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# Toxicity of newer insecticide molecules against lesser grain borer, *Rhyzopertha dominica* (Fabricius) (Bostrichidae: Coleoptera)

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**Abstract**
To find out the insecticidal activity of commercial formulations of newer insecticides with novel mode of action *viz.*, emamectin benzoate, lufenuron, chlorfenapyr, chlorantraniliprole are compared with check malathion and deltamethrin were evaluated for their toxicity against *Rhyzopretha dominica* by jute cloth disc impregnation method under laboratory conditions during the year 2015-16 at the Department of Entomology. Among the new insecticides tested for the management of *R. dominica*, chlorfenapyr was found to be the best at $LC_{99.9}$ level with the highest relative toxicity of 7.45 times than malathion and 7.34 times than deltamethrin. Emamectin benzoate was found to be the best at $LC_{99.9}$ level with the relative toxicity of 1.82 times than malathion and 1.79 times than deltamethrin. The relative toxicity at $LC_{50}$ level of chlorantraniliprole 2.67 times than malathion and 4.25 times than deltamethrin. Lufenuron expressed relative toxicity at $LC_{50}$ level 0.63 times than malathion and 0.68 times than deltamethrin and at $LC_{99}$ level 1.00 times than malathion and 0.67 times than deltamethrin.

**Keywords:** *Rhyzopertha dominica*, malathion, deltamethrin, newer insecticide molecules

## 1. Introduction

Storage of the grains and seeds is very important in agriculture to start a new life and also in food security point of view. The quality grains and seeds during storage depends on various factors such as crop or variety, initial seed quality, storage conditions, seed moisture content, insect pests, bacteria and fungi [1]. Among these factors insect pests are problematic throughout the world, because they decrease the quantity and quality of grain. Food grain accounts for 20-25% damage by storage insect pests [2] which is really a brainstorming matter. Among various storage insect pests lesser grain borer, *Rhyzopertha dominica* is a severe insect pest of wheat and other cereal grains under storage condition. It is an internal feeder and cause significant loss to cereals affecting the quantity as well as the quality of the grains. The use of chemical agents to prevent or control insect infestations has been the main method of grain protection, since it is the simplest and most cost-effective means of dealing with stored product pests [3]. Insect pests may behave differently when in contact with pesticides and these changes in behaviour may contribute to their tolerance of pesticide. Resistance of insect pests to pesticides is an example of evolution of the species showing how they can survive and change physiologically under pressure by chemicals. Therefore, there is a great need to find out suitable insecticides which prove effective against the insecticide resistant insect species.

## 2. Materials and methods

### 2.1. Beetle culture and maintenance

The population of the test insect, *R. dominica*, collected from the Rice Research Unit (Bapatla) were maintained on wheat grains in the laboratory. Initially the wheat grains were disinfested by fumigating with aluminium phosphide tablets @ one per 30 kg grains for seven days to ensure that they were free from insects and mites. About 250 g of wheat grains were taken in a plastic jar measuring 45 × 15 cm and about 20 adults were released into it for oviposition. Adults were removed after 20 days and released into another jar containing wheat grains, thus a succession of the insects was maintained for utilizing the eggs laid staggeredly to ensure constant supply of test insects of known age. The newly emerged adults were transferred into new containers with fresh wheat grains and used for the multiplication of culture and also for conducting the experiments.

The pest population was maintained at an optimum temperature of 32 +$1^0$ C and 75 per cent relative humidity throughout the period of investigation [4].

### 2.2 Test insecticides

| S. No | Common Name and Strength of the insecticide | Trade Name |
|---|---|---|
| 1 | Emamectin benzoate 5% SG | Proclaim |
| 2 | Lufenuron 5.4% SC | Cigna |
| 3 | Chlorfenapyr 10% SC | Intreprid |
| 4 | Chlorantraniliprole 18.5% SC | Rynaxypyr |
| 5 | Malathion (Check) 50% EC | Meltox |
| 6 | Deltamethrin (Check) 2.8% EC | Decis |

### 2.3 Test insect population
The adult beetles of *R. dominica* (seven days old) of the F1 generation, reared in the laboratory from the initial culture obtained from the Rice Research Unit (RRU) - Bapatla, Andhra Pradesh were subjected to bioassay.

