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Status of insecticide resistance in lesser grain borer, *Rhyzopertha dominica* to Malathion and Deltamethrin in Andhra Pradesh

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Abstract
A laboratory experiment was carried out with insecticide resistance levels of malathion and deltamethrin against different populations of lesser grain borer during 2015-16. *Rhizopertha dominica* populations showed 3.07, 2.61 and 3.80 folds resistant at LC_{50} level to malathion (from Ghantasala, Maruteru and Bapatla, respectively) in comparison to laboratory susceptible population. The Jangamaheswarapuram and Nalgonda populations of *R. dominica* showed 2.10 and 1.80 folds resistant (LC_{50}) to malathion, respectively when compared to their laboratory susceptible population. The Bapatla and Maruteru populations were 1.60 and 1.07 folds resistant at LC_{50} level to deltamethrin, respectively in comparison with laboratory susceptible population at 72 hours after treatment. The Jangamaheswarapuram population recorded 1.04 (LC_{50}) folds resistant to deltamethrin in comparison to laboratory susceptible population. The Ghantasala and Nalgonda populations were recorded resistance as 0.92 folds at LC_{50} resistance was recorded as 1.01 and 1.21 folds in comparison with the laboratory susceptible population, respectively.

Keywords: *Rhyzopertha dominica*, malathion, deltamethrin, insecticide resistance

1. Introduction
In India, large quantities of food grains are stored by Food Corporation of India, Central and State Warehousing Corporations and other agencies to maintain adequate buffer and reserve stocks to supply to the needy during the periods of emergency and natural calamities. Insects infest the crops and cause damage both in the field and storage [1]. In India, approximately 10 per cent of food grains were lost during storage and half of which is due to insect pests [2]. During storage, various biotic and abiotic factors are responsible in deterioration of physical and chemical quality of the food grains and amongst the biotic factors, insect pests cause the major damage [3].

Among the several storage insect pests, the lesser grain borer, *Rhyzopertha dominica* (Fabricius) (Bostrichidae: Coleoptera), also known as Australian wheat weevil is a primary pest attacking sound grains of wheat, maize, paddy, sorghum *etc.* [4]. It was first described by Fabricius in 1972 from a shipment of seeds carried from India to South America [5]. The adults are more harmful than the grubs and they destroy more than what they eat. The grubs eat upon the kernel leaving husk behind. The weight loss in wheat by the feeding of grub and adult stages of *R. dominica* was 5 and 149 mg kg^{-1}, respectively [6]. 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 [7]. General practice of protecting stored food grains is through insecticides and continuous usage of these protectants has resulted in health hazards and increased resistance to insecticides in storage pests [8]. A better understanding of pest resistance and its effective management will go a long way in providing 'Food for All' and 'Health for All'. Keeping this in view an experiment carried out with the objective of status of insecticide resistance in lesser grain borer, *R. dominica* to Malathion and Deltamethrin in Andhra Pradesh.

2. Materials and methods
2.1 Collection of the test insect
The field population of the test insect *R. dominica* were collected from Rice Research Unit (RRU), Bapatla; ARS, Ghantasala; Food Corporation of India (FCI), Nalgonda; APRRI & RARS, Maruteru; ARS, Jangamaheswarapuram, susceptible culture from PHTC 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 [10].Stock solution of one per cent concentration of corresponding 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 wide range of concentrations followed by a narrow range to get mortality in the range of 5-90%. There was no occurrence 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 experimentation conducted under controlled ambient conditions of 32^0C temperature and 75 per cent relative humidity. In order to know the immediate toxicity of the chemical, the mortalities were recorded at 24 HAT, 48 HAT and 72 HAT.

2.6 Assessment of the Degree of Resistance

The mortalites of adult beetles of *R. dominica* collected from Rice Research Unit (RRU), Bapatla; ARS, Ghantasala; Food Corporation of India (FCI), Nalgonda; APRRI & RARS, Maruteru; ARS- Jangamaheswarapuram and PHTC (susceptible) populations against all the test insecticides were subjected to probit analysis [11].

