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Length of Exposure and Quantal Responses of Four Strains Ofprostephanus Truncatus (Horn) (Coleoptera: Bostrichidae) Strains to Pyrethroid Insecticides

Dr. E. N. Nwankwo
Lecturer, Department of Parasitology and Entomology
Faculty of Biosciences, NnamdiAzikiwe University, Awka, Nigeria
Dr. N. J. Okonkwo
Associate Professor, Department of Crop Science and Horticulture
Faculty of Agriculture, NnamdiAzikiwe University, Awka, Nigeria
R. I. Egwuatu
Professor, Department of Crop Science and Horticulture
Faculty of Agriculture, NnamdiAzikiwe University, Awka, Nigeria

Abstract:
Comparative studies on exposure time to two pyrethriod insecticides, deltamethrin (12.5g/L EC) and bifenthrin (10% WP) on the larger grain borer, Prostephanustruncatus (Horn) (Coleoptera: Bostrichidae) strains were investigated under laboratory conditions 28-33^{o}C and 70-85% r.h. Serial concentrations of the toxicants ranging from 2.5 to 50µg/ml for deltamethrin and 1.2 to 31.3µg/ml forbifenthrin including a control were used. Mortality was recorded at 3-hourly intervals for periods 3, 6, 9, 12 and 24 hours post-treatment. Data wereanalysed using log_{10}dose versusprobit-regression and analysis of variance (ANOVA). Results showed that dosage-related mortality responses were noted at different time intervals and these were significant (P< 0.05). The mean mortalities for the Enugu strain significantly (P< 0.01) increased after every three hours of exposure to deltamethrin, although the increase between 9th and 12th hours was not. However, the mortality responses of this strain to bifenthrin were not significantly (P> 0.05) different during the first 3 to 6 hours of exposure (LSD=13.56). Significant mortalities (P < 0.05) occurred after 9 and 12 hours of contact with insecticides. TheP. truncatus strain from Ibadan appeared to be more susceptible with LD_{50} value of 3.19µg/ml, than all the other strains compared. The Benue strain on the other hand exhibited greater tolerance to insecticides with LD_{50} of 58.39µg/ml, than the others being about 17 times more tolerant than the Ibadan strain.

Keywords: *Prostephanustruncatus, Strains,Deltamethrin, Bifenthri, Toxicity*

1. Introduction

Prostephanustruncatus thought to be native to Central America, was accidentally introduced into the hot Tabora region of Tanzania in the late 1970s and was found attacking on- farm-stored maize and dried cassava resulting in severe losses (Gilman, 1984). It subsequently spread widely within Tanzania and into southern Kenya, Burundi and Malawi (GASGA, 1998) and had spread to other countries in the region. In West Africa, a serious outbreak of the pest was first reported in Togo in early 1980s. It has spread to many other African countries thus becoming the most destructive insect pest of stored maize and dried cassava in both West and East.

The use of synthetic insecticides dominated attempts to control *P. truncatus*for years. Compounds from virtually all classes of insecticides have been used, including organochlorines, organophosphates, carbamates and pyrethroids (Egwuatu, 1987).The earliest report of insecticide testing against *P. truncatus* came from Central America and Mexico. Delgardo and Hernandez Lunar (1951) investigated the protection of maize grain using Dichloro-diphenyltetrachloroethene (DDT), Benzene hexachloride (BHC), magnesium oxide, and chlordane, and observed that all treatments gave good protection at 10 months of storage. Unfortunately, the use of DDT has been banned. Good results have also been obtained using primiphos-methyl, fenitrothion and bromophos.

In Africa, the first field trials which tested the admixture of diluted dusts of pirimiphos-methyl, fenithrothion and bromophos to shelled maize showed that only pirimipohos-methyl maintained the grain in good condition (Golob*et al.*, 1985). However, pyrethroids gave the best result. Magnesium phosphide fumigation also gave good results. Consequently, Golob*et al.*, 1985 recommended that maize should be shelled and admixed with diluted dust of permethrin admixed before storage.

The treatment of dried cassava with residual insecticide against *P. truncatus* has been investigated in the laboratory (Senkondo, 1984). Dried roots of cassava were dipped in insecticidal dispersions with deltamethrin, permethrin and pirimiphos-methyl. The results showed that only dipping treatments of deltamethrin and permethrin were effective at the end of the first month and still

gave good protection after 6 months.The cocktail dusts (Actellic super) effectively controlled LGB and other storage pests. The cocktail dust was recommended after testing a range of insecticides for their effectiveness against LGB and other storage pests (Hodges, 2008). However, notwithstanding the potency of these chemicals, other socioeconomic and technical factors militate against the introduction of these conventional improved technologies in the rural areas.