### 2.4 Bioassay
The adult beetles of *R. dominica* of one week old were subjected to the bioassay with the test insecticides by following jute cloth disc impregnation method [5]. Stock solution of one per cent concentration of respective test insecticides was prepared by weighing the required quantities of insecticides, by using acetone as solvent. The graded concentrations of the test insecticides were prepared with acetone as solvent by following serial dilution technique. The quantity of insecticidal solution required to impregnate the jute cloth of nine centimeters diameter was determined. After impregnation, the jute cloth discs are air dried. One day old beetles were collected from the culture and kept under starvation for two hours. The starved beetles are transferred to the petriplates containing insecticide impregnated jute cloth disc @ 20 beetles/petriplate in three replications for each test insecticide. The insects were confined to the treated surface for 24 hours, 48 hours and 72 hours. Simultaneously, a control was also maintained with jute cloth disc impregnated in acetone only.

### 2.5 Data collection
Mortality was recorded at 24, 48 and 72 hours after treatment (HAT). A preliminary experiment was conducted with a wide range of concentrations followed by a narrow range to get mortality in the range of 5-90%. There was no occasion of the use of Abbott's formula since mortality was not recorded in control, because of the use of almost same age beetles and the experiment conducted under controlled ambient conditions of $32^0$C temperature and 75 per cent relative humidity. Moreover, a separate set of new petriplates were utilized for control avoiding the use of petriplates that were used for insecticidal treatments. In order to know the immediate toxicity of the chemical, the mortalities were recorded at 24 HAT and subsequently at 48 HAT. Mortality at 72 HAT was also recorded to know the mortality end point.

### 2.6 Assessment of relative toxicity of newer insecticide molecules:
The relative toxicity of newer insecticide molecules over malathion and deltamethrin is calculated by following formula

$$\text{Relative toxicity of newer insecticide} = \frac{\text{LC 50 of malathion or deltamethrin (check)}}{\text{LC 50 of newer insecticide molecules}}$$

### 2.7 Statistical Analysis
Data was analyzed by using Probit analysis in SPSS 16.0 v. (Statistical Package for Social Sciences) software to calculate LC $_{50}$, LC $_{99.9}$, heterogeneity ($\chi 2$), intercept : (a), slope of the regression line (b), regression equation and fiducial limits. The degree of resistance acquired by *R. dominica* were calculated for the data at 72 HAT. The resistance factor was calculated by dividing the LC $_{50}$ / LC $_{99.9}$ value of each population with the LC $_{50}$ / $LC_{99.9}$ value of susceptible populations. The log concentration probit (lcp) lines were drawn by plotting log concentrations on X-axis and probits on Y-axis and the response of test insect populations was studied at different concentrations of the test insecticides [6].

## 3. Results
### 3.1 Toxicity of insecticides against the *R. dominica*
#### 3.1.1 Malathion
*R. dominica* recorded (Table 1) the $LC_{50}$ and $LC_{99.9}$ values as 0.0578 and 8.1402 per cent, respectively to malathion at 24 HAT. The corresponding values slightly decreased with increased mortality at 48 HAT (0.0387% and 6.9915%) and at 72 HAT (0.0217% and 3.4883%). The slope (b) values of log concentration probit (lcp) lines of malathion were 1.082, 1.030 and 1.054 at 24, 48 and 72 HAT, respectively.

#### 3.1.2 Deltamethrin
The data (Table 1) revealed that $LC_{50}$ and $LC_{99.9}$ values of deltamethrin with population of *R. dominica* at 24 HAT were 0.0752 and 6.3903 per cent, respectively. At 48 and 72 HAT there was a slight increase in the mortality with consequent decrease in the $LC_{50}$ (0.0533 and 0.0345%) and $LC_{99.9}$ (5.2900% and 3.4338%) values, respectively. The slope (b) values of log concentration probit (lcp) lines were 1.205, 1.165 and 1.164 at 24, 48 and 72 HAT, respectively.

#### 3.1.3 Lufenuron
The toxicity of lufenuron to the adults of *R. dominica* revealed (Table 1) the $LC_{50}$ and $LC_{99.9}$ values of 0.0826 and 8.1678; 0.0641and 7.5409; 0.0342 and 5.1004 per cent at 24, 48 and 72 HAT, respectively. The slope (b) values of log concentration probit (lcp) lines for lufenuron were 1.166, 1.123 and 1.070 at 24, 48 and 72 HAT, respectively. Lufenuron was 0.99, 0.92 and 0.68 times more toxic than malathion at 24, 48 and 72 HAT, respectively at $LC_{99.9}$ level and while at $LC_{50}$ level, it showed relatively less toxic in comparison with malathion. (Table 2). At $LC_{50}$ it showed 0.91, 0.83 and 1.00 times more toxic than deltamethrin (Table 3), whereas at $LC_{99.9}$ it showed less relative toxicity.