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 (χ^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 population. 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 [11].

3. Results and discussion

3.1 Toxicity of Malathion to different populations of *R. dominica*

3.1.1 Bapatla population: The Bapatla population of *R. dominica* recorded 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 (Table 1).

3.1.2 Ghantasala population: The LC_{50} and $LC_{99.9}$ values obtained for malathion against Ghantasala population of *R. dominica* at 24 HAT were 0.0368 and 2.8233 per cent, respectively. Since there was a slight increase in the mortality of adults at 48 and 72 HAT, there was a decrease in the LC_{50} (0.0257% and 0.0175%) and $LC_{99.9}$ values (2.0532% and 1.7956%). The slope (b) of log concentration probit (lcp) lines of malathion were 1.234, 1.223 and 1.156 at 24, 48 and 72 HAT, respectively (Table 1).

3.13 Jangamaheswarapuram population: The LC_{50} and $LC_{99.9}$ values of 0.0405% and 6.4782% were obtained for malathion against Jangamaheswarapuram population of *R. domonica* at 24 HAT, (Table 1). Since there was a slight increase in the mortality of adults at 48 and 72 HAT, correspondingly decrease in the LC_{50} (0.0188% and 0.0120%) and $LC_{99.9}$ values (3.7037% and 2.3320%) were observed. The slope (b) values of log concentration probit (lcp) lines for Jangamaheswarapuram population were 1.055, 1.014 and 1.017 at 24, 48 and 72 HAT, respectively.

3.14 Maruteru population: The Maruteru population of *R. dominica* recorded (Table 1) the LC_{50} and $LC_{99.9}$ values of 0.0393 and 4.6691 per cent, respectively to malathion at 24 HAT. The corresponding values of LC_{50} and $LC_{99.9}$ obtained after 48 HAT (0.0220% and 0.0149%) and 72 HAT (3.2086% and 1.5967%) indicated that there has been a marginal increase in the mortality of insects as time lapsed. The slope (b) of log concentration probit (lcp) lines for Maruteru population were 1.121, 1.075 and 1.014 at 24, 48 and 72 HAT, respectively.

3.15 Nalgonda population: The Nalgonda population of *R. dominica* showed the LC_{50} and $LC_{99.9}$ values as 0.0260%, 6.5137% and 0.0129%, 4.1753%, respectively at 24 and 48 HAT. Since there was a slight increase in the mortality of adults 72 HAT, there was a decrease in the LC_{50} (0.0103%) and $LC_{99.9}$ values (2.2020%) (Table 1). The slope (b) values of log concentration probit (lcp) lines of malathion were 0.969, 0.926 and 0.999 at 24, 48 and 72 HAT, respectively.

3.16 Laboratory susceptible population: The LC_{50} and $LC_{99.9}$ values obtained for malathion against Laboratory susceptible population of *R. dominica* which is being maintained in the department of Entomology, Agricultural college, Bapatla at 24 HAT were 0.0172 and 2.5359 per cent respectively (Table 1). Since there was a slight increase in the mortality of adults at 48 and 72 HAT, there was a decrease in the LC_{50} (0.0116% and 0.0057%) and $LC_{99.9}$ values (1.9305% and 1.3337%). The slope (b) values of log concentration probit (lcp) lines of malathion were 1.072, 1.047 and 0.982 at 24, 48 and 72 HAT, respectively.

