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Full Length Research Paper

Deltamethrin contact bioassay and boring/chewing tests with the maize weevil, *Sitophilus zeamais* (Mot).

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This paper presents results following contact of *Sitophilus zeamais* with different storage bags at various exposure times (24 hrs, 48 hrs and 72 hrs) to deltamethrin. Insect knockdown and mortalities were observed during each exposure period and for up to seven days after the start of the exposure. High knockdown was observed after 6 hours of exposure to the ZeroFly storage bag (>93%). Although some *Sitophilus zeamais* recovered after initial impact of the exposure, 100% mortality was observed after three (3) days of exposure. Increased exposure times resulted in high mortalities. Whereas no mortality was observed in the untreated Jute throughout the experiment, the control (untreated Ghana-made polypropylene) and untreated India-made polypropylene each recorded a maximum mortality of 1.7%. The ZeroFly bag on the other hand recorded 61.7 after 24 hrs and 100% after 48 hrs of exposure.

Keywords: *S. zeamais,* P. runcates, mortalities, ZeroFly

INTRODUCTION

Food and seed insecurity in Africa is a recurrent problem which is more acute among the poorest farmers (Gari, 2004, Anankware et al., 2013). Among the causes of food and seed insecurity in Africa is inadequate storage facilities and inappropriate methods for seed storage especially among rural farmers. Successful seed storage is paramount to farmers' seed security and may also enable communities to generate income through collecting, storing and selling seeds (Anankware et al., 2012).

This study seeks to determine the contact-sensitivity of each pest to deltamethrin for different exposure times and different concentrations (log-dose curves).

Details of pest species tested

The maize weevil, Sitophilus zeamais (Coleoptera: Curculionidae)

Eggs are laid throughout most of the adult life, although 50 % may be laid in the first 4-5 weeks; each female laying up to 150 eggs. The eggs are laid individually in small cavities, chewed into cereal grains by the female; each cavity is sealed, thus protecting the egg, by a waxy secretion

(usually referred to as an 'egg-plug') produced by the female. The incubation period of the egg is about 6 days at 25 °C (Howe, 1952). Eggs are laid at temperatures between 15 and 35 °C (with an optimum around 25 °C) and at grain moisture contents over 10 %; however, rates of oviposition are very low below 20 °C or above 32 °C, and below about 12 % moisture content.

Upon hatching, the larva begins to feed inside the grain, excavating a tunnel as it develops. Pupation takes place within the grain; the newly developed adult chews its way out, leaving a large, characteristic emergence hole. Total developmental periods range from about 35 days under optimal conditions to over 110 days in unfavourable conditions (Howe, 1952). The actual length of the life cycle also depends upon the type and quality of grain being infested: for example, in different varieties of maize, mean development periods of *Sitophilus zeamais* at 27 °C and 70 % r.h. have been shown to vary from 31 to 37 days. Therefore, the adult weevil stage is an appropriate target for testing.

Lager Grain Borer, Prostephanus runcates (Coleoptera:Bostrichidae)

The Larger Grain Borer (LGB), *Prostephanus runcates* (Horn) belongs to the family Bostrichidae, most of which are wood boring beetles. In maize, it infests both the standing crop (Quintana et al., 1960; Giles, 1975) and the stored grain (Giles and Leon, 1974; Hodges et al., 1983a).

After mating, adult females lay fertilized eggs within the grain, in blind-ending chambers bored at right angles to the main tunnels (Hodges, 1982; Howard, 1983). Eggs are usually laid in batches of up to 20 and covered with finely chewed maize powder.

Larvae hatch out after three days at 37 ^{o} C and seem to thrive well on the powder produced by the adult (Seidu, 1998). Its life cycle can be completed within a wide range of temperatures (12-40 ^{o}C) and relative humidity (r.h) conditions of 30-90 r.h. On maize grain diet, development of larvae to adult at the optimum temperature of 32 ^{o} C and 80% r.h takes only 27 days (Obeng-Ofori, 2008). On emergence, female *P. runcates* tend to weigh more than males.

