers (%±SE) of progeny, percent dead progeny and percent progeny inhibition of R. dominica adults exposed to wheat treated with raw and enhanced DE.

40 Days		80 Days				
Dose rate (Mg/kg)	Mean no. of progeny	% Dead progeny	% progeny inhibition	Mean no. of progeny	% Dead progeny	% progeny inhibition
0.0	113.7±6.4a	2.5±0.4b	-	202.7±4.4a	1.9±0.5c	-
500	2.5±0.1b	69.3±0.5	94.1	2.0±0.3b	75.2±6.3b	98.2
750	2.1±0.2b	71.9±1.6a	95.9	1.6±0.2b	83.0±3.5ab	99.0
1000	1.8±0.2b	75.4±5.2a	97.1	1.5±0.1b	88.8±1.7ab	99.2
1500	1.4±0.0c	77.6±1.4a	98.2	0.4±0.4c	95.8±4.2c	99.9
F	308	160	-	2054	100	-
P	<0.0001	<0.0001	-	<0.0001	<0.0001	-
0.0	93.7±6.0a	3.2±0.8d	-	192.7±7.1a	2.1±0.3d	-
500+2mg(perm)	2.3±0.1b	66.7±0.0c	93.6	1.9±0.0b	81.4±1.4c	98.4
750+2mg(perm)	2.1±0.1b	70.9±2.1bc	95.7	1.6±0.2b	84.3±2.8c	98.9
1000+2mg(perm)	1.8±0.1b	75.0±2.9a	97.1	1.5±0.1b	88.3±1.7bc	99.1
1500+2mg(perm)	1.2±0.0b	95.2±0.1a	98.9	-	96.3±3.7ab	-
2mg(permethrin)	0.0±0.0b	-	-	-	-	-
F	350	537	-	720	298	-
P	<0.0001	<0.0001	-	<0.0001	<0.0001	-
0.0	95.0±7.0a	2.7±0.4	-	213.7±27.4a	3.3±0.2b	-
500+5mg(perm.)	2.0±0.2b	73.5±5.6	96.1	1.8±0.1b	83.0±1.9a	96.1
750+5mg(perm.)	1.9±0.0b	75.0±2.1	96.5	1.2±0.0b	89.3±3.0a	96.5
1000+5mg(perm.)	1.8±0.1b	80.1±0.9	97.2	-	-	-
1500+5mg(perm)	0.0±0.0b	-	-	-	-	-
5mg (permethrin)	0.0±0.0b	-		-	-	
F	175	279	-	60.2	318	-
P	<0.0001	<0.0001	-	<0.0001	<0.0001	-

Mean within columns and within treatment group followed by the same letter(s) are not significantly different (p>0.05) from each other: Tukey-kramer HSD test.

Effect of raw and enhanced DE on grain damage kernel caused by R. dominica:

The results obtained shows that the percentage of insect damage kernel (IDK) was significantly affected by both raw and enhanced DE treatments. There were significant differences in the number of damage kernel among different treatment dose rates. Untreated control after 80 days of storage complete kernel damage was observed and this was significantly higher than values in all other treatments. The result revealed that at the lowest dose rate of 500 mg/kg of raw DE 7.0% kernel damage were recorded; and as the dose rate increases the rate of damage kernel decreases, in this way very few 3.0%damage kernel were observed at 1500 mg/kg. Furthermore, when raw DE combined with 2 mg/kg of permethrin dose and applied with 500 mg/kg only 4.0% damaged kernels was recorded. As the dose rate increases to 1500 mg/kg only 0.3% kernels were damaged, as against the untreated control with complete damaged kernel werenoted. More so, combination of 5mg/ kg permethrin dust with 500 mg/kg DE only 2.3% kernel were damage. Finally, at the highest dose rate of 1500mg/ kg no damaged kernel was observed, though there was significant different from combined treatments containing 5 mg/kg permethrin with 750 and 1000 mg/kg raw DE with 1.7 and 0.7% damaged kernels respectively (Table, 4).

Effect of raw and enhanced DE on grain damage caused by R. dominica.