#### 3.1.4 Emamectin Benzoate
The toxicity of emamectin benzoate to the adults of *R. dominica* revealed (Table 1) that the $LC_{50}$ and $LC_{99.9}$ values were 0.0256 and 6.8105; 0.0164 and 3.2302 ; 0.0085 and 1.9150 per cent at 24, 48 and 72 HAT respectively. The slope (b) values of log concentration probit (lcp) lines for emamectin benzoate were 0.959, 1.013 and 0.988 at 24, 48 and 72 HAT, respectively. At $LC_{50}$ emamectin benzoate was 2.25, 2.35 and 2.55 times more toxic than malathion (Table 2), whereas same insecticide was found to be 2.93, 3.25 and 4.05 times more toxic than deltamethrin (Table 3) at 24, 48 and 72 HAT, respectively while at $LC_{99.9}$ level it showed less relative toxicity.

### 3.1.5 Chlorfenapyr

The toxicity of chlorfenapyr to the adults of *R. dominica* revealed the $LC_{50}$ and $LC_{99.9}$ values of 0.0837 and 2.5970; 0.0616 and 1.5367; 0.0555 and 0.4678 per cent at 24, 48 and 72 HAT, respectively (Table 1). The slope (b) values of lcp lines for deltamethrin were 1.559, 1.665 and 2.512 at 24, 48 and 72 HAT, respectively. The chi-square test revealed that the population used in the study was homogenous ($P$<0.05%). Chlorfenapyr was 3.13, 4.54 and 7.45 times more toxic than malathion (Table 2) and 2.46, 3.44 and 7.34 times more toxic than deltamethrin (Table 3) at 24, 48 and 72 HAT, respectively at $LC_{99.9}$. While at $LC_{50}$ level it did not show relative toxicity in comparison with malathion and deltamethrin.

### 3.1.6 Chlorantraniliprole

Chlorantraniliprole showed $LC_{50}$ and $LC_{99.9}$ values of 0.0214 and 8.8799; 0.0113 and 4.4143; 0.0081 and 3.1491 per cent at 24, 48 and 72 HAT, respectively to the adults of *R. dominica* (Table 1). The slope (b) values of lcp lines for deltamethrin were 0.888, 0.898 and 0.897 at 24, 48 and 72 HAT, respectively. The chi-square test revealed that the population used in the study was homogenous ($P$<0.05%). At $LC_{50}$ chlorfenapyr was recorded as 2.70, 3.42 and 2.67 times more toxic than malathion (Table 2) and 3.51, 4.71 and 4.25 times more toxic than deltamethrin (Table 3) at 24, 48 and 72 HAT, respectively. While at $LC_{99.9}$ level 0.91, 1.58 and 1.10 times more toxic than malathion and 0.71, 1.19 and 1.09 times more toxic than deltamethrin.

A comparison of the $LC_{50}$ and $LC_{99.9}$ values of the newer insecticides with those of malathion revealed the relative toxicity in decreasing order as chlorantraniliprole (2.67) > emamectin benzoate (2.55) > lufenuron (0.63) > chlorfenapyr (0.39) at $LC_{50}$ level and chlorfenapyr (7.45) > emamectin benzoate (1.82) > chlorantraniliprole (1.10) > lufenuron (0.68) at $LC_{99.9}$ level at 72 HAT. The $LC_{50}$ and $LC_{99.9}$ values of the newer insecticides with those of deltamethrin revealed the relative toxicity in decreasing order as chlorantraniliprole (4.25) > emamectin benzoate (4.05) > lufenuron (1.00) > chlorfenapyr (0.62) at $LC_{50}$ level and chlorfenapyr (7.34) > emamectin benzoate (1.79) > chlorantraniliprole (1.09) > lufenuron (0.67) at $LC_{99.9}$ level at 72 HAT.

## 4. Discussion

Malathion and deltamethrin has been in use as common insecticides for postharvest insect control in the United States since 1958 [7]. Its use spread to several countries in the 1960s, and its intensive use against stored grain insect pests resulted in the development of severe resistance in many insect species ([8, 9]). Malathion resistance was earlier reported in the United States populations of lesser grain borer by ([8, 10; 11]). Several studies in the past have also shown that many OP insecticides including malathion resulted in the development of resistance in many insect species including lesser grain borer ([9; 12]). Sublethal doses of malathion greatly suppressed AcP (acid phosphatase) activity in resistant beetles, which might be due to inhibition of this enzyme under insecticidal toxicity and impairing of the lysosomal activity to hydrolyze the macromolecules and in turn limiting the ability of the resistant beetles to use energy rich compounds to obtain energy.

