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# ASSESSMENT OF RESISTANCE STATUS OF THE MAJOR STORAGE INSECT PESTS OF COCOA TO DELTAMETHRIN IN GHANA

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**ABSTRACT**

Due to the versatility of insects, many of them quickly and easily develop resistance to insecticides they have been subjected to for long periods. Should resistance strains arise in a population, its control with same, and at times with similar, insecticides becomes more difficult. Possible development of resistance in the major insect pests of stored cocoa bean to Deltamethrin was studied at the Entomology laboratory of the Research Department of Quality Control Company of the Ghana COCOBOD at Tema. Samples of *Ephestia cautella, Tribolium castaneum* and *Cryptolestes ferrugineus* were collected from two sites with different insecticide use history, and exposed to different concentrations of Deltamethrin. The results showed that the response of the two populations of the insects followed a similar trend. *Ephestia cautella* was the most susceptible insect to Deltamethrin, where 100 % mortality was attained at 10 x $10^4$ ppm concentration in both populations. Generally, the 10 x $10^4$ ppm concentration achieved 90 % mortality in the *Tribolium castaneum* and *Cryptolestes ferrugineus populations* studied. Therefore all the three storage beetles tested for resistance to deltamethrin had not developed resistance to the insecticide.

**Keywords:** deltamethrin, resistance, diagnostic/discriminating concentration, ppm.

## INTRODUCTION

Chemical control remains the most important and widely used tactic against most insect pests around the world, and studies have shown that multiple resistance mechanisms in insects confer resistance to a range of insecticide classes (Georghiou, 1972; Hemingway, 1999; Liu, 2015).

As at 2003, about 520 insect and mite species, 150 plant pathogen species, and about 273 weeds species were reported to be resistant to pesticides (Sukhoruchenko *et al.*, 2008). Insecticide resistance is the major obstacle to the control of agriculturally and medically important insect pests. This worldwide problem has been documented mainly in arthropod species, particularly among flies, caterpillars, beetles and mites (Georghiou, 1990).

Development of pesticide resistance leads to increased pesticide application frequencies, increased dosages, which also lead to issues of pesticide residues above the allowable limits. Insecticide resistance and the consequent losses of food arising from failure of chemicals to control pests cause economic losses of several billion dollars worldwide each year (Elzen, and Hardee, 2003).

Insecticide resistance in stored product insects has been reported from many countries dotted around the globe (Sayaboc and Acda, 1990; Yao and Lo, 1995; DARP, 2003; Benhalima *et al.*, 2004).

According to APRD (2007) populations of all the major insect pests have shown resistance to many insecticides. For example *Tribolium* spp. has been found to be resistant to 39 insecticides, *Oryzaephilus surinamensis* (L.) to 11 insecticides, *Sitophilus granarius* (L.) to 10 insecticides, *Rhyzopertha dominica* (Fab.) to 8 insecticides, *Callosobruchus maculatus* (Fab.) to 2 insecticides, *Cryptolestes ferrugineus* (Stephens) and *Lasioderma serricorne* (Fab.) to 1 insecticide each.

Given the tremendous difficulty and investment associated with development of new, safer and better cost-effective insecticides (Szczepanski, 1990), there is a grave need to preserve the efficacy of current and future insecticides. Deltamethrin is a synthetic pyrethroid insecticide which possesses an extremely high level of toxicity to a wide range of insects (Worthing and Walker, 1987), including Lepidoptera, Hemiptera, Diptera and Coleoptera (Roussel-Uelaf, 1982). It acts by both direct contact and as stomach poison when ingested (Worthing and Walker, 1987). It is used mostly for crop protection mostly on cotton, fruit and vegetable crops, cereals, maize and soya beans. It is also used in public health programmes (against Chagas disease and malaria) and to protect stored crops, primarily cereal grains, coffee beans and dry beans (WHO, 1990)

Insect pest infestation in the cocoa storage environment, prior to shipment, has been a serious problem to the cocoa industry in Ghana for some time now. As a result of this, Ghana's cocoa exports, despite pre-shipment fumigation, have had to be disinfested a couple of times at the ports of destination due to detection of insect infestation, resulting in huge cost to Ghana. There is the suspicion that stored cocoa insects have developed resistance to the insecticides being used to control them in Ghana. There is therefore, the need to constantly monitor for any sign of development of insecticide resistance in order to manage it.

