Journal of

Entomology

ISSN 1812-5670

Academic
Journals Inc.

www.academicjournals.com

Journal of Entomology 5 (1): 24-30, 2008
ISSN 1812-5670

Assessment of the Efficacy of Actellic and Sumithion in Protecting Grains from Insect Infestation During Storage

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Abstract: The insecticidal efficacy of Actellic and Sumithion (2%) dusts was assessed against 0-3 day old adult *Callosobruchus maculatus* (Coleoptera; Bruchidae) on cowpea (*Vigna unguiculata*) and 0-7 day old adult *Sitophilus zeamais* (Coleoptera; Curculionidae) on maize (*Zea mays*) grains in the laboratory at 30±1°C temperature and 70±2% relative humidity. Each insect species was exposed to insecticide/grain admixtures ranging from 0.063 to 0.5 g kg^{-1} in comparison with untreated controls. Sumithion with LC_{50} values of 0.073 g kg^{-1} for *S. zeamais* and 0.104 g kg^{-1} against *C. maculatus* was more effective than Actellic (LC_{50} = 0.090 and 0.112 g kg^{-1} *S. zeamais* and *C. maculatus*, respectively) in acute toxicity tests. The efficacy of the two compounds declined as storage period increased with Sumithion showing consistent toxicity against *S. zeamais*. Both test compounds significantly reduced adult emergence in treated grains after infestation was established ($p \leq 0.05$). Both Sumithion and Actellic were effective at controlling *C. maculatus* and *S. zeamais*, but at admixture concentrations higher than the 0.005 g kg^{-1} recommended by manufacturers.

Key words: Insecticide, insect pests, stored grains, sumithion, actellic, *Callosobruchus maculatus*, *Sitophilus zeamais*

INTRODUCTION

Farmers, produce merchants and housewives in Africa store food grains, for which they use various facilities. Storage ensures food security, profit maximization and seed availability for the next planting season. Insects benefit from the presence of large bulks of food and produce successive generations in store. These insect activities are accompanied by varying degrees of damage and consequent losses.

Over 200 insects ravage grains in storage (Haines, 1991; Odeyemi and Daramola, 2000) and among these the cowpea bruchid, *Callosobruchus maculatus* (F.) and maize weevil, *Sitophilus zeamais* Motsch, are serious pests because of the importance of the commodity they infest and the severity of the damage they cause, which amounts to several million dollars per year. These insects can cause total loss of cowpea (*Vigna unguiculata* Walp) and maize (*Zea mays*) in storage (Osuji, 1985; Jackai and Daoust, 1986; Egwuatu, 1987; Lale, 2002) if the grains are stored without protection for upwards of six months. The protection of grains from insect infestation during storage is therefore very important.

In Nigeria, as in other African countries, grains are protected from insects during storage by chemical (mainly synthetic organic insecticides), non-chemical (including male sterilization, extremes of temperature, admixtures with oils, powders and extracts from plants) and often the integration of these control measures in a compatible manner to reduce their individual negative effects (Delobel and

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Malonga, 1987; Makanjuola, 1989; Don-Pedro, 1989; Denloye and Makanjuola, 1997; Ogendo *et al*., 2004). Many of these non-chemical methods are cheap, locally available and easily applicable without need for technical expertise. However they are slow acting and not standardized, their use depending mainly on experience and tradition (Delobel and Malonga, 1987; Belmain and Stevenson, 2001). They are mainly used by subsistence farmers. In addition, the superiority in efficacy of synthetic compounds over non-chemical methods has been shown by recent studies. Okunade *et al*. (2002) reported that Pyrimiphosmethyl was more potent against Rhizopertha dominica on sorghum in comparison to 12 natural plant products. Similarly, Obeng-Ofori and Amiteye (2005) reported that only pyrimiphosmethyl showed effective control of *S. zeamais* on stored maize grains when its efficacy was compared with products from three plant species. The foregoing increase support for the use of synthetic chemicals, which are often quick-acting and persistent in the stored grain, thus ensuring long-term protection.

A wide variety of insecticides such as aluminum phosphide, lindane, methyl bromide, ethylene dibromide, Iodofenphos, malathion, actellic, permethrin and sumithion are used against stored product insects either as single applications or as mixtures. These insecticides are marketed for the control of a broad spectrum of stored product insects albeit with blanket dosage prescriptions.

