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Assessment of efficacy of unstabilized *pyrethrins* and diatomaceous earth admixture on sitophilus zeamais in maize grains

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Abstract
Maize crop provides source of livelihood to all groups of people that depend on it. Its adaptability to different agro-ecological zones has led to its increased production and consumption worldwide. Significant proportion of post-harvest losses of maize grain is attributed to storage insect pests including *Sitophilus zeamais* (maize weevil) which thrive mostly under tropical climates. Chemical insecticides like carbamates, organophosphates and synthetic pyrethroids used in maize grain protection have raised concerns on undesirable environmental and human health effects as well as effects on non-target organisms owing to their prolonged persistence. A laboratory investigation was carried out to explore the possibility of controlling *S. zeamais* with admixture of unstabilized *pyrethrins* and diatomaceous earth in five different ratios of unstabilized *pyrethrins* and diatomaceous earth but maintaining the application rate at 3g kg^{-1}. Twenty (20) adult *S. zeamais* were seeded into each glass jar in 4 replicates per treatment. Separately in other glass jars, *S. zeamais* were treated with *pyrethrins* alone and diatomaceous earth alone. Untreated maize grains were also seeded with adult *S. zeamais* (Control). Actellic Super Dust – a commercial grain protectant (containing 1.6% *pirimiphos-methyl* and 0.3% *permethrin*) was included for comparison with the admixture. Mortality was monitored in all the treatments at intervals of 7th, 14th, 21st and 28th day. Within the first 7 days the admixture treatments had attained >73% mortality while *pyrethrins* alone was at 70% mortality and diatomaceous earth alone had induced 13.75% mortality. By end of 28th day, all the treatments had showed 100% mortality except the diatomaceous treatment which was at 90% mortality. Analysis of mortality using one-way ANOVA showed significant differences among the treatments within the first 7 days, but by the 14th day, all the treatments showed no significant differences. Based on the study it is recommended that combinations of unstabilized *pyrethrins* and diatomaceous earth be utilized as grain storage protectant.

Keywords: Post-harvest; *Pyrethrins*; Diatomaceous Earth (DE); *Sitophilus zeamais*; Mortality; Admixture

1. Introduction

The Maize grains provide a source of livelihood to all groups that depend on it as staple food and an industrial raw material [1]. Adaptability to different agro-ecological zones has led to increased production over the years. Maize grains whether stored in own or commercial storage facility is susceptible to insect pest infestation leading to quantitative, qualitative, germinative, nutritive and economic losses implying significant losses of the maize grain [2, 6].

The maize weevil (*Sitophilus zeamais)* attack stored maize grain and maize cob in the field and storage facility. Under optimum weather conditions, *S. zeamais* life cycle take a minimum of 30 days with all developmental stages taking place inside the maize grain with the larva being the most active stage of the insect as it feeds within the grain.

Chemical insecticides like carbamates, organophosphates and synthetic pyrethroids have been used to control *S. zeamais* among other insect pests with some degree of success. Consumer concerns on the use of these chemicals insecticides with prolonged residuality and their effects on human health, ecosystem balance and impact on non-target organisms [7]. There is global drive towards reduction in pesticide use with the ultimate goal of reducing undesirable ones such as organophosphates by identifying other viable stored insect pests control options [8, 9]. Investigation on efficacy of pyrethrum powder among other grain protectants in stored maize found that the powder offered effective protection against *Sitophilus zeamais* and *Prostephanus truncatus* [10]. Exposure to light and high temperature accelerate degradation of *pyrethrins* rendering it ineffective for desired prolonged storage period of grain [11, 15]. The *pyrethrins* properties of insect flushing, excitation, quick knockdown, rapid degradation and low mammalian toxicity are desired in short-term grain protection, but where long-term storage period is required, there is need for reapplication or addition of anti-oxidant [16].

Diatomaceous Earth (DE) consist of dead fossilized diatoms. DE has been used as insecticide since ancient times [17]. Its insecticidal properties has been investigated by a number of researchers [18, 31].

Diatomaceous earth in combination with other formulations has also been found to confer effective insect pest control in stored grains [32, 38]. Diatomaceous earth mode of action is physical in nature through insect pest exoskeleton abrasion, cuticle piercing and absorption of fluid thereby dehydrating the insect pest.

The objective of this study was to explore the potential insecticidal activity of different ratios of unstabilized *pyrethrins* and diatomaceous earth admixture on *S. zeamais* in

stored maize grains as part of insect pest management for reducing grain losses.

2. Materials and Methods

2.1 Test Insects

Two week old *Sitophilus zeamais* reared on laboratory maize grains used in the study were obtained from National Agricultural Research Laboratories (NARL) – the postharvest research unit of Kenya Agricultural and Livestock Research Organization (KALRO) in Nairobi, Kenya.

2.2 Pyrethrum Powder

Finely ground pyrethrum powder with 1% *pyrethrins* was obtained from Pyrethrum Board of Kenya (PBK) in Nakuru, Kenya and sieved using 106µm sieve.

2.3 Diatomaceous earth dust

Finely ground diatomaceous earth dust (>85% Si_2O) was obtained from African Diatomite Industries Limited (ADIL) in Kariandusi-Gilgil, Kenya. The powder was sieved to pass through 106µm sieve.

2.4 Actellic Super Dust

Actellic Super Dust – a commercial grain protectant was bought from Mea Limited – an Agrovet shop in Nakuru, Kenya.

2.5 Maize Grains

Clean, dry, uninfested and untreated maize grains were obtained from a farmer in Njoro, Nakuru, Kenya. The grains were sterilized by subjecting to 60^0C for 4 hours in an oven in the Pyrethrum Board of Kenya analytical laboratory.