3.17 Degree of resistance acquired by adults of *R. dominica* to malathion at 72 HAT:

The Ghantasala , Maruteru and Bapatla populations of *R. dominica* were 3.07, 2.61 and 3.80 folds resistant at LC_{50} and 1.34, 1.19 and 2.61 folds resistant at $LC_{99.9}$ level to malathion, respectively in comparison with Laboratory susceptible population (LC_{50} = 0.0057% and $LC_{99.9}$ = 1.3337%). The Jangamaheswarpuram and Nalgonda populations of *R. dominica* showed only 2.10 and 1.80 folds

resistance at LC_{50} and 1.74 and 1.65 folds resistance at $LC_{99.9}$ to malathion respectively when compared with the LC_{50} and $LC_{99.9}$ values of Laboratory susceptible population (Table 3).

Malathion has been in use as a common insecticide for postharvest insect control in the United States since 1958 [12]. 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 ([13, 14]). Malathion resistance was earlier reported in the United States populations of lesser grain borer by ([13, 15; 16]). 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 ([14; 17]). Sub lethal 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. The acquisition of resistance to malathion in *Tribolium castaneum* was reported nearly three decades back [18]., who found 38 folds resistance to malathion at Naraina in Delhi, whereas [19] reported 13.33 and 51.28 folds resistance to malathion in Charlapalli and Sanathnagar strains, respectively and 55.27 folds in Shillong strain of *T. castaneum.*

The results are at par with [20] who reported that the adults of six populations of *R. dominica* behaved differently when exposed to malathion under laboratory conditions. These populations showed different levels of resistance to malathion. Multan (M) population was found to be the least resistant and Chichawatni population (C), the most resistant with 9.3 folds resistance than M population. In the present study, increased levels of resistance to malathion in all the populations of *R. dominica* was observed. The toxicity of most organophosphate insecticides applied as residual crack and crevice treatments to control insects in and around gowdons, mills and processing plants is positively correlated with the temperature. Malathion being one of the oldest insecticide that has been registered nearly for more than five decades, its low cost, moderate toxicity to mammals and optimal residual activity in storage godowns are reasons of support for continuous and wide use in the control of the stored product insects and thus resulted in the widespread and increased level of resistance to *R. dominica* in the present study.

3.2 Toxicity of Deltamethrin to different populations of *R. dominica*

3.2.1 Bapatla population: The data revealed that LC_{50} and $LC_{99.9}$ values of deltamethrin with Bapatla 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 (Table 2).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.

3.2.2 Ghantasala population: The LC_{50} and $LC_{99.9}$ values of deltamethrin at 24 HAT were 0.0505 and 3.6782 per cent, respectively for the Ghantasala population of *R. dominica* (Table.2). Since there was a slight increase in the mortality of adults at 48 and 72 HAT, there was a decrease in the LC_{50} (0.0312% and 0.0199%) and at $LC_{99.9}$ (1.4924% and 0.9063%), respectively. The slope (b) values of log concentration probit (lcp) lines were 1.249, 1.384 and 1.403 at 24, 48 and 72 HAT, respectively.

3.2.3 Nalgonda and Jangamaheswarapuram populations: The LC_{50} and $LC_{99.9}$ values at 24 HAT were recorded as 0.0689; 0.0711 and 4.3046; 6.9311 per cent for deltamethrin against Nalgonda and Jangamaheswarapuram populations of *R. dominica* respectively (Table 2). There was a slight decrease in the LC_{50} (0.0317%; 0.0352% and 0.0207%; 0.0224% at 48 and 72 HAT respectively) and $LC_{99.9}$ (2.4235%; 2.4556% and 1.0901%; 0.9904% at 48 and 72 HAT, respectively) values due to increase in mortality of adults at 48 and 72 HAT. The slope (b) values of log concentration probit (lcp) lines of deltamethrin against Nalgonda population were recorded 1.295, 1.235 and 1.351 at 24, 48 and 72 HAT and for the Jangamaheswarapuram population it was recorded as 1.169, 1.262 and 1.412, respectively at 24, 48 and 72 HAT.