## MATERIALS AND METHODS

### Source of Insects for the study

Live pre-adult insects sieved from insecticide treated cocoa stored in sacs in warehouses were reared to adulthood. The rearing medium comprised wheat bran, finely ground maize and glycerol in the ratio 8:8:1 (w/w) (Amoako-Attah and Partida., 1976). in Kilner jars covered with muslin cloth and fastened with rubber band. The set up was placed in metallic trough containing mineral oil to prevent invasion of crawling insects. Similar insects from a different untreated locality (Irani Brothers flour mill, Ghana) were also collected and reared. Each culture containing 600 g of the rearing medium, was infested with 100 mixed sex adults of *T. castanem*, *C. ferrugineus* and *E. cautella* separately.

All equipment used in handling the insects was dry heat sterilised at 100 $^{o}$C for at least 3 h while the food medium was sterilised in a Gallenkamp oven at 60 $^{o}$C for 3 h before experimentation. All cultures and experimental set-ups were maintained at ambient laboratory conditions (temperature range 27.5±30 $^{o}$C) and relative humidity (r.h.) range 60-73 %) using thermohygrometer.

All the cultures in jars were held in trays with supports immersed in white oil to prevent insects from crawling into them (Sayaboc and Acda, 1990; Yao and Lo, 1995).

The first filial generation ($F_1$) adults of *Ephestia cautella*, *Cryptolestes ferrugineu*s and *Tribolium castaneum* were used for susceptibility test. Bioassay tests were conducted on the insects using eight concentrations of the insecticide (Deltamethrin).

The presence of insecticide resistance in a population is usually detected with one or more of three techniques. The traditional approach uses complete dose/concentration-response tests, using a range of doses/concentrations that produce 10-90 % mortality. Resistance is then expressed in terms of the ratio of the $LC_{50}$ or $LC_{90}$ of the resistant strain to that of the susceptible strain (Halliday and. Burnham, 199). The response of the insects to the insecticides was determined, and discriminating concentrations, that is, the concentration of insecticide that caused at least 90 % mortality (Grafton-Cardwell, 1991) was determined. The discriminating concentrations were used to calculate Resistance Factor (RF): the ratio of concentration that produce 90 % mortality in the resistant strain to concentration that produce 90 % mortality in the most susceptible strain (Grafton-Cardwell, 1991).

### Insecticides tested

Commercial formulation of the insecticide, Supergold ULV insecticide, containing Deltamethrin was used. Supergold was used because it has been in used for at least six years now. Fresh insecticide dilutions were prepared on each test day. Five, 10, 15, 20, 25, 30, 35 and 40 parts of technical grade deltamethrin Super ULV were added to 95, 90, 85, 80, 75, 70, 65 and 60 parts of vegetable oil (rape seed oil) respectively to make a range of 5 to 40 % concentrations or 5 x $10^4$ to 40 x $10^4$ ppm respectively.

### Bioassay

A modified diet incorporation technique was used as follows: Six to ten concentrations of the insecticide were used, as well as the vegetable oil used in diluting the insecticide. Five replicates were used for each insecticide concentration in a completely randomized design.

Two milligrammes of each of the insecticide concentrations were mixed thoroughly with 10 g of the medium used in rearing the insect and kept in Kilner jar covered with a lid of muslin cloth. Five minutes after the preparation, 50 adult insects (except in the case of *Ephestia*, where larvae were used) were transferred into the Kilner jars. The set up was kept at a temperature range of 25-27$^{o}$C and relative humidity range of 74-76 % (Owusu *et al*., 1995, modified).

## DATA ANALYSIS

Data collected on mortality was subjected to ANOVA using GenStat Discovery Edition Version 12, 2012 and Tukey's test was used to separate the means that were found to be significant at 5 % significance level.

Insect mortality and insecticide concentrations were used to compare the responses of populations to the insecticides. Concentration-mortality curves were drawn while resistance factor was calculated to determine insect resistance if any and its intensity.