Table 4: Mean percent (%±SE) of damage kernel caused by R. dominica in wheat treated with to raw and enhanced DE

Dose rate (mg/kg)	Insect Damage Kernel (IDK) (SE±)
0.0	100.0 ± 0.0^{a}
500	7.0 ± 0.6^{b}
750	5.3 ± 0.7^{bc}
1000	4.3 ± 0.9^{bc}
1500	3.0 ± 0.7^{c}
F	4847
P	<0.0001
0.0	100 ± 0.0^{a}
500+2mg(Perm)	4.0 ± 0.6^{b}
750+2mg(Perm)	2.0 ± 0.6^{bc}
1000+2mg(Perm)	1.0 ± 0.6^{c}
1500+2mg(Perm)	0.3 ± 0.3^{c}
2mg (permethrin)	1.0 ± 0.6^{c}
F	6701
P	<0.0001
0.0	100.0 ± 0.0^{a}
500+5mg(Perm)	2.3 ± 0.3^{b}
750+5mg(Perm)	1.7 ± 0.2^{bc}
1000+5mg(Perm)	0.7 ± 0.4^{cd}
1500+5mg(Perm)	0.0 ± 0.0^{d}
5mg (permethrin)	0.0 ± 0.0^{d}
F	35630
P	<0.0001

Mean within columns and within treatment group followed by the same letter(s) are not significantly different (p>0.05) from each other: Tukey-kramer HSD test.

Discussion:-

The result of the present study has showed that raw DE and raw DE enhanced with permethrin could be used against R. dominica on stored wheat. Both raw DE alone and raw DE combined with permethrin dust caused high adult mortality in this insect specie. Adult mortality increased with increase in dose rate and exposure period. The results are in agreement with the finding of Athanassiou et al. (2005) and Wakil et al. (2010) who reported that mortality increased with increase in dose rate and exposure period. An increase in exposure time period to commercial inert DE formulations was shown to increase mortality of stored product beetles (Arthur, 2000; Subramanyan and Roesli, 2000; Athanassiou et al., 2003). In addition to dessication, it has been reported that DE also reduces the locomotion ability of stored product insects (Vardeman et al., 2007). Longer exposure interval or DE higher dose rate needed to achieve 100% mortality for adult of the insect tested (Fields and Korunic, 2000; Athanassiou et al., 2004).

The raw DE caused 95-100% adults mortality after 14 days of exposure. The results agrees with Kabir et al.(2010, 2011) who reported that raw DE was effective against R. dominica (F.) at higher dose rates 1500 mg/kg or above. Similarly, Mvumi et al. (2008) found that African DE applied at higher dose rate shows significantly high mortality of Sitophilus zeamais, T. castaneum and R. dominica after 7, 14 and 28 days exposure period. Hence the result of this study suggest that relatively higher dose 1500 mg/kg or above is required to suppress R. dominica and after 14 days in stored wheat. This rate was more than the labeled rate for commercial DE products. For instance, the labeled rate for Protect It®, Insecto® and Dryacide are 400, 500 and 1000 ppm respectively (Vardeman et al., 2007). In another earlier study, Mvumi et al. (2006) noted that African DE samples were unsuitable as grain protectant at dose rate of 1000 ppm. The explanation was that samples contain high level of contaminants and were not collected from deep enough layers of DE deposits. In the case of the raw DE tested in this study, the researcher was not involved in the sample collection of DE. Nevertheless, high efficacy was observed against R. dominica which sustained 97.8 % adult mortality. Progeny suppression at dose rate 1500 mg/kg on wheat was almost 100%. Thus, the present DE seems to be more effective against stored grain insects than those studied by Mvumi et al. (2006).

The general trend of efficacy observed in the present study was similar to those reported by other authors. According to Athanassiou and Korunic (2007) progeny production in the treated commodity is perhaps more important than parental mortality because a grain protectant should protect the grain for a long storage period. The most important finding of this study is that the raw DE product used affect the test insect species in same way as commercial DE formulations.

The number of progeny developedand their subsequent survival was significantly affected by DE dose alone and in combination with permethrin dust and storage period. Noticeable reduction in progeny production was obtained with increase in dose rates and storage period. Furthermore, complete progeny inhibition was not observed at 40 days of storage in all the treatments. In a test, using Protect It® against S. oryzae, Arthur and Throne (2003) reported that progenies emerged in treatment where 100% mortality of exposed adult was observed, and this could be attributed to the mode of action of DEs. It appears that stored product insect can lay eggs following initial exposure to DE before subsequent lethality manifest.

Conclusion:-

This present study document that raw DE alone and in combination with 2 and 5 mg/kg permethrin has insecticidal potential in control of R. dominica. The efficacies varies with dose rate and exposure periods. However, additionsof permethrin increases potency of raw DE. R. dominica could be effectively control with raw DE at dose rate of 1500 mg/kg raw DE at 1000 mg /kg + 5 mg permethrin or 1500 mg + 2 mg permethrin may required. Complete prevention of grain damage by R. dominica could be achieved at 1500 mg raw DE+ 5mg permethrin.

Recommendations:-

Based on the findings of this research it is possible to recommend 1500 mg/kg of raw DE combined with 5 mg/kg permethrin dust for the control of R. dominica in stored wheat. Further investigations are recommended to investigate potential effective dosage in controlling other stored product insects. The use of DE in management of stored product insects in Nigeria should be encourage as their use is safe both humanly and environmentally.

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