Chlorantraniliprole was found effective at $LC_{50}$ level for complete control of *R. dominica* followed by emamectin benzoate. The present results are at par with the research findings of [13] who reported that more than 92 per cent of mortality was observed in *R. dominica* when exposed to chlorantraniliprole about 14 days. Similarly, emamectin benzoate had an adverse effect on stored grain pest *Cryptolestes ferrugineus* and with an increase in concentration the effect also increases [14]. Emamectin benzoate showed very lethal effects against salmon louse when it is applied to its different stages [15]. Chlorfenapyr was found to be 7.45 times more toxic than malathion at $LC_{99.9}$ level and 7.34 times more toxic than deltamethrin. But at $LC_{50}$ level, they did not show any relative higher toxicity *i.e*., total control of adults of *R. dominica* was not possible. [16] reported that, no adult of *Tribolium castaneum* survived when exposed on concrete treated with chlorfenapyr at the maximum rate of 1.1 g a.i.$m^{-2}$ and no progeny were produced in bioassays conducted at 0-8 weeks post treatment. Chlorfenapyr is an insecticidal pyrrole, and the primary mode of action is to affect oxidative phosphorylation in the mitochondria, which will eventually result in the death of the cell through inhibition of ATP synthesis [17]. Lufenuron showed less relative toxicity compared to other insecticides. Lufenuron @ 0.5g.$kg^{-1}$ could completely prevent the adult emergence of rice weevil, *Sitophilus oryzae* [18]. Similarly, [19] concluded that at sub-lethal concentrations ($LC_{10}$, $LC_{20}$ and $LC_{40}$) of lufenuron has a very good larvicidal and ovicidal activity in *T. castaneum.*

**Table 1:** Toxicity of newer insecticide molecules against population of lesser grain borer, *R. dominica*

| Hours after treatment | $LC_{50}$% (95%FL) | $LC_{99.9}$% (95%FL) * | Slope b (±SE) | Heterogeneity ( $\chi 2$ ) | Regression Equation (Y=a+bx) |
|---|---|---|---|---|---|
| **Lufenuron (5.4% EC)** | | | | | |
| 24 | 0.0826(0.0650-0.1071) | 8.1678(3.5284-28.5061) | 1.166 (±0.120) | 9.52 | Y= 1.62+1.25x |
| 48 | 0.0641(0.0499-0.0827) | 7.5409(3.2542-26.3169) | 1.123 (±0.115) | 11.88 | Y= 2.25+1.50x |
| 72 | 0.0342(0.0254-0.0444) | 5.1004(2.2660-17.0302) | 1.070 (±0.110) | 7.28 | Y= 2.12+1.25x |
| **Emamectin Benzoate (5% Sg)** | | | | | |
| 24 | 0.0256(0.0191-0.0351) | 6.8105(2.5486-28.4649) | 0.959 (±0.093) | 2.40 | Y= 1.5+1.00x |
| 48 | 0.0164(0.0123-0.0218) | 3.2302(1.3822-10.7993) | 1.013 (±0.093) | 5.41 | Y= 2.1+1.20 x |
| 72 | 0.0085(0.0061-0.0113) | 1.9150(0.8432-6.1848) | 0.988 (±0.093) | 2.96 | Y= 2.6+1.20x |
| **Chlorfenapyr (10% Sc)** | | | | | |
| 24 | 0.0837(0.0702-0.1018) | 2.5970(2.2531-8.5704) | 1.559 (±0.196) | 8.18 | Y= 2.08+1.66x |
| 48 | 0.0616(0.0517-0.0727) | 1.5367(0.8507-3.8658) | 1.665 (±0.190) | 11.05 | Y= 2.33+1.66x |
| 72 | 0.0555(0.0471-0.063) | 0.4678(0.3263-0.8263) | 2.512 (±0.298) | 8.51 | Y= 3.50+2.50x |
| **Chlorantraniliprole (18.5% Sc)** | | | | | |
| 24 | 0.0214(0.0155-0.0299) | 8.8799(3.2189-37.9370) | 0.888 (±0.083) | 3.58 | Y= 1.50+1.00x |
| 48 | 0.0113(0.0081-0.0156) | 4.4143(1.7693-15.9536) | 0.898 (±0.080) | 5.63 | Y= 2.00+1.00x |
| 72 | 0.0081(0.0057-0.0111) | 3.1491(1.3063-10.7863) | 0.897 (±0.080) | 8.56 | Y= 2.50+1.00x |
| **Malathion (Check)** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 24 | 0.0578(0.0432-0.0824) | 8.1402(2.8953-40.1016) | 1.082 (±0.120) | 3.72 | Y=2.33+1.67x |
| 48 | 0.0387(0.0290-0.0536) | 6.9915(2.4898-34.3798) | 1.030 ( ±0.115) | 3.19 | Y=1.39+2.11x |
| 72 | 0.0217(0.0162-0.0288) | 3.4883(1.4029-13.8462) | 1.054 (±0.113) | 2.40 | Y=3.11+1.39x |
| **Deltamethrin (Check)** | | | | | |
| 24 | 0.0752(0.0581-0.1059) | 6.3903(2.2113-38.5913) | 1.205 (±0.161) | 3.65 | Y=2.0+1.67x |
| 48 | 0.0533(0.0415-0.0713) | 5.2900(1.9117-28.8660) | 1.165 (±0.151) | 4.47 | Y=2.5+1.67x |
| 72 | 0.0345(0.0265-0.0444) | 3.4338(1.3685-15.3492) | 1.164 (±0.145) | 5.05 | Y=3.0+1.67x |