Pyrethrins are neurotoxin insecticides that are derived from the extract of *Chrysanthemumcinerariifolium* (pyrethrum) flowers (Matsumura, 1985). The plant extract, pyrethrum contains pyrethrins. Pyrethroids are synthesized directly from naturally occurring pyrethrins which are taken from pyrethrum, the oleo-resin extract of dried *Chrysanthemum* flower. The insecticidal properties of pyrethrins are derived from ketoalchoholic esters of chrysanthemic and pyrethric acids. These acids are strongly lipophilic and rapidly penetrate many insects and paralyze their nervous system (Matsumura, 1985). There are two types that differ in chemical structure. Type 1 pyrethroids include allethrin, tetramethrin, resmethrin, d-phenothrin, bioresmethrin and permethrin (1). Bifenthrin and deltamethrin are type two pyrethroids (Matsumura, 1985). Both types 1 and 2 pyrethroids inhibit the nervous system of insects and produce paralysis. This occurs at the sodium ion channels in the nerve cell membrane. Some type 2 pyrethroids also affect the action of the neuron transmitter called GABA (Matsumura, 1985).Pyrethrins are extremely sensitive to light, heat and moisture. However, the pyrethroids, the synthetic analogues of naturally occurring pesticides, were developed to capture the effective insecticidal activity of this botanical insecticide with increased stability in light, yielding longer residue time (Elliot, 1977).

Recent developments concerning pyrethroids are quite remarkable. They are fast becoming the most potent group of synthetic insecticides ever to enter the market. With the modification of both alcohol and acid components, they are also becoming stable enough to be used for agricultural purposes (Williams and Brown, 1979). The synthetic pyrethroid compounds permethrin, deltamethrin, phenothrin and fenvalerate have been found to be more effective than organophosphorus compounds in causing adult mortality of *P. truncatus* and reducing the development of succeeding generations (Golob*et al.*, 1985). The recommended control measures, for protecting maize stored on farms in areas of Tanzania affected by *P. truncatus*, include shelling maize after harvest and applying permethrin dust at the rate of 50 g of 0.5% dust per 90 kg grain (the content of a new standard sack) (Dales and Golob, 1997). Although this treatment reduced storage losses caused by *P. truncatus*, it led to an increase in the importance of damage caused by *S.oryzae*(Linnaeus) and *S. zeamais*Motschulsky and other indigenous insect pests (Golob, 1991).

Permethrin (e.c.) and deltamethrin (e.c.) were applied at doses ranging from 0.05 to 0.5 a.i. m^{-2} to glass, jute, or plywood panels, or blocks of mud, and the persistence and activity against *P.truncatus* (Horn) and *S. zeamais* (Motsch.) were compared (Hodges and Meik, 1984). The effectiveness of the treatments was influenced by the type of surface, the insecticide, its concentration and the age of deposits. The treated surfaces were bioassayed up to 18 weeks after initial treatment. Deltamethrine.c. was the most effective treatment on all surfaces against both insect species. *S. zeamais* was less susceptible to the pyrethroids than *P. truncatus*.

Laboratory results on the efficacy of two synthetic pyrethroids, deltamethrin and cyfluthrin, against *P.truncatus* were presented. Deltamethrin (LD_{50}= 0.0063ug/ insect) was less toxic than cyfluthrin (LD_{50} =0.000217ug /insect) by topical application. Both pyrethroids were equally effective against *P. truncatus* when applied in dust formulation in maize. The two pyrethroids were similarly synergized by PiperonylButoxide (PB) at 1.5 ratios by topical application and the dusting dosages leading to 100% mortality of adult *P.truncatus* were considerably reduced by PB at 1:10 ratio. Evaluation of deltamethrin and cyfluthrin dust over a 4-week period has indicated their possible potential for future control application.

Bifenthrin like otherpyrethroids affects the nervous system of insects (Chemical Book, 2010) and is relatively insoluble in water. The half-life in soil ranges from 7 days to 8 months depending on the soil type. It has been noted to be one of the few synthetic pyrethroids that are relatively stable in direct sunlight, and valued for its broad-spectrum control including plant sucking bugs and aphids, weevils, leaf eating Lepidoptera among others (Kegley*et al.*, 2009).