## RESULTS

The response of the two populations of the insects to the different concentrations of Deltamethrin followed a similar trend (Figures 1 - 3). *Ephestia cautella* was found to be the most susceptible to the Deltamethrin, where 100 % mortality was attained at 10 x $10^4$ ppm concentration in both populations (Figure-1). *Cryptolestes ferrugineus* suffered 100 % mortality at double strength (20 x $10^4$ ppm) of the concentration that killed all the introduced *Ephestia cautella* (Figure-2), while still a higher concentration of 35 x $10^4$ ppm was needed to cause 100 % mortality in *T. castaneum* (Figure-3).

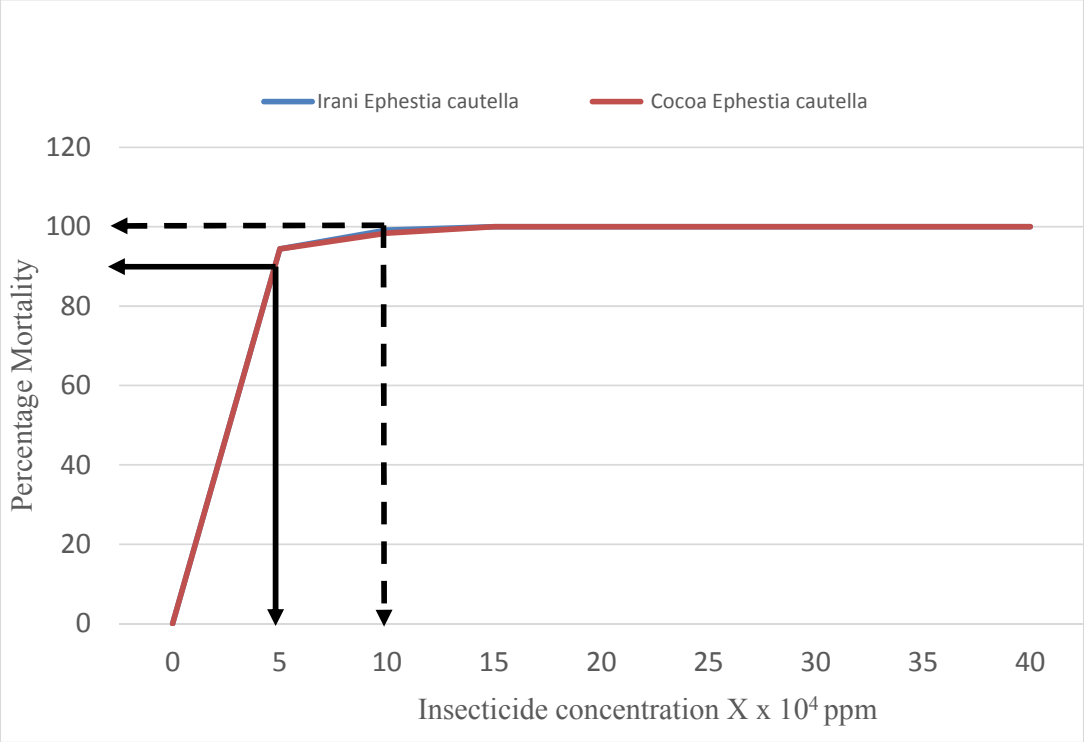


**Figure-1.** Dose-Mortality Response of *Ephestia cautella* to Deltamethrin.

Mortality increased with increasing concentration for all the three insects but the differences in response of the two populations to the Deltamethrin was negligible. Generally the same concentration achieved 90 % mortality in both populations of all three insects studied. Hence, there was no diagnostic/discriminating concentration. A diagnostic/discriminating concentration distinguishes resistant from susceptible insect genotypes thereby differentiating between homozygous susceptible (SS) and resistant (R-), but not between RS and RR. *E cautella* suffered 90 % mortality at 5 x $10^4$ ppm concentration (Figure-1) but 90 % of *C. ferrugineus* succumbed at 15 x $10^4$ ppm concentration (Figure-2) while *Tribolium castaneum* suffered 90 % mortality at 35 x $10^4$ ppm (Figures-3).