3.2.4 Maruteru population: The Maruteru population of *R. dominica* has recorded the LC_{50} and $LC_{99.9}$ values of 0.0471 and 4.8268 per cent, respectively for deltamethrin at 24 HAT (Table 4.2). The corresponding LC_{50} (0.0303% and 0.0231%) and $LC_{99.9}$ (2.3999% and 1.9639%) values at 48 and 72 HAT were decreased due to slight increase in mortality. The slope (b) values of log concentration probit (lcp) lines were 1.156, 1.225 and 1.205 at 24, 48 and 72 HAT, respectively. The chi-square test revealed the homogeneity of the test population (P<0.05%).

3.2.5 Laboratory susceptible population: The LC_{50} and $LC_{99.9}$ values obtained for deltamethrin against laboratory susceptible population of *R. dominica* at 24 HAT were 0.0576 and 3.0305 per cent respectively (Table 2). Since there was a slight increase in the mortality of adults at 48 and 72 HAT, there was a decrease in the LC_{50} (0.0294% and 0.0215%) and $LC_{99.9}$ values (1.0142% and 0.8965%). The slope (b) values of log concentration probit (lcp) lines of deltamethrin were 1.351 at 24 HAT and 1.513 at 48 and 1.435 at 72 HAT, respectively.

3.2.6 Degree of resistance acquired by adults of *R. dominica* to deltamethrin at 72 HAT

The Bapatla and Maruteru populations showed 1.60 and 1.07 folds resistance at LC_{50} and 3.83 and 2.19 folds resistance at $LC_{99.9}$ level to deltamethrin respectively in comparison with Laboratory susceptible population (LC_{50} = 0.0215% and $LC_{99.9}$ = 0.8965%) at 72 HAT. The Jangamaheswarapuram population is 1.04 folds resistant at LC_{50} and 1.10 folds resistant at $LC_{99.9}$ level to deltamethrin respectively in comparison with Laboratory susceptible population. The Ghantasala and Nalgonda populations recorded resistance as 0.92 and 0.96 folds at LC_{50} and at $LC_{99.9}$ the resistance was recorded as 1.01 and 1.21 folds in comparison with the laboratory susceptible population (Table 3).

Development of resistance to deltamethrin in *R. dominica* was earlier reported by [20] from Pakistan, wherein, the adults of six populations of the pest *viz*., Chichawatni (C), Karachi (K), Wazirabad (W), Sialkot (S), Lahore (L), and Multan (M) were treated with an organophosphate insecticides malathion, and a synthetic pyrethroid, deltamethrin (Decis). C population was found to be most resistant to malathion (LC_{50}, 115.50 ppm), whereas M population was least resistant (LC_{50} 12.40 ppm). On the other hand, M population was most resistant to deltamethrin (LC_{50} 10.55 ppm), whereas L population was most susceptible (LC_{50} 2.83 ppm).

The present results were on par with those of [21] who reported that a population of *T. granarium* has developed resistance which is ranged from 1.55 to 3.65 folds in six successive generations at 80 percent selection pressure. In the present research study, Bapatla and Maruteru populations showed 3.83 and 2.19 folds of resistance to deltamethrin and remaining populations Nalgonda, Jangamaheswarapuram and Ghantasala showed 1.21, 1.10 and 1.01 folds of resistance to deltamethrin when compared with the laboratory cultured susceptible population.

Table 1: Relative toxicity of malathion to different populations of lesser grain borer, *Rhyzopertha dominica* from different regions of Andhra Pradesh