Early laboratory experiment on bifenthrin by the Queensland Department of Primary Industries was conducted with the aim of identifying effective application rates of bifenthrin for control of the saw-toothed grain beetle, *Oryzaephilussurinamensis* (L.) and lesser grain borer, *Rhyzoperthadominica* (F.). *O. surinamensis* was chosen because resistance to the organophosphates (fenitrothion, primiphos-methyl and chlorpyriphos-methyl) was becoming common. *R. dominica* was chosen because some population had appeared in Queensland that was resistant to the pyrethroid, bioresmethrin. An application rate of 0.5 mg/kg of bifenthrin gave complete control of susceptible and resistant *O. surinamensis*in freshly-treated wheat. This rate also gave complete control of susceptible and malathion –resistant *R. dominica* but not *R. dominica* that was resistant to both malathion and bioresmethrin. Recently, Nwankwo*et al*. (2010) reported that bifenthrin was three times more toxic to adults of *P truncatus* than *Aloe vera* leaf powder with 50% lethal dose of 6.06mg/ml.

2. Materials and Methods

2.1.1. Rearing of *P. truncatus* from Three Locations in Nigeria and a Strain from Ghana

*Prostephanustruncatus*adults were collected from three geographical locations of Nigeria namely, Enugu, Benue and Ibadan, representing, South- East, North- central and South- Western agricultural zones of Nigeria and a strain collected from Legon, Accra, Ghana. These strains of the insect were reared on a standard maize variety, White Mangu Jos (preferred substrate) obtained from Ogbete market in Enugu. The maize was transferred to an oven set at 50^{o}C and heat sterilized for two hours to kill further any existing infestation. After cooling, 500g lots were each measured into one-liter capacity Kilner jars and further sterilized at 50^{o}C for three hours. Fifty to one hundred adult insects were introduced into each jar. The whole set up was placed in a large tray containing some vegetable oil to prevent other insects from crawling into the culture. The culture was allowed to stand on the laboratory bench under ambient conditions for two months to obtain enough progeny used for the study.

2.1.2. The synthetic chemical treatments:
The pyrethroid formulations, deltamethrin (12.5g/L EC) (Deltaforce) was purchased from Agrotech Chemical Company, Ibadan and bifenthrin (10%, 62.5g WP) (Bistar) was procured from Dizengoff Chemical Company, Enugu. Lethal dose of 0.003g/mg a.i of the deltamethrin and 0.01g/ml a.i of bifenthrin were determined from residual treatment study using standard by Dales and Golob (1997).

2.1.3. Residual Application of the insecticides to determine the lethal doses.
No. 1 Whatmann filter paper (9cm in diameter) was placed in each of the Petri-dishes used for the experiment. The various dosage levels of the two insecticides used included 50µg/ml, 25µg/ml, 12.5µg/ml, 5.0µg/ml and 2.5µg/ml of delthamethrin; 31.3µg/ml, 15.6µg/ml, 5.0µg/ml, 2.5µg/ml and 1.2µg/ml of bifenthrin and each was replicated three times. Aliquots of 0.5ml of each concentration was evenly dispensed onto the filter paper and left for about one hour to ensure proper spreading of the solution and allow the acetone solvent to evaporate completely. Subsequently, 10 unsexed one week old adults were introduced into each Petri-dish by means of a mouth operated aspirator. Each of the Petri-dishes was covered with its lid to prevent escape of the insects. Mortality counts were taken for 12 hours at 3 hours interval.

2.1.4. Statistical analysis.
Count of dead insects was taken to determine mortality rate after 7 days.Correction of mortality data obtained in the residual application was done by using Abbot Formula (1925): PT = (Po – Pc / 100 – Pc x100); where PT is the corrected mortality, Po is observed mortality and Pc is control mortality. Log- probit regression analysis was carried out (Finney, 1971) for determining $LD_{50.}$ The data collected on insect number, damage and percentage weight loss were analyzed using simple factorial ANOVA model in SPSS version 17 for Windows statistical package (SPSS Inc., 1999). Treatments with significant differences were compared and separated at 0.05% level of significance using Student- Newman-Keuls (SNK) test and multiple comparison test(LSD values at $P < 0.05$).