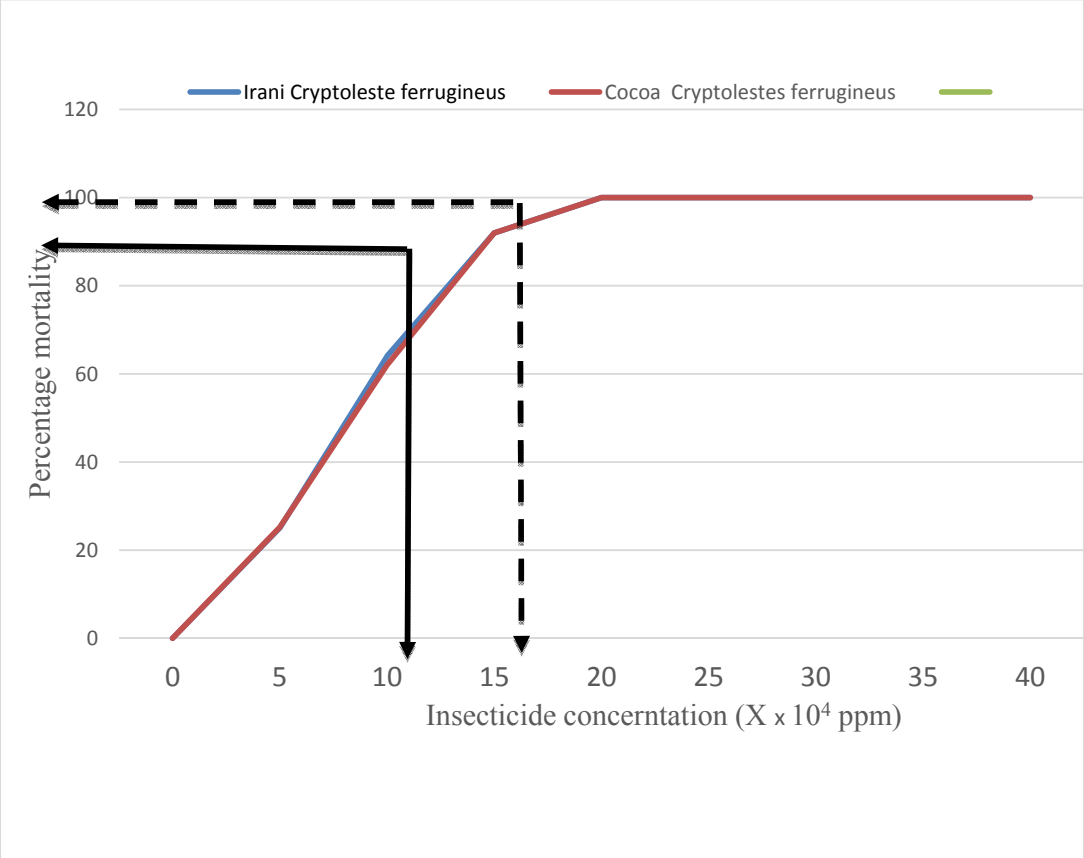


**Figure-2.** Dose-Mortality Response of *Cryptolestes ferrugineus* to Deltamethrin.

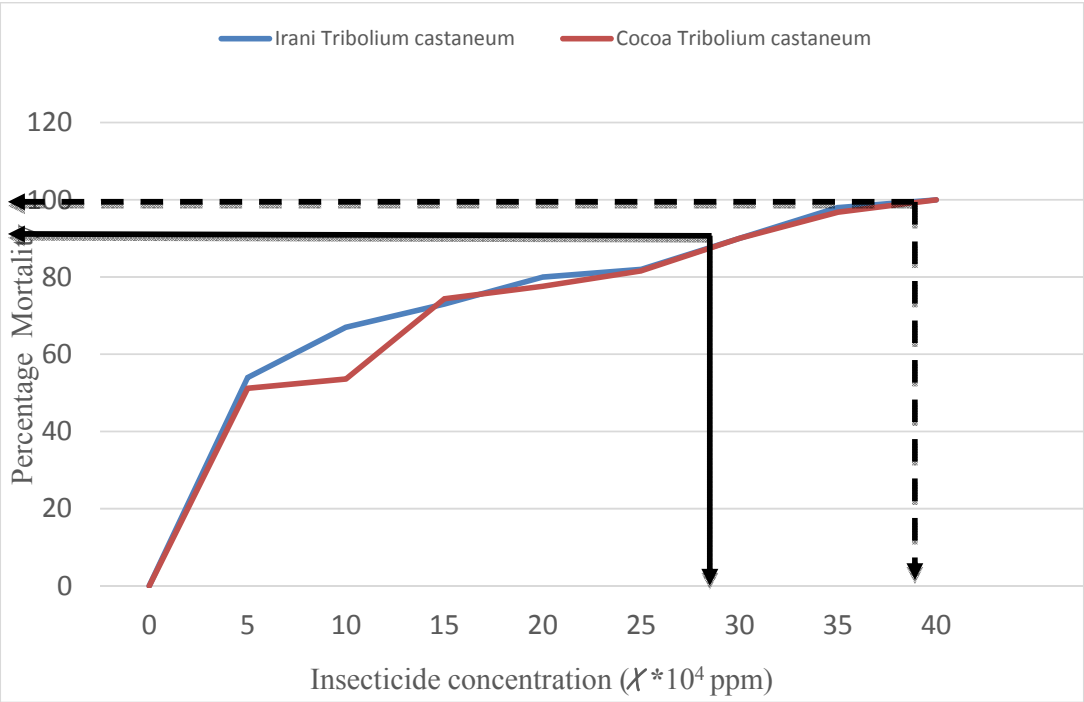


**Figure-3.** Dose-Mortality Response of *Tribolium castaneum* to Deltamethrin.

The ratio of $LC_{90}$ between the populations studied indicated that the insects have not developed resistance to Deltamethrin. Normally the ratio should be more than 1 to prove a level of resistance in one of the strains (i.e. the suspected resistant insect) as compared to the susceptible one to the insecticide in question.

**DISCUSSIONS**

Insect resistance to insecticides arises as a result of accelerated microevolution where, under selection pressure of insecticide application, the fittest insects survive, multiply and spread resulting in resistant insect genotypes that have the capability to endure subsequent insecticide applications in the environment. When the frequency of resistant genotypes increases to a certain level in field populations, control efficacy with the concerned insecticide becomes almost impossible. However, poor insecticide efficacy under field conditions is not always due to insecticide resistance. Other factors such as the quality of technical grade material used, the formulation, the application dose and the method of application also play important roles in impairing field control (Kranthi, 2005).

The results of this study showed that intermittent poor insecticide (Deltamethrin) efficacies under field conditions were not due to resistance developed by *T. castaneum*, *C. ferrugineus* and *E. cautella* to the insecticide, as 35 x $10^4$ ppm concentration was potent enough to cause 100 % mortality in these insect pests in cocoa storage facility. That being the case, there is no need to increase the current recommended dosage of 35 x $10^4$ ppm to avoid unnecessary wastage and contamination of the environment and produce.

According to Bielza (2008) and Durmuşoğlu *et al.* (2015) the indiscriminate use of insecticides coupled with insect traits such as high fecundity and short generation time promote the development of insect resistance to insecticides. Even though almost all insect pests of stored cocoa beans have high fecundity, they do not generally have short generation time. For example, it takes *T castaneum* 239.5 days to complete its cycle from egg to adult on cocoa beans (Shrikant *et al*., 2016), hence univoltine. A generation time of almost 240 days is long time enough for maximum contact between the various instars of the insect, which is more likely to die from chronic toxicity of the insecticide applied. This would not permit such an insect to develop resistance. Again, Deltamethrin is not used indiscriminately in the cocoa storage environment. Management of application dose, constraining the number of applications, use of pesticide mixtures, alternation of pesticides with different modes of action and combinations of some of these approaches are the strategies often used to prevent or delay resistance development in the field (van den Bosch *et al.,* 2011). Some of these approaches were in place in the COCOBOD storage sites. A rigid programme of pesticide application and dose management has been put in place by Quality Control Company of COCOCBOD where pesticide applicators undergo regular training on adherence to pest management practices, and backed by routine monitoring of pesticide application by superiors. These reasons may explain why the insects have not as yet developed resistance to Deltamethrin.

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