Sl. No.	Hours after treatment	LC_{50}% (95%FL)	$LC_{99.9}$% (95%FL)	Slope b (±SE)	Heterogeneity ($\chi 2$)	Regression Equation (Y=a+bx)
BAPATLA						
1	24	0.0578(0.0432-0.0824)	8.1402(2.8953-40.1016)	1.082 (±0.120)	3.72	Y=2.33+1.67x
2	48	0.0387(0.0290-0.0536)	6.9915(2.4898-34.3798)	1.030 (±0.115)	3.19	Y=1.39+2.11x
3	72	0.0217(0.0162-0.0288)	3.4883(1.4029-13.8462)	1.054 (±0.113)	2.40	Y=3.11+1.39x
GHANTASALA						
1	24	0.0368(0.0287-0.0481)	2.8233(1.2959-8.7797)	1.234 (±0.121)	4.80	Y=2.33+1.66x
2	48	0.0257(0.0200-0.0332)	2.0532(0.9779-6.0023)	1.223 (±0.118)	3.34	Y=2.83+1.66x
3	72	0.0175(0.0132-0.0227)	1.7956(0.8347-5.5205)	1.156 (±0.116)	2.37	Y=2.61+1.39x
JANGAMAMAHESWARAPURAM						
1	24	0.0405(0.0305-0.0559)	6.4782(2.3751-30.1434)	1.055 (±0.116)	2.30	Y=2.11+1.39x
2	48	0.0188(0.0138-0.0252)	3.7037(1.4309-15.9310)	1.014 (±0.112)	1.48	Y=1.89+1.11x
3	72	0.0120(0.0085-0.0162)	2.3320(0.9504-9.2562)	1.017 (±0.113)	2.88	Y=2.61+1.39x
MARUTERU						
1	24	0.0393(0.0300-0.0530)	4.6691(1.8785-18.3171)	1.121 (±0.118)	1.69	Y=2.33+1.67x
2	48	0.0220(0.0165-0.0291)	3.2086(1.3243-12.1366)	1.075 (±0.114)	2.88	Y=2.11+1.39x
3	72	0.0149(0.0112-0.0194)	1.5976(0.7456-4.9007)	1.014 (±0.116)	1.91	Y=2.61+1.39x
NALGONDA						
1	24	0.0260(0.0191-0.0357)	6.5137(2.2390-34.6332)	0.969 (±0.111)	1.29	Y=1.89+1.11x
2	48	0.0129(0.0089-0.0178)	4.1753(1.4593-22.2584)	0.926 (±0.111)	2.01	Y=1.89+1.11x
3	72	0.0103(0.0017-0.0141)	2.2020(0.8871-9.0129)	0.999 (±0.114)	2.57	Y=2.61+1.39x
SUSCEPTIBLE POPULATION						
1	24	0.0172(0.0128-0.0227)	2.5359(1.0736-9.2291)	1.072 (±0.114)	2.35	Y=2.61+1..39x
2	48	0.0116(0.0083-0.0155)	1.9305(0.8225-7.0633)	1.047 (±0.114)	1.91	Y=2.61+1.39x
3	72	0.0057(0.0035-0.0082)	1.3337(0.5499-5.4417)	0.982 (±0.118)	2.44	Y=2.61+1.39x

Lethal concentrations and 95% fiducial limits (FL) were estimated using probit analysis (SPSS 16.0).
The Chi-square test revealed the homogeneity of the test population (P<0.05%).

Table 2: Relative toxicity of deltamethrin to different populations of lesser grain borer, Rhyzopertha dominica from different regions of Andhra Pradesh