3. Results
Tables 1a to 1d show the mortality responses of *P. truncatus* from different locations exposed to residual application of deltamethrin at 3 hourly intervals. The results show that deltamethrin exhibited significant ($P< 0.01$) levels of toxicity to *P. truncatus* strains. There were dose-dependent mortality responses to both toxicants. At the highest concentration of 50µg/ml of deltamethrin, mortalities of 68.9±18.9%, 87.5±12.5%, 52.5±20.6% and 54.2±24.7% were recorded for Enugu, Ibadan, Benue and Ghana strains, respectively (Tables 1a-d). These tables also show that at the lowest concentration of 2.5µg/ml, mortalities of 25.9±6.6%, 48.3±12.4%, 34.1±12.9% and 13.3±4.7%, respectively were recorded. These values were found to besignificantly ($P<0.01$) different from each other.
After 12-hours of exposure, percentage mortalities were respectively, 69.7±11.9, 84.7±4.9, 73.4±6.6 and 63.3±16.6 for Enugu, Ibadan, Benue and Ghana. Also, after 3 hours of exposure, percentage mortalities were 11.9±1.4, 29.3±7.6, 12.0±1.2 and 2.7±1.3 for Enugu, Ibadan, Benue and Ghana strains, respectively. The *P. truncatus* strain from Ibadan appeared to be more susceptible than all the other strains. However, Benue strain exhibited greater tolerance to the insecticides than other strains and was approximately 17 times more resistant than the Ibadan strain
Table 1a shows that mean mortalities for this strain significantly ($P< 0.01$) increased after every three hours of exposure to deltamethrin. However, the increases between the 9th hours and the 12th hours were not significant (LSD= 21.06, $P> 0.05$). Table 1b shows the mortality responses of the Ibadan strain to the same toxicant and also shows significant increasing mortalities with longer time of exposure. The LSD value (9.25) indicates that after 6 hours of exposure, the levels of response were not really significantly different ($P> 0.05$) up to the time of terminating the experiment.

Dose(µg/ml)	3hrs	6hrs	9hrs	12hrs	Mean ± s.e
50	16.7	73.4	86.7	98.7	**68.4 ± 18.9^{b}**
25	13.3	33.3	83.3	93.3	**55.8 ± 18.6 ^{ba}**
12.5	13.3	23.3	70.0	73.3	**44.9 ± 15.4 ^{a}**
5.0	10.0	36.7	40.0	46.7	**33.4 ± 8.06 ^{a}**
2.5	6.7	26.7	33.4	36.7	**25.9 ± 6.59^{a}**
Mean ± s.e	**11.9 ± 1.4 ^{a}**	**38.7 ± 7.8 ^{b}**	**62.7 ± 11.5 ^{c}**	**69.7 ± 11.9 ^{c}**	
Control	**0**	**0**	**0**	**0**	**0**

Table 1a: The mean percentage mortality effects of different concentrations of deltamethrin on adults of P. truncatus from Enugu at 3 hourly intervals.

Means of three replicates (±s.e), LSD= 21.06, Means followed by the same superscript letters are not significantly different.

Conc. g/ml	3hrs	6hrs	9hrs	12hrs	**Mean ± s.e**
50	50.0	100	100	100	**87.5 ± 12.5** [d]
25	43.3	80	80	86.7	**72.5 ± 9.7** [bc]
12.5	26.7	73.4	80.1	80.1	**65.1 ± 12.9** [b]
5.0	13.3	70.0	80.0	86.7	**62.5 ± 16.8** [b]
2.5	13.3	50.0	60.0	70.0	**48.3 ± 12.4** [a]
Mean ± s.e	**29.3 ± 7.56** [a]	**74.7 ± 8.07** [b]	**80.0 ± 6.32** [b]	**84.7 ± 4.90** [bc]	
Control	**5**	**5**	**0**	**5**	**3.8**

Table 1b: The mean percentage mortality effects of different concentrations of deltamethrin on adults of P. truncatus from Ibadan at 3 hourly intervals.

Means of three replicates (±s.e), LSD= 9.25, Means followed by the same superscript letters are not significantly different.