The proposed insecticide for use in the crop storage sacks is the synthetic pyrethroid deltamethrin. It is used as a broad spectrum insecticide (Tomin, 2006) and is currently registered for use on stored crops such as cereals, cotton, soybeans and vegetables to control pests including weevils, beetles, mites and ants. Recommended methods of pesticide residues analysis can be found in Codex standard 229-1993. The sampling methods for pesticide residue compliance with MLRs can be found in CAC/GL 33 (1999).

METHODOLOGY

Preliminary contact testing and reducing oviposition

The research was conducted at the Vestergaard Frandsen laboratories at the University of Ghana under optimum temperature of 32 ± 2^{o}C. Required quantity of deltamethrin was weighted out and diluted in acetone to give a serial dilution of 100, 50, 25, 12.5 and 0 ppm. The methodology used is modified from that used by Toews and subranmanyam (2003). The following equipment were be used:

- Technical grade deltamethrin (DTM)
- Acetone
- 600 *P. runcates*
- 600 *S. zeamais*
- 120 Petri dishes (60 for each insect species)
- 1kg of clean untreated maize
- A microscope (for dissecting each species to determine the sex ratios)
- Timer

The inside (lid and base) of 9-cm glass Petri dishes were treated with 1.0ml of each concentration or acetone control, with three replicate dishes for each concentration. The Petri dishes were left to dry for 24 hours prior to the test. Twenty (1 week old) adult (*Sitophilus zeamais* and *P. runcates*) pests were placed inside each Petri dish and sealed with parafilm. The insects were exposed to the treated dishes for 24 hours and separately for 48 hours and then transferred to clean Petri dishes containing 10g of maize. The dishes were kept at 28°C at 60-70% RH, in dark conditions throughout the experiment.

Table 1: Contact exposure (24 hrs) to Jute storage bag

Jute bag	Jute 1	Jute 2	Jute 3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (6 hrs)	0	0	0	0	0	0
No. KD (12 hrs)	0	0	0	0	0	0
No TD (24 hrs)	0	0	0	0	0	0
No. TD (2 days)	0	0	0	0	0	0
No. TD (3 days)	0	0	0	0	0	0
No. TD (4 days)	0	0	0	0	0	0
No. TD (5 days)	0	0	0	0	0	0
No. TD (6 days)	0	0	0	0	0	0
No. TD (7 days)	0	0	0	0	0	0

Table 2: Contact exposure (24 hrs) to PP (Ghana) storage bag

Polypropylene (Ghana)	PP GH 1	PP GH 2	PP GH 3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (6 hrs)	0	0	0	0	0	0
No. KD (12 hrs)	0	0	0	0	0	0
No TD (24 hrs)	0	0	0	0	0	0
No. TD (2 days)	1	0	0	1	1.7	0.6
No. TD (3 days)	1	0	0	1	1.7	0.6
No. TD (4 days)	1	0	0	1	1.7	0.6
No. TD (5 days)	1	0	0	1	1.7	0.6
No. TD (6 days)	1	0	0	1	1.7	0.6
No. TD (7 days)	1	0	0	1	1.7	0.6

Dishes were observed at 15mins, 30mins, 1hr, 2hrs,4hrs,8hrs,12hrs,24hrs,48hrs and 72hrs from initial exposure for insect knock down and mortality and to establish an LT50/LT95. After 28 days, the adults were removed and the number of eggs/larvae/oviposited grain was counted per dish. The adults were then sexed at the end of the test.

Probit analysis was used to establish LC50 and LC90 levels for each pest. ANOVA and Linear regression analysis was used to establish differences in egg/larval numbers relative to controls and female numbers over time.