There are problems with the use of insecticides against storage insects. Firstly, Insects react to chemicals differently owing to differences in their physiology, size, life history and behaviour in the stored commodity (Makanjuola, 1989; Bell, 1992). Secondly, the weather and climatic conditions are not uniform throughout the year and even vary from one geographical location to another at any given time, thus their use and consequent efficacy in the tropics in the stable form may not be the same as obtains in temperate countries (Akingbade, 1991; Boroffice and Boroffice, 1993). Futhermore, recent studies have shown the alarming increase in the rate insects become resistant to synthetic insecticidal compounds such that there is no insecticide group that does not have record of resistance to it by insects (Wallbank *et al*., 2002). Also, the synthetics leave residues as exemplified by the recent studies by Toteja *et al*. (2006) and Uygun *et al*. (2007). A continued use of the same insecticide compounds under the same conditions can only result in a continuation or aggravation of the problems associated with their use.

The foregoing justifies the need for a critical assessment and reappraisal of compounds commonly used in tropical countries to protect stored grains from insect attack at the dosage and conditions under which they are utilized. In the present study we assess the activity of two organophosphorus insecticides namely Actellic and Sumithion against *C. maculatus* (on cowpea) and *S. zeamais* (on maize) at doses higher than the 5.0 mg kg^{-1} recommended by the manufacturers under ambient tropical laboratory conditions.

MATERIALS AND METHODS

Test Insect and Grains Species

Callosobruchus maculatus on Cowpea (*Vigna unguiculata*) and *Sitophilus zeamais* on maize (*Zea mays*) were obtained from starter cultures of the respective insects in the insectary of Nigerian Stored Product Research Institute (NSPRI) Akoka, Lagos, Nigeria where they had been maintained over several generations without contact with insecticides. Subsequent cultures of each test species were established from these cultures. The grains used for culture maintenance were *V. unguiculata* c.v Ife Brown (for *C. maculatus*) and maize cv flint (for *S. zeamais*). These grain cultivars were also used in subsequent experiments. The grains were first disinfested by heating each grain species in the oven for 4 h at 60°C to destroy any hidden infestation. The cultures were maintained at 30±1°C temperature and 70±2% relative humidity in the Toxicology Research Laboratory of the Department of Zoology, University of Lagos, Lagos, Nigeria (6°28' N, 3°11'E). All bioassays were carried out under these laboratory conditions.

Test Compounds

The test compounds were two organophosphate insecticides, Actellic and Sumithion, both 2% dusts; from Chemical and Allied Products (CAP) Plc., Agrochemicals division, Ikeja, Lagos, Nigeria.

Bioassays

Acute Toxicity of Test Compounds to *C. maculatus* and *S. zeamais*

Lots of 200 g of disinfested cowpea or maize were admixed with Actellic or Sumithion 2% dust at the rate of 0.5, 0.25, 0.125 or 0.063 g kg^{-1} in plastic containers that served as exposure chambers. Chambers were shaken vigorously for 2 min to ensure a good mix. Each admixture lot was inoculated with 30 0-3 day old adult *C. maculatus* (mixed sexes). Each lot was covered with muslin held tightly in place with elastic rubber bands. All treatments and controls were replicated four times. In the same manner admixtures were prepared at the same rate using maize grains and each inoculated with 30 0-7 day old adult *S. zeamais*. Four untreated controls; one for each treatment, respectively were set up and replicated four times in the same way, but received no insecticide. The number of dead insect in each treatment and control was recorded daily for seven days. Insects that failed to move any part of the body when the exposed part of their abdomen was probed with the sharp end of a tweezer were counted as dead.

Effect of Storage on the Insecticidal Efficacy of Test Compounds

Lots (1 kg) of cowpea or maize were divided into three batches and admixed with either Actellic or Sumithion at the rate of 0.5, 0.25, 0.125 and 0.063 g kg^{-1}, respectively and mixed thoroughly by vigorous shaking for 5 min each. Four lots were also prepared with either cowpea or maize grains but without insecticide. All treatments for cowpea/Actellic, cowpea/Sumithion, maize/Actellic or maize/Sumithion as well as the untreated controls were replicated four times and left in a dark corner under the laboratory bench where they were stored for 4-12 weeks at 30±1°C temperature and 70±2% relative humidity. At the end of the first four weeks one batch of each treatment was inoculated with 30 adults of the appropriate insect species (0-3 day old *C. maculatus* for Cowpea mixtures; 0-7 day old *S. zeamais* for maize admixtures) another batch received insects at the end of 8 weeks while the last batch received insect species at the end of 12 weeks of storage. The number of dead insects (determined as described earlier) was recorded daily for seven days. Data obtained were used to determine LC_{50} (median lethal concentration) values of each treatment against each test insect species.