Conc(µg/ml)	**3hrs**	**6hrs**	**9hrs**	**12hrs**	**Mean ± s.e**
50	16.7	20.0	83.3	90.0	**52.5 ± 20.6**[ab]
25	13.3	20.0	56.7	80.0	**42.5 ± 17.3** [a]
12.5	10.0	16.7	56.7	80.4	**40.9 ± 16.9** [a]
5.0	10.0	16.7	53.4	60.1	**35.0 ± 13.3** [a]
2.5	10.0	16.7	53.4	56.7	**34.2 ± 12.9** [a]
Mean ± s.e	**12.0 ± 1.2** [a]	**18.0 ± 0.7** [a]	**60.7 ± 5.8** [b]	**73.4 ± 6.6** [c]	
Control	**0**	**0**	**0**	**0**	**0**

Table 1c: The mean percentage mortality effects of different concentrations of deltamethrin on adults of P. truncatus from Benue at 3 hours interval

Means of three replicates (±s.e), LSD= 11.76, Means followed by the same superscrip letters are not significantly different.

Conc.(µg/ml)	**3hrs**	**6hrs**	**9hrs**	**12hrs**	**Mean ± s.e**
50	6.7	16.7	93.4	100	**54.2 ± 24.7**[ba]
25	3.3	16.6	93.3	96.8	**52.5 ± 24.7**[ba]
12.5	3.3	16.6	36.6	69.9	**31.6 ± 14.8**[a]
5.0	0	13.3	26.6	29.9	**17.5 ± 6.8**[a]
2.5	0	13.3	20.0	20.0	**13.3 ± 4.7**[a]
Mean ± s.e	**2.7 ± 1.3** [a]	**15.3 ± 0.8** [a]	**53.9 ± 16.2** [b]	**63.3 ± 16.6** [b]	
Control	**0**	**0**	**0**	**0**	**0**

Table 1d: The mean percentage morality effects of different concentrations of deltamethrin on adults of P. truncatus from Ghana at 3 hourly intervals.

Means of three replicates (±s.e), LSD= 31.39, Means followed by the same superscript letters are not significantly different.

The Benue strain did not show significant differences (P> 0.05) to the insecticide between the first 3 and 6 hours of exposure (LSD, 11.76). Nevertheless, the response after 9 hours was significantly different (P< 0.05) from that of 6 hours. Also, the mortality responses after 12 hours was more significant compared with the value at the9th hours.

The Ghana strain (Table 1d) did not show any significant differences (P> 0.05) during the first 3 and 6 hours. However, significant differences (P< 0.05) were observed during the 9th and 12th hours (LSD= 31.39).

Figure 1 shows the graph of probit against log-dose for deltamethrin. The Ibadan strain had the lowest LD_{50} value of 3.19µg/ml indicating that was the most susceptible strain to deltamethrin. This was followed by Enugu (15.67 µg/ml) and Ghana (32.40 µg/ml) strains, respectively. Benue strain recorded the highest LD_{50} value of 58.39µg/ml and was the most resistant to the toxicant.

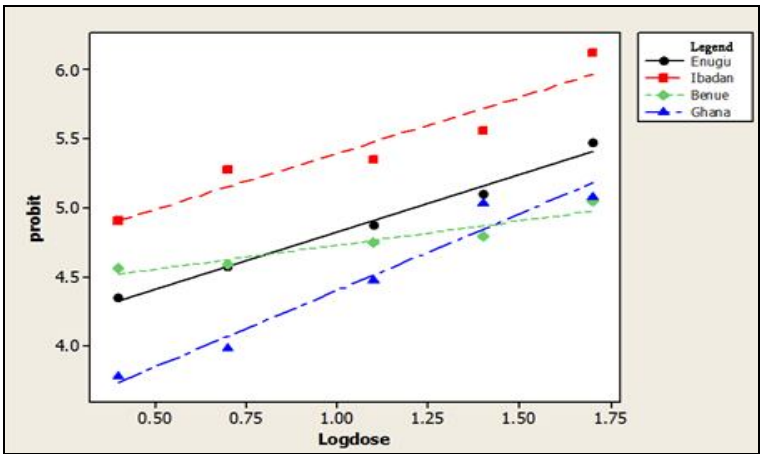

Figure 1: Plot of Probit versus log-dose for deltamenthrin

Legend:

- Enugu= r^2 = 3.981+ 0.853x; LD_{50} = 15.67 µg/ml
- Ibadan= r^2 = 4.59+ 0.813x; LD_{50} = 3.19 µg/ml
- Benue= r^2 = 4.408+ 0.342x; LD_{50} = 53.8 µg/ml
- Ghana= r^2 = 3.424+ 1.043x; LD_{50} = 32.40 µg/ml

In the case of *P. truncatus* treated with Bifenthrin (Tables 2a-2d), the percentage mortality responses were, respectively 53.4±14.8%, 70.1±17.3%, 50.0±17.2 %and 57.5±13.3% for Enugu, Ibadan, Benue and Ghana strains. Mortality also increased with increasing concentrations. Mortality was also time dependent, showing that the responses increased with increasing time of exposure to the insecticides. In terms of the relative susceptibility of these strains to Bifenthrin, Benue was found to be 2.9 times more resistant than Ibadan strain.