RESULTS, DISCUSSION AND CONCLUSSION

Contact exposure to storage bags and ability to bore/chew storage bags - *Sitophilus zeamais*

Results were taken following contact of *Sitophilus zeamais* with different storage bags at various exposure times (24 hrs, 48 hrs and 72 hrs). Insect knockdown and mortalities were observed during each exposure period and for up to seven days after the start of the exposure. High knockdown was observed after 6 hours of exposure to the ZeroFly storage bag (>93%). Although some *Sitophilus zeamais* recovered after initial impact of the exposure, 100% mortality was observed after three (3) days of exposure. Increased exposure times resulted in high mortalities.

Whereas no mortality was observed in the untreated Jute throughout the experiment, the control (untreated PP. Ghana) and untreated PP. India each recorded a maximum mortality of 1.7%. The ZeroFly bag on the other hand recorded 61.7 after 24 hrs and 100% after 48 hrs of exposure.

Table 1 to 4 shows the mortalities in each bag after 24 hrs of exposure. Table 5 to 8 shows the results after 48 hrs whiles table 9 to 12 gives results after 72 hrs. Each exposure time set-up was allowed to stay for 7 days as seen in the tables.

Table 3: Contact exposure (24 hrs) to PP (India) storage bag

Polypropylene (India)	PP IN 1	PP IN 2	PP IN 3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (6 hrs)	0	0	0	0	0	0
No. KD (12 hrs)	0	0	0	0	0	0
No TD (24 hrs)	0	1	0	1	1.7	0.6
No. TD (2 days)	0	1	0	1	1.7	0.6
No. TD (3 days)	0	1	0	1	1.7	0.6
No. TD (4 days)	0	1	0	1	1.7	0.6
No. TD (5 days)	0	1	0	1	1.7	0.6
No. TD (6 days)	0	1	0	1	1.7	0.6
No. TD (7 days)	0	1	0	1	1.7	0.6

Table 4: Contact exposure (24 hrs) to ZeroFly storage bag

Zerofly	ZF1	ZF2	ZF3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (6 hrs)	19	18	19	56	93.3	0.6
No. KD (12 hrs)	19	20	20	59	98.3	0.6
No TD (24 hrs)	13	12	12	37	61.7	0.6
No. TD (2 days)	19	19	20	58	96.7	0.6
No. TD (3 days)	20	20	20	60	100.0	0.0
No. TD (4 days)	20	20	20	60	100.0	0.0
No. TD (5 days)	20	20	20	60	100.0	0.0
No. TD (6 days)	20	20	20	60	100.0	0.0
No. TD (7 days)	20	20	20	60	100.0	0.0

Table 5: Contact exposure (48 hrs) to Jute storage bag

Jute bag	Jute 1	Jute 2	Jute 3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (6 hrs)	0	0	0	0	0	0
No. KD (12 hrs)	0	0	0	0	0	0
No TD (24 hrs)	0	0	0	0	0	0
No. TD (2 days)	0	0	0	0	0	0
No. TD (3 days)	0	0	0	0	0	0
No. TD (4 days)	0	0	0	0	0	0
No. TD (5 days)	0	0	0	0	0	0
No. TD (6 days)	0	0	0	0	0	0
No. TD (7 days)	0	0	0	0	0	0

Polypropylene (India)	PP IN 1	PP IN 2	PP IN 3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (6 hrs)	0	0	0	0	0	0
No. KD (12 hrs)	0	0	0	0	0	0
No TD (24 hrs)	0	0	0	0	0	0
No. TD (2 days)	0	0	0	0	0	0
No. TD (3 days)	1	0	0	1	1.7	0.6
No. TD (4 days)	1	0	0	1	1.7	0.6
No. TD (5 days)	1	0	0	1	1.7	0.6
No. TD (6 days)	1	0	1	2	3.3	0.6
No. TD (7 days)	1	0	1	2	3.3	0.6