Effects of Test Compounds on Existing Infestation of *C. maculatus* and *S. zeamais*

Twelve 200 g lots of cowpea and maize grains were infested with 20 adult (10 ♂; 10 ♀) *C. maculatus* or *S. zeamais*, respectively. All adult *C. maculatus* were removed after 10 days while *S. zeamais* adults were removed after 17 days of infestation. Each lot was then admixed with either test insecticide at the rate of 0.5 or 0.25 g kg^{-1} (obtained from results of previous experiments). There were also untreated controls in each case. Each treatment and control lot was replicated three times. Emerging adults in each lot was removed and recorded until there was no emergence for 14 days. Data obtained were square root ($\sqrt{x} + 0.5$) transformed (Sokal and Rholf, 1995) and means compared to determine differences on adult emergence at the different treatment levels.

Data Analyses

Data from all dose-response tests were analyzed by probit analysis (Finney, 1971) using a computer soft ware based on maximum likelihood as adopted from Don-Pedro (1989) after controlling for control mortality following Abbott (1925). Differences between means were compared by Analysis of Variance (ANOVA) and ranking was done after LSD test using Statistical Package for Social Scientists (SPSS,) version 11.0 (SPSS, 2001).

RESULTS

Toxicity of Test Compounds

Both Actellic and Sumithion showed different toxicities to *C. maculatus* and *S. zeamais* as shown in Table 1. The two test compounds were more toxic to *S. zeamais* than they were to *C. maculatus* as they gave lower LC_{50} values against *S. zeamais*. Sumithion (0.073 g kg^{-1}) was more toxic than Actellic (0.09 g kg^{-1}), but there was no significant difference between its toxicity and that of Actellic against *S. Zeamais* as shown by overlap in 95% fiducial limits (Table 1). The LC_{50} values for *C. maculatus* show that Actellic was similar in potency to Sumithion against *C. maculatus*. The LC_{95} values 0.28 g kg^{-1} (Actellic) and 0.225 g kg^{-1} (Sumithion) against *S. zeamais* were significantly lower than those obtained for *C. maculatus* 0.444 g kg^{-1} (Sumithion) and 0.603 g kg^{-1} (Actellic).

Effect of Storage

The efficacy of Actellic and Sumithion, respectively decreased with increasing period of storage as shown in Fig. 1. The figure shows that both compounds were most toxic at 4 weeks storage and least toxic at 12 weeks for both *C. maculatus* and *S. zeamais*, respectively. Actellic was similarly toxic against both *C. maculatus* and *S. zeamais* at 4 and 8 weeks storage prior to insect introduction but more toxic to *C. maculatus* than *S. zeamais* at 12 weeks storage. Sumithion on the other hand gave similar toxicity against the two test insect species at the various storage periods tested (Fig. 1).

Table 1: Toxicity of Actellic and Sumithion to *C. maculatus* and *S. zeamais*

Test insect species	Test compounds	LC_{50} (g kg^{-1})	95% fiducial limits	LC_{95} (g kg^{-1})	95% fiducial limits	Slope (±SE)
S. zeamais	Actellic	0.090	0.081-0.101	0.280	0.232-0.337	3.36±0.09
	Sumithion	0.073	0.064-0.082	0.225	0.186-0.272	3.36±0.12
C. maculatus	Actellic	0.112	0.097-0.129	0.603	0.452-0.804	2.26±0.05
	Sumithion	0.104	0.092-0.118	0.444	0.350-0.561	2.62±0.05

Table 2: Adult insect emergence from grains treated with Actellic or Sumithion after established infestation

Treatment concentration (g kg^{-1})	*Sitophilus zeamais* Actellic	*Sitophilus zeamais* Sumithion	*Callosobruchus maculatus* Actellic	*Callosobruchus maculatus* Sumithion
0.50	2.67[a]	1.00[a]	10.33[a]	11.33[a]
0.25	6.33[b]	5.00[b]	13.33[b]	23.00[b]
0.00 (Control)	15.67[c]	13.67[c]	41.33[c]	38.33[c]

Each datum is a mean of three replicates, Data were square root ($\sqrt{x} + 0.5$) transformed before analysis of variance, Differences between column means bearing different superscripts are significant following Least Significant Difference (LSD) test $p \leq 0.05$