*Values in parenthesis indicates fiducial limits (FL)

The chi-square test revealed the homogeneity of the test population ($P$<0.05%).

**Table 2:** Relative toxicity of newer insecticides in comparison with malathion against resistant lesser grain borer, *R. dominica* for its management at 72 HAT

| Hours after treatment | Lufenuron (5.4% EC) | | Emamectin benzoate (5% SG) | | Chlorfenapyr (10% SC) | | Chorantraniliprole (18.5% SC) | |
|---|---|---|---|---|---|---|---|---|
| | $LC_{50}$ | $LC_{99.9}$ | $LC_{50}$ | $LC_{99.9}$ | $LC_{50}$ | $LC_{99.9}$ | $LC_{50}$ | $LC_{99.9}$ |
| 24 | 0.69 | 0.99 | 2.25 | 1.19 | 0.69 | 3.13 | 2.70 | 0.91 |
| 48 | 0.60 | 0.92 | 2.35 | 2.16 | 0.62 | 4.54 | 3.42 | 1.58 |
| 72 | 0.63 | 0.68 | 2.55 | 1.82 | 0.39 | 7.45 | 2.67 | 1.10 |

**Table 3:** Relative toxicity of newer insecticides in comparison with deltamethrin against lesser grain borer, *R. dominica* for its management at 72 HAT

| Hours after treatment | Lufenuron (5.4% EC) | | Emamectin benzoate (5% SG) | | Chlorfenapyr (10% SC) | | Chorantraniliprole (18.5% SC) | |
|---|---|---|---|---|---|---|---|---|
| | **$LC_{50}$** | **$LC_{99.9}$** | **$LC_{50}$** | **$LC_{99.9}$** | **$LC_{50}$** | **$LC_{99.9}$** | **$LC_{50}$** | **$LC_{99.9}$** |
| | | | | | | | | |
| 24 | 0.91 | 0.78 | 2.93 | 0.93 | 0.89 | 2.46 | 3.51 | 0.71 |
| 48 | 0.83 | 0.70 | 3.25 | 1.63 | 0.86 | 3.44 | 4.71 | 1.19 |
| 72 | 1.00 | 0.67 | 4.05 | 1.79 | 0.62 | 7.34 | 4.25 | 1.09 |

## 5. Conclusion

Among the new insecticides tested for the management of *R. dominica*, chlorfenapyr (10% SC) was found to be the best treatment at $LC_{99.9}$ level for complete control of *R. dominica* with the highest relative toxicity (7.45 and 7.34 times) than malathion (50% EC) and deltamethrin (2.8% EC) respectively followed by emamectin benzoate (5% SG) (1.82 and 1.79 times). Chlorantraniliprole (18.5% SC) was also found to be effective at $LC_{50}$ level (2.67; 4.25) compared to malathion and delamethrin. Lufenuron (5.4% EC) recorded to be toxic at $LC_{50}$ and $LC_{99.9}$ level (0.63 and 0.68 times) to malathion and (1.00 and 0.67 times) to deltamethrin.