Sl. No.	Hours after treatment	LC_{50}% (95%FL)	$LC_{99.9}$% (95% FL)	Slope b (±SE)	Heterogeneity ($\chi 2$)	Regression Equation (Y=a+bx)
BAPATLA						
1	24	0.0752(0.0581-0.1059)	6.3903(2.2113-38.5913)	1.205 (±0.161)	3.65	Y=2.0+1.67x
2	48	0.0533(0.0415-0.0713)	5.2900(1.9117-28.8660)	1.165 (±0.151)	4.47	Y=2.5+1.67x
3	72	0.0345(0.0265-0.0444)	3.4338(1.3685-15.3492)	1.164 (±0.145)	5.05	Y=3.0+1.67x
GHANTASALA						
1	24	0.0505(0.0399-0.0657)	3.6782(1.4905-15.8754)	1.249 (±0.153)	4.23	Y=2.5+1.67x
2	48	0.0312(0.0248-0.0387)	1.4924(0.7564-4.1881)	1.384 (±0.150)	0.51	Y=2.5+1.67x
3	72	0.0199(0.0153-0.0249)	0.9063(0.4958-2.2261)	1.403 (±0.147)	7.87	Y=3.0+1.67x
JANGAMAMAHESWARAPURAM						
1	24	0.0711(0.0547-0.1000)	6.9311(2.3290-44.4015)	1.169 (±0.157)	5.53	Y=1.7+1.33x
2	48	0.0352(0.0276-0.0446)	2.4556(1.0905-8.8414)	1.262 (±0.148)	4.81	Y=2.5+1.67x
3	72	0.0224(0.0174-0.0279)	0.9904(0.5369-2.4701)	1.412 (±0.148)	7.46	Y=3.8+2.00x
MARUTERU						
1	24	0.0471(0.0366-0.0622)	4.8268(1.7792-25.2601)	1.156(±0.149)	6.93	Y=2.5+1.67x
2	48	0.0303(0.0234-0.0385)	2.3999(1.0541-8.8462)	1.225 (±0.145)	5.92	Y=2.2+1.33x
3	72	0.0231(0.0173-0.0296)	1.9639(0.8839-6.9508)	1.205 (±0.143)	7.19	Y=3.0+1.67x
NALGONDA						
1	24	0.0689(0.0543-0.0928)	4.3046(1.6878-20.0562)	1.295 (±0.164)	4.32	Y=1.7+1.33x
2	48	0.0317(0.0246-0.0402)	2.4235(1.0671-8.8830)	1.235 (±0.146)	4.49	Y=2.2+1.33x
3	72	0.0207(0.0158-0.0260)	1.0901(0.5711-2.8948)	1.351 (±0.146)	8.58	Y=3.8+2.00x
SUSCEPTIBLE POPULATION						
1	24	0.0576(0.0461-0.0744)	3.0305(1.3149-11.4872)	1.351 (±0.161)	6.36	Y=2.5+1.67x
2	48	0.0294(0.0237-0.0359)	1.0142(0.5667-2.3903)	1.513 (±0.153)	3.94	Y=3.3+2.00x
3	72	0.0215(0.0167-0.0267)	0.8965(0.4970-2.1473)	1.435 (±0.148)	5.41	Y=2.2+1.33x

Lethal concentrations and 95% fiducial limits (FL) were estimated using probit analysis (SPSS 16.0).
The Chi-square test revealed the homogeneity of the test population (P<0.05%).

Table 3: Degree of resistance acquired by the adults of *Rhyzopertha dominica* to malathion and deltamethrin

Name of the population	LC_{50} (%)	$LC_{99.9}$ (%)	Resistance Factor	
			In comparison with Laboratory Susceptible population	
			LC_{50}	$LC_{99.9}$
Malathion (50% EC)				
Bapatla	0.0217	3.4883	3.80	2.61
Ghantasala	0.0175	1.7956	3.07	1.34
Jangamameheswarapuram	0.0120	2.3320	2.10	1.74
Maruteru	0.0149	1.5976	2.61	1.19
Nalgonda	0.0103	2.2020	1.80	1.65
Susceptible population	0.0057	1.3337	-	-
Deltamethrin (2.8% EC)				
Bapatla	0.0345	3.4338	1.60	3.83
Ghantasala	0.0199	0.9063	0.92	1.01
Jangamameheswarapuram	0.0224	0.9940	1.04	1.10
Maruteru	0.0231	1.9639	1.07	2.19
Nalgonda	0.0207	1.0901	0.96	1.21
Susceptible population	0.0215	0.8965	-	-

4. Conclusion

The results showed the Ghantasala, Maruteru, Nalgonda, Jangamaheswarapuram and Bapatla populations of *R. dominica* have exhibited 3.07, 2.61, 1