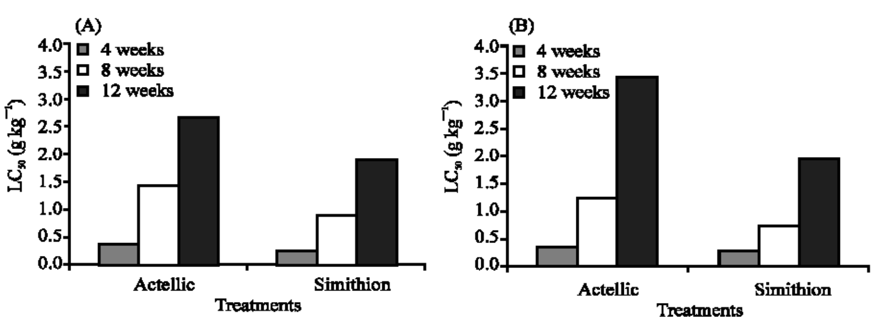

Fig. 1: Toxicity of Actellic and Sumithion 2% dusts to (A) *Callosobruchus maculatus* and (B) *Sitophilus zeamais* in treated grains stored for various periods before insect introduction

Adult Emergence

The emergence of adults of each test insect species increased as the treatment concentration reduced in all cases tested (Table 2). ANOVA ($p \leq 0.05$) show that more adults emerged at successive treatment concentrations. More adult *C. maculatus* emerged than did *S. zeamais* (Table 2).

DISCUSSION

The study show that both Sumithion and Actellic were toxic to *S. zeamais* and *C. maculatus*, respectively, but at concentrations higher than the 5.0 ppm (0.005 g kg^{-1}) dosage recommended by the manufacturers. The results demonstrating the efficacy of Actellic has further confirmed the findings of earlier workers who have shown that Actellic is an effective insecticide for the control of *S. zeamais* and *C. maculatus* (Caswell and Akibu, 1980; Obeng-Ofori and Amiteye, 2005; Asawalam and Emosairue, 2006). Earlier studies carried out by Obeng-Ofori and Amiteye (2005) shows that Pyrimiphosmethyl, the active compound in Actellic was effective for the control of *S. zeamais* on maize grains at one-quarter of the recommended dose, a contradiction of findings in the present study where Actellic demonstrated effectiveness with LC_{50} value of 0.09 g kg^{-1} against *S. zeamais*.

The LC_{50} values for the test compounds increased as the post treatment period preceding introduction of each of the two test insect species increased (Fig. 1). This suggests that both Actellic and Sumithion may have broken down and having their efficacy reduced as storage time increased. Mensah *et al*. (1979) reported that the organophosphate insecticides degrade under most storage conditions. If the organophosphates had degraded in the present study, they may have resulted in compounds that are less toxic to the test insects than either Sumithion or Actellic. Furthermore, it has been noted that the efficacy of organophosphate insecticides decrease with increasing temperature and humidity (Matthews and Maliphant, 1993). The laboratory temperature (30±1°C) and relative humidity (70±2%) under which the experiments were carried out may therefore have contributed to the degradation of the suspected in the test compounds. There is need to further investigate the influence of these laboratory conditions and the breakdown products of organophosphates on the survival of *C. maculatus* and *S. zeamais*, respectively.

The progressive increase in LC_{50} values is notable, but more profound is the fact that the LC_{50} values obtained after 8 weeks are above 1.0 g kg^{-1}, which is X20 of the recommended dosage for the two test compounds. This indicates that high amount of the insecticidal dusts would be applied in typical storage systems, heightening the possibility of residues on the protected grains in agreement with the reports of Hilton and Banks (1997), Lee *et al*. (2003), Toteja *et al*. (2006) and Uygun *et al*. (2007). In Nigeria several reports including those of Adeola and Fafunsho (1998) have shown insecticide residues in food stuff from different parts of the country.

Futhermore, that the LC_{50} values (Fig. 1) given by both Actellic and Sumithion are more than X4 of the recommended dosage is a pointer to the fact that treatment should be repeated more frequently. The results shown in Fig. 1 is suggests the need for repeat treatment every 8 weeks in order to adequately protect grains from these insects for the 3-6 months period that they (food grains) are normally stored in Nigeria (Egwuatu, 1987; Lale, 2002; Iken and Amusa, 2004).

Table 2 shows that the two compounds caused a significant reduction of adult emergence of the two test insect species when treatment was carried out after infestation. The two compounds can therefore be conveniently recommended for use in typical storage systems, insect infestations in stored grains are usually hidden until damage becomes noticeable.

ACKNOWLEDGMENTS

We gratefully acknowledge the supply of samples of test insects as starter cultures from the insectary of the Nigerian Stored Product Research Institute (NSPRI), Lagos. We thank Mr. Ajibade, M.A. of the Zoology Laboratory, Department of Zoology, Lagos State University (LASU) for technical assistance.

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