Conc. (µg/ml)	3hrs	6hrs	9hrs	12hrs	Mean ± s.e
31.3	26.7	43.4	50.1	94.4	**53.4 ± 14.8 [bc]**
15.6	23.3	26.6	46.6	73.3	**42.5 ± 11.7 [b]**
5.0	20.0	23.3	43.3	66.6	**38.3 ± 10.9 [b]**
2.5	10.0	13.3	29.9	36.6	**22.5 ± 7.5 [a]**
1.2	6.7	6.7	16.7	23.4	**13.4 ± 4.8 [a]**
Mean ± s.e	**17.3 ± 4.1 [a]**	**22.7 ± 6.4 [a]**	**37.3 ± 6.4 [b]**	**58.9 ± 12.4 [c]**	
Control	**0**	**5**	**0**	**0**	**1.3**

Table 2a: The mean percentage mortality effects of different concentrations of bifenthrin on adults of P. truncatus from Enugu at 3 hourly intervals.

Means of three replicates (±s.e), LSD= 13.56, Means followed by the same superscript letters are not significantly different.

Conc.(µg/ml)	3hrs	6hrs	9hrs	12hrs	Mean ± s.e
31.3	26.7	76.7	83.4	93.4	**70.1 ± 17.3[bc]**
15.6	16.7	53.4	73.4	83.4	**56.7 ± 14.2 [b]**
5.0	16.7	30.0	73.3	80.0	**50.0 ± 15.3 [b]**
2.5	6.7	13.4	23.4	40.0	**20.9 ± 7.5 [a]**
1.2	3.3	6.6	13.3	26.6	**12.5 ± 4.9 [a]**
Mean ± s.e	**14.0 ± 3.5 [a]**	**36.0 ± 12.3 [b]**	**53.4 ± 15.2 [b]**	**64.7 ± 13.6 [bc]**	
Control	**0**	**0**	**0**	**5**	**1.3**

Table 2b: The mean percentage morality effects of different concentrations of bifenthrinon adults of P. truncatus from Ibadan at 3 hourly intervals.

Means of three replicates (±s.e), LSD= 19.88, Means followed by the same superscript letters are not significantly different.

Conc. (µg/ml)	3hrs	6hrs	9hrs	12hrs	Mean ± s.e
31.3	10.0	36.7	63.4	90.1	**50.0 ± 17.2 [b]**
15.6	6.7	30.3	60.3	70.3	**41.9 ± 14.2 [b]**
5.0	6.7	16.7	36.7	66.7	**31.7 ± 12.7[ab]**
2.5	3.3	13.3	30.0	36.7	**20.8 ± 7.9 [a]**
1.2	3.3	6.7	20.0	33.3	**15.8 ± 6.7 [a]**
Mean ± s.e	**6.0 ± 1.2 [a]**	**20.7 ± 5.3 [b]**	**42.1 ± 8.2 [c]**	**59.4 ± 10.5 [d]**	
Control	**0**	**0**	**0**	**0**	**0**

Table 2c: The mean percentage morality effects of different concentrations of bifenthrin on adults of P. truncatus from Benue at 3 hourly intervals.

Means of three replicates (±s.e), LSD= 14.46, Means followed by the same superscript letters are not significantly different.

Conc. (µg/ml)	3hrs	6hrs	9hrs	12hrs	Mean ± s.e
31.3	26.7	50.0	64.1	90.2	**57.5 ± 13.3 [c]**
15.6	20.0	26.7	50.3	72.1	**42.6 ± 11.7 [b]**
5.0	16.7	20.0	30.0	47.8	**29.1 ± 6.8[ab]**
2.5	13.3	16.6	23.3	23.3	**19.1 ± 2.5 [a]**
1.2	10.0	10.0	22.0	22.8	**16.7 ± 3.3 [a]**
Mean ± s.e	**17.3 ± 2.9 [a]**	**24.7 ± 6.5 [a]**	**38.7 ± 8.3 [ab]**	**51.4 ± 13.3 [b]**	
Control	**0**	**0**	**0**	**0**	**0**

Table 2d: The mean percentage morality effects of different concentrations of bifenthrin on adults of P. truncatus from Ghana at 3 hourly intervals.