Table 8: Contact exposure (48 hrs) to ZeroFly storage bag

Zerofly	ZF1	ZF2	ZF3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (6 hrs)	18	19	18	55	91.7	0.6
No. KD (12 hrs)	19	19	19	57	95.0	0.0
No TD (24 hrs)	12	12	13	37	61.7	0.6
No. TD (2 days)	20	20	20	60	100.0	0.0
No. TD (3 days)	20	20	20	60	100.0	0.0
No. TD (4 days)	20	20	20	60	100.0	0.0
No. TD (5 days)	20	20	20	60	100.0	0.0
No. TD (6 days)	20	20	20	60	100.0	0.0
No. TD (7 days)	20	20	20	60	100.0	0.0

Table 9: Contact exposure (72 hrs) to Jute storage bag

Jute bag	Jute 1	Jute 2	Jute 3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (6 hrs)	0	0	0	0	0	0
No. KD (12 hrs)	0	0	0	0	0	0
No TD (24 hrs)	0	0	0	0	0	0
No. TD (2 days)	0	0	0	0	0	0
No. TD (3 days)	0	0	0	0	0	0
No. TD (4 days)	0	0	0	0	0	0
No. TD (5 days)	0	0	0	0	0	0
No. TD (6 days)	0	0	0	0	0	0
No. TD (7 days)	0	0	0	0	0	0

Table 10: Contact exposure (72 hrs) to PP (Ghana) storage bag

Polypropylene (Ghana)	PP GH1	PP GH 2	PP GH 3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (6 hrs)	0	0	0	0	0	0
No. KD (12 hrs)	0	0	0	0	0	0
No TD (24 hrs)	0	1	0	1	1.7	0.6
No. TD (2 days)	0	1	0	1	1.7	0.6
No. TD (3 days)	0	1	0	1	1.7	0.6
No. TD (4 days)	0	1	0	1	1.7	0.6
No. TD (5 days)	0	1	0	1	1.7	0.6
No. TD (6 days)	0	1	0	1	1.7	0.6
No. TD (7 days)	1	1	0	2	3.3	0.6

Table 11: Contact exposure (72 hrs) to PP (India) storage bag

Polypropylene (India)	PP IN 1	PP IN 2	PP IN 3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (6 hrs)	0	0	0	0	0	0
No. KD (12 hrs)	0	0	0	0	0	0
No TD (24 hrs)	0	0	0	0	0	0
No. TD (2 days)	0	0	0	0	0	0
No. TD (3 days)	0	0	0	0	0	0
No. TD (4 days)	0	0	0	0	0	0
No. TD (5 days)	0	0	0	0	0	0
No. TD (6 days)	0	0	0	0	0	0
No. TD (7 days)	0	0	0	0	0	0

Table 12: Contact exposure (72 hrs) to ZeroFly storage bag

Zerofly	ZF1	ZF2	ZF3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (6 hrs)	19	19	18	56	93.3	0.6
No. KD (12 hrs)	19	19	20	58	96.7	0.6
No TD (24 hrs)	13	13	12	38	63.3	0.6
No. TD (2 days)	20	20	20	60	100.0	0.0
No. TD (3 days)	20	20	20	60	100.0	0.0
No. TD (4 days)	20	20	20	60	100.0	0.0
No. TD (5 days)	20	20	20	60	100.0	0.0
No. TD (6 days)	20	20	20	60	100.0	0.0
No. TD (7 days)	20	20	20	60	100.0	0.0

Table 13: Number of holes bored/chewed by *P. truncatus* after 48 hours

NO. OF HOLES	ZF1	ZF2	ZF3	TOTAL
No. Exposed	20	20	20	60
No. holes - 24hrs	0	0	0	0
No. holes - 48hrs	0	0	0	0

Table 14: Mortality after contact to ZeroFly storage during boring/chewing experiment

MORTALITY	ZF1	ZF2	ZF3	TOTAL	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. TD-24hrs	19	19	20	58	96.7	0.6
No. TD-48hrs	20	20	20	60	100	0.0