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## 7. Reference

1. Amruta N, Sarika G, Umesha, Maruthi JB, Basavaraju GV. Effect of botanicals and insecticides seed treatment and containers on seed longevity of black gram under natural ageing conditions. Journal of Applied and Natural Science. 2015; 7(1):328-334.
2. Rajashekar Y, Gunasekaran N, Shivanandappa T. Insecticidal activity of the root extract of *Decalepis hamiltonii* against stored product insect pests and its application in grain protection. Journal of Food science and Technology. 2010; 47(3):310-314.
3. Hidalago E, Moore D, Patourel LE. The effect of different formulations of *Beauveria bassiana* on *Sitophilus zeamais* in stored maize. Journal of stored products research. 1998; 34:171-179.
4. Andrewartha HG. Introduction to the study of animal populations. Chapman and Hall Ltd. 1961; 261-262.
5. Najitha Ummer, Madhumathi T, Krishnayya PV. Efficacy of insecticides against *Caryedon serratus* (Olivier) on jute cloth disc Surface. Pesticide Research Journal. 2013; 25(1):63-65.
6. Finney DJ. Probit analysis. Cambridge University Press, London. 1971, 109.
7. Anonymous. Tolerances and exemptions from tolerances for pesticide chemicals in or on raw agricultural commodities. Fed. Reg. 1958; 23:6417.
8. Champ BR, Dyte CE. Report of the FAO global survey of pesticide susceptibility of stored-grain pests. *FAO Plant* Production and Protection Services No. 5. Food and Agricultural Organization of the United Nations, Rome, 1976.
9. Badmin JS. IRAC survey of resistance of stored grain pests: Results and Progress. Proceedings of the Fifth International Working Conference on Stored Product Protection. Bordeaux, France. 1990, 973-982.
10. Halliscak JP, Beeman RW. Status of malathion resistance in five genera of beetles infesting stored corn, wheat and oats in United States. Journal of Economic Entomology. 1983; 76:717-722.
11. Zettler JL, Cuperus GW. Pesticide resistance in *Tribolium castaneum* (Coleoptera:Tenebrionidae) and *Rhyzopertha dominica* (Coleoptera :Bostrichidae) in wheat. Journal of Economic Entomology. 1990; 83:1677-1681.
12. Rossiter LC, Gunning RV, Rose HA. The use of Polyacrylamide Gel Electrophoresis for the investigation and detection of fenitrothion and chlorpyrifos-methyl resistance in *Oryzaephilus surinamensis* (L.) (Coleoptera, Silvanidae). Pesticide Biochemistry and Physiology. 2001; 69:27-34.
13. Kavallieratos NG, Athanassiou CG, Boukouvala MC. Insecticidal effect of chlorantraniliprole against major stored-product insect pests in different grain commodities under laboratory tests. Pest Management Science. 2013; 69(10):3478.
14. Imran F, Mansoor-ul-Hasan, Muhammad S, Shahzad S.

Evaluating the potential of some plant extracts along with new chemistry insecticides thiamethoxam and emamectin benzoate against *Cryptolestes ferrugineus.* International Journal of Scientific and Research Publications. 2015; 5:2250-3153.

15. Lees F, Baillie M, Gettinby, Revie G. The efficacy of emamectin benzoate against infestations of *Lepeophtheirus salmonis* on Farmed Atlantic Salmon (*Salmo salar* L) in Scotland. Plos One. 2008; 3(2):1549.
16. Arthur FH. Dosage rate, temperature and food source provisioning affect susceptibility of *Tribolium castaneum* and *Tribolium confusum* to chlorfenapyr. Journal of Pesticide Science. 2013; 86:507-513.
17. McLeod P, Diaz FJ, Johnson DT. Toxicity, persistence, and efficacy of spinosad, chlorfenapyr and thiamethoxam on eggplant when applied against the eggplant flea beetle (Coleoptera: Chrysomelidae). Journal of Economic Entomology. 2002; 95:331-335
18. Visalakshi M. Management of stored grain pests of maize using safer grain protectants. Pestology. 2006; 30(3).
19. Mishra PB, Salokhe SG, Deshpande SG. Biological and biochemical effects of lufenuron (IGR) on growth, development and reproductive performance of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) (adults). Research Journal of Pharmaceutical, Biological and Chemical Sciences. 2013; 4(1):802-810.