Means of three replicates (±s.e), LSD= 15.80, Means followed by the same superscript letters are not significantly different.

The mortality responses of the Enugu strain of *P. truncatus* (Table 2a) showed that there were no significant ($P > 0.05$) differences during the first 3 and 6 hours of exposure to Bifenthrin (LSD, 13.56). However, significant mortalities ($P < 0.05$) occurred after 9 and 12 hours of contact with the insecticide. Table 2b shows that the mortality responses of the Ibadan strain of the insect was significantly higher (LSD, 19.88; $P < 0.05$) at the 6th and 9th hours. However, the LSD shows that the mean responses at the 12th hour were not actually significantly different from those at the 9th hour. The Benue strain (Table 21c) shows significantly higher responses ($P < 0.05$; LSD, 14.46) after every three hours increase in the time of exposure to bifenthrin.Table 2d shows that the Ghana strain exhibited increases in percentage mortality with increasing exposure to bifenthrin. This was not significantly ($P > 0.05$, LSD= 15.80) different for the 3rd, 6th and 9th hours. However, the response at the 12th hour increased significantly but this was not actually significantly different from the response at the 9th hour of exposure.

The graph of probit response of *P. truncatus* strains to bifenthrin is presented in Figure 2. From the analysis, Ibadan strain had LD_{50} value of 10.19µg/ml and appeared to be the most susceptible while Benue strain with LD_{50} value of 29.60µg/ml appeared to be the most resistant to Bifenthrin. The Ghana and Enugu strains have almost the same level of response with LD_{50} values of 22.42µg/ml and 23.04µg/ml, respectively. The two pyrethroid toxicants showed significant differences ($P< 0.05$) on the level of mortality responses of *P. truncatus* from the four different locations. However, deltamethrin appeared to be more toxic, thereby resulting in higher mortality than bifenthrin. Furthermore, the Ibadan strain of this species appeared to be more susceptible to both toxicants when compared with the other strains.

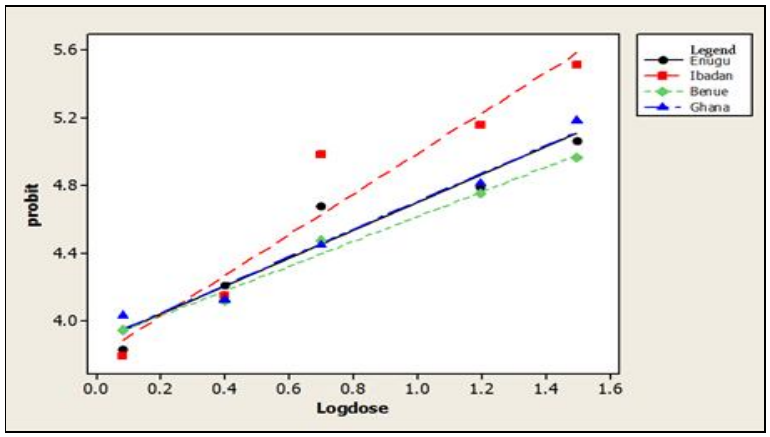

Figure 2: Plot of Probit against log-dose for bifenthrin.

Legend

- Enugu = r^2 = 3.885+ 0.819x; LD_{50} = 23.04 µg/ml
- Ibadan = r^2 = 3.790+ 1.200x; LD_{50} = 10.19 µg/ml
- Benue = r^2 = 3.947+ 0.716x; LD_{50} = 29.60 µg/ml
- Ghana = r^2 = 3.883+ 0.827x; LD_{50} = 22.42 µg/ml

4. Discussion

Laboratory study was conducted to evaluate the effect of exposure time and toxicity of deltamethrin and bifenthrin (pyrethroids) to adult of the larger grain borer, *Prostephanustruncatus* from different geographical locations. Results obtained from this study demonstrate theimportance of timing of application of insecticides. In the present study, mortality increased with increase in the exposure time. Deltamethrin was more efficient and would give longer period of protection than bifenthrin. After 12 hours of exposure, up to 50% of *P. truncatus* from different geographical locations were killed. This showed that with long post exposure periods, the direct effect of deltamethrin increased leading to *P. truncatus* mortality. This however, indicates that it is a long lasting insecticide and may be used for pre-infestation treatment before most field-to-store pest colonizes the stored products.