Table 15: Effect of 0.0ppm of DM on *S. zeamais*

0.0 ppm	Petri D 4	Petri D 5	Petri D 6	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (15 Mins)	0	0	0	0	0.0	0.0
No. KD (30 Mins)	0	0	0	0	0.0	0.0
No. KD (1 hr))	0	0	0	0	0.0	0.0
No. KD (2 hrs)	0	0	0	0	0.0	0.0
No. KD (4 hrs)	0	0	0	0	0.0	0.0
No. KD (8 hrs)	0	0	0	0	0.0	0.0
No. kD (12 hrs)	0	0	0	0	0.0	0.0
No. TD (24 hrs)	0	0	0	0	0.0	0.0
No. TD (48 hrs)	0	0	0	0	0.0	0.0
No. TD (72 hrs)	0	0	0	0	0.0	0.0

Ability of *Sitophilus zeamais* to bore through ZeroFly storage bag

Sitophilus zeamais could not chew/bore through the ZeroFly bag (Table 13). No holes were observed even after 48 hrs. Table 14 shows the *Sitophilus zeamais* mortality after 24 and 48 hrs. 100% mortality was recorded after 48 hrs of exposure.

Contact sensitivity of *Sitophilus zeamais* in different concentrations of deltamethrin

The results from this experiment show that *Sitophilus zeamais* reacts differently with different concentrations of deltamethrin. After only 8 hrs of exposure, 98% knockdown was recorded for 1000ppm while 76.7%, 53.3%, 30%, 28%, 21.7%, 23.3% and 0% were recorded for 500ppm, 250ppm, 100ppm, 50ppm, 25ppm, 12.5ppm 0.0ppm respectively (Table 15 to 22). After 12 hrs of exposure, 100% knockdown was observed for 1000ppm. Although *Sitophilus zeamais* survived the impact of the knockdown, 96.7% mortality was observed after 72 hrs whereas no mortality was observed in the control (0.0ppm) throughout the experiment. The results also show a reduction in mortality with reduced concentration.

The above results show that the ZeroFly bag can be used for effective control of the maize weevil, *S. zeamais*. This will go a long way in

Table 16: Effect of 1000ppm of DM on *S. zeamais*

1000 ppm	Petri D 1	Petri D 2	Petri D 3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (15 Mins)	0	0	0	0	0.0	0.0
No. KD (30 Mins)	10	13	9	32	53.3	2.1
No. KD (1 hr))	17	18	16	51	85.0	1.0
No. KD (2 hrs)	18	18	19	55	91.7	0.6
No. KD (4 hrs)	18	18	19	55	91.7	0.6
No. KD (8 hrs)	19	20	20	59	98.3	0.6
No. kD (12 hrs)	20	20	20	60	100.0	0.0
No. TD 24 hrs	13	13	15	41	68.3	1.2
No TD (48 hrs)	19	18	19	56	93.3	0.6
No. TD (72 hrs)	19	19	20	58	96.7	0.6

Table 17: Effect of 500ppm of DM on *S. zeamais*

500 ppm	Petri D 4	Petri D 5	Petri D 6	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (15 Mins)	0	0	0	0	0.0	0.0
No. KD (30 Mins)	0	4	4	8	13.3	2.3
No. KD (1 hr))	11	12	13	36	60.0	1.0
No. KD (2 hrs)	11	12	13	36	60.0	1.0
No. KD (4 hrs)	12	12	13	37	61.7	0.6
No. KD (8 hrs)	15	15	16	46	76.7	0.6
No. kD (12 hrs)	18	18	19	55	91.7	0.6
No. TD 24 hrs	8	10	10	28	46.7	1.2
No TD (48 hrs)	17	15	18	50	83.3	1.5
No. TD (72 hrs)	17	15	18	50	83.3	1.5