2.6 Experimental Set up

Five different combinations (50mg/250mg; 100mg/200mg; 150mg/150mg; 200mg/100mg and 250mg/50mg) of pyrethrum powder (containing 1% *pyrethrins)* and diatomaceous earth were mixed and homogenized. The experiment was carried out at the Entomology laboratory of Pyrethrum Board of Kenya in Nakuru, Kenya and set according to protocol described [39]. Experimental design was of completely randomized design (CRD). There were 4 replicates in each of the 5 treatments denoted as T_1, T_2, T_3, T_4 and T_5 with each glass jar containing 100g of maize grains seeded with 20 adult *S. zeamais* insect pests. The laboratory temperature and RH were maintained at 28 ± 2ºC and 65 ± 5% respectively.

Sitophilus zeamais mortality was monitored at intervals of 7th, 14th, 21st and 28th day post treatment with mortality due to control was corrected using Abbot's [40] formula. The mortality data was subjected to one-way analysis of variance (ANOVA) and significant differences in the means were separated using Tukey's HSD test (at P = 0.05).

3. Results

S. zeamais mortality within the first 7 days upon correction of the control mortality were >73% for all the admixture treatments with T_1; T_2; T_3; T_4 and T_5 inducing mortality of 73.75; 78.75; 95.00; 100 and 98.75% respectively. The *pyrethrins* alone and DE alone treatments resulted in 70 and 13.75% mortality respectively. Increase of exposure period to 14th day, resulted in increased mortality to 91.58% and 93.42% for T_1 and T_2 respectively, while there was 100% mortality observed in T_3, T_4 and T_5. There was also an increase in *S. zeamais* mortality induced by *pyrethrins* alone and DE alone to 90.79 and 75% respectively. Further increase in exposure period and mortality assessment on 21st day, revealed 100% mortality in all admixture treatments except in T_2 where mortality was at 98.11%. The mortality due to pyrethrins alone had also attained 100% while the DE alone had induced 89.20% mortality. There was no change in *S. zeamais* mortality at the end of the bioassay period at 28th day. Actellic Super Dust induced 100% mortality of *S. zeamais* by the first 7 days post treatment. *S. zeamais* mortality data was subjected to one-way analysis of variance (ANOVA) to establish any significant difference by 7th day in the admixture treatments which revealed existence of significant difference among the admixtures ($F_{[4,15]} = 4.519$, $p<0.05$). By 14th day, there was noted to be no significant difference among the different admixture treatments ($F_{[4,15]} = 2.937$, $p > 0.05$) being the case for 21st and 28th exposure periods. The mean mortality was subjected to Tukey's HSD test to separate the means as noted from the one-way ANOVA analysis at the 7th day (Table 1).

Table 1: Mean mortality of S. zeamais at different exposure periods

Treatment Combinations	% mean ± SE mortality of four replications per treatment			
	7th Day	14th Day	21st Day	28th Day
T_1	73.75±7.74[a]	91.58±3.23[a]	100.00±0.00[a]	100.00±0.00[a]
T_2	78.75±9.44[b]	93.42±3.75[a]	98.11±1.25[a]	100.00±0.00[a]
T_3	95.00±3.54[c]	100.00±0.00[a]	100.00±0.00[a]	100.00±0.00[a]
T_4	100.00±0.00[d]	100.00±0.00[a]	100.00±0.00[a]	100.00±0.00[a]
T_5	98.75±1.25[cd]	100.00±0.00[a]	100.00±0.00[a]	100.00±0.00[a]
ASD	100.00±0.00[d]	100.00±0.00[a]	100.00±0.00[a]	100.00±0.00[a]
Control	0.00±0.00[e]	5.00±2.04[b]	7.50±3.82[b]	7.50±3.82[b]

Means within the same column followed by same letter do not significantly differ, Tukey's SD test (α = 0.05)

4. Discussion

The study results showed that the level of mortality of the *Sitophilus zeamais* is dependent on the proportion of *pyrethrins* in the admixture. It indicated that the more the quantity of the *pyrethrins* in the admixture, the more mortality of S. zeamais induced. This was evident in T_4 where *pyrethrins* portion in the admixture was more than diatomaceous earth resulting in 100% mortality of *S. zeamais*. Using unstabilized *pyrethrins* alone induced 70% mortality within the first 7 days interval unlike diatomaceous earth alone where 13.25% insect mortality was observed during the first 7 days period of exposure. This indicates that *pyrethrins* effectiveness is superior to that of diatomaceous earth alone within a few days of application. However, on mixing

pyrethrins with diatomaceous earth, it was observed that mortality within the first 7 days for all the treatments were above the mortality for individual treatments. This corroborates a study by [41], using admixture of *Deltamethrin* and diatomaceous earth where they found out that combined treatments against *S. zeamais* in stored corn, resulted in faster mortality than in treatments using diatomaceous earth alone.

Insect mortality was also dependent on time period of exposure. It was observed that where DE was used alone, mortality had increased from 13.25% at 7th day interval to 75% at 14th day interval, an indication that there was sufficient exposure time period by the 14th day for the DE to establish contact with the insect pests to produce the increase in mortality. This is informed by the mode of action of DE which is through abrasion, piercing of insect cuticle and absorbing the fluid thereby desiccating the insect pest. This action requires sufficient contact time between the insect and DE. Earlier studies had also found out that efficacy increased with increasing concentration of diatomaceous earth [42] and exposure period [43, 44].

Conclusion

The results from the study have demonstrated that increased proportion of unstabilized *pyrethrins* in combination with diatomaceous earth offer grain protection comparable to the commercial chemical grain protectants. *Pyrethrins* alone and DE alone induce lower *S. zeamais* mortality than the admixture treatments within the first 14 days.

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