It has been reported by Lale (2002) that nearly all storage insects are more active in the dark than in the light. According to him, most stored product insects shy away from light. In the present study, higher mortalities of *P. truncatus* strains occurred at the last hours of exposure. Timing of spray application is important in any pest management operations. According to Matthew (1992) few applications of pesticides may be needed if they are timed more accurately and this will reduce selection pressure for resistance.

The present study also demonstrates the attractive potentials of bifenthrin and deltamenthrin synthetic pyrethroids against the larger grain borer. The resultant high mortalities of adults of the grain borer observed in the residual application of the insecticides to the test insects could be due to high toxic effect of these products on the adults. There was increase in the percentage mortality with increased concentration as the time progressed. These toxicants containketoalchoholic esters of chrysanthemic and pyrethric acids which are highly lipophilic and can rapidly penetrate the insects'body and paralyze their nervous system (Matsumura, 1985). Matsmura (1985) reported that some type II pyrethroids to which deltamethrin and bifenthrin belong affect the action of the neuron-transmitter called gamma amino butyric acid (GABA) and that the synergist used with pyrethrins, (piperonylbutoxide, PBO) inhibits mixed-function oxidases (mfo). Kegley*et al.*(2009) reported that bifenthrin had a high toxic effect on the mortality of the saw-toothed grain beetle, *Oryzaephilussurinamensis* (L.) and lesser grain borer, *Rhyzoperthadominica* (F.). The toxicant has a broad-spectrum of activity in controlling plant sucking bugs (e.g. aphids), weevils, and leaf eating Lepidoptera. Similarly, Golob*et al.* (1985) reported that deltamethrin, permethrin,fenvalerate and phenothrin performed better than organophosphates in causing adult mortality in *P. truncatus*.The results of the present studies agree with these authors that bifenthrin and deltamethrin have high toxic effect and potentials in controlling *P. truncatus.*

In residual treatment, mortality was generally higher in deltamethrin treatment than in bifenthrin despite the fact that both are type II pyrethroids. The reasons for this are not entirely clear. One possible explanation may be due to the chemical nature of these compounds and the nature of their formulations. Also the differences in toxicity according to Matsumura (1985) are determined by the rate of cuticular penetration, solubility in haemolymph and the polarity of the compounds as polar compounds penetrated faster than less polar (lipophilic) compounds. O'Brien and Fisher (1958) reported that toxicity of insecticides depends on the route of transport to the nervous system, the distance to the target (nervous system), and the permeability of the insect nerve sheath, which is more permeable to highly liposoluble compounds. There were dose and time dependent responses of the insects in the present studies. Thus, mortality increased with time in both cases and decreased as concentration decreased.

The *P. truncatus* from Ibadan with the lowest LD_{50} was more susceptible to the two toxicants than the other strains from other regions. This was the case in spite of the heavier size of the strain from Ibadan. This could be as a result of the physiological composition of the insects (Matsumura 1985) which may be implicated. The other strains with smaller body size and which were tolerant may have higher concentrations of enzymes that confer resistance to insecticides. Matsumura (1985) observed that the relative importance of any given metabolic enzyme system may vary from species to species, and depending upon the mode of life of the species involved, the degree to which it depends upon that system and the mode of resistance. For instance, Mullin *et al.*

(1982) compared organophosphate-resistant and organophosphate susceptible strains of a phythophagous mite species, *Tetranychusurticae*, and reported increased levels of mixed-function oxidase.These observations may indicate the intraspecific differences in the mechanism of resistance and the differences in the species in the way of utilizing enzymatic system.
The *P. truncatus* strain from Benue was found to be more tolerant to the two toxicants more especially deltamethrin. It is possible that this strain may have acquired resistance to the toxicant as a result of frequent use and treatment of cassava chips. It should be noted that the bulk of cassava chips produced in this country comes from Benue State and may have been treated with insecticides especially deltamethrin which was among the earliest pyrethroid insecticides used against this pest. It is, therefore, not suprising to suggest that the *P. truncatus* strains used in the present studies had higher LD_{50} and tolerance of deltamethrin than bifenthrin.

5. References

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