Table 18: Effect of 250ppm of DM on *S. zeamais*

250 ppm	Petri D 1	Petri D 2	Petri D 3	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (15 Mins)	0	0	0	0	0.0	0.0
No. KD (30 Mins)	2	2	4	8	13.3	1.2
No. KD (1 hr))	8	8	10	26	43.3	1.2
No. KD (2 hrs)	8	8	10	26	43.3	1.2
No. KD (4 hrs)	9	9	10	28	46.7	0.6
No. KD (8 hrs)	10	11	11	32	53.3	0.6
No. kD (12 hrs)	12	12	13	37	61.7	0.6
No. TD 24 hrs	6	6	6	18	30.0	0.0
No TD (48hrs)	14	13	13	40	66.7	0.6
No. TD (72 hrs)	14	13	13	40	66.7	0.6

Table 19: Effect of 100ppm of DM on *S. zeamais*

100 ppm	Petri D 4	Petri D 5	Petri D 6	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (15Mins)	0	0	0	0	0.0	0.0
No. KD (30 Mins)	2	1	0	3	5.0	1.0
No. KD (1 hr))	5	4	3	12	20.0	1.0
No. KD (2 hrs)	3	4	3	10	16.7	0.6
No. KD (4 hrs)	4	4	4	12	20.0	0.0
No. KD (8 hrs)	6	6	6	18	30.0	0.0
No. kD (12 hrs)	18	18	17	53	88.3	0.6
No. TD (24 hrs)	3	2	4	9	15.0	1.0
No TD (48 hrs)	7	6	6	19	31.7	0.6
No. TD (72 hrs)	7	6	6	19	31.7	0.6

Table 20: Effect of 50ppm of DM on *S. zeamais*

50 ppm	Petri D 4	Petri D 5	Petri D 6	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (15 Mins)	0	0	0	0	0.0	0.0
No. KD (30 Mins)	0	0	0	0	0.0	0.0
No. KD (1 hr))	0	1	1	2	3.3	0.6
No. KD (2 hrs)	1	1	1	3	5.0	0.0
No. KD (4 hrs)	5	4	5	14	23.3	0.6
No. KD (8 hrs)	6	5	6	17	28.3	0.6
No. kD (12 hrs)	16	16	16	48	80.0	0.0
No. TD (24 hrs)	1	0	0	1	1.7	0.6
No TD (48 hrs)	1	1	0	2	3.3	0.6
No. TD (72 hrs)	1	1	0	2	3.3	0.6

Table 21: Effect of 25ppm of DM on *S. zeamais*

25 ppm	Petri D 4	Petri D 5	Petri D 6	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (15 Mins)	0	0	0	0	0.0	0.0
No. KD (30 Mins)	0	0	1	1	1.7	0.6
No. KD (1 hr)	2	2	2	6	10.0	0.0
No. KD (2 hrs)	2	2	3	7	11.7	0.6
No. KD (4 hrs)	5	3	5	13	21.7	1.2
No. KD (8 hrs)	5	3	5	13	21.7	1.2
No. kD (12 hrs)	6	5	5	16	26.7	0.6
No. TD (24 hrs)	0	0	0	0	0.0	0.0
No TD (48 hrs)	0	0	0	0	0.0	0.0
No. TD (72 hrs)	0	0	0	0	0.0	0.0

Table 22: Effect of 12.5ppm of DM on *S. zeamai*

12.5 ppm	Petri D 4	Petri D 5	Petri D 6	Total	% KD/TD	SD KD/TD
No. Exposed	20	20	20	60		
No. KD (15 Mins)	0	0	0	0	0.0	0.0
No. KD (30 Mins)	0	0	0	0	0.0	0.0
No. KD (1 hr))	0	1	1	2	3.3	0.6
No. KD (2 hrs)	1	3	2	6	10.0	1.0
No. KD (4 hrs)	2	7	4	13	21.7	2.5
No. KD (8 hrs)	3	6	5	14	23.3	1.5
No. kD (12 hrs)	3	6	5	14	23.3	1.5
No. TD (24 hrs)	0	0	0	0	0.0	0.0
No TD (48 hrs)	0	0	0	0	0.0	0.0
No. TD (72 hrs)	0	0	0	0	0.0	0.0

solving the heavy infestation and damage caused by the insect in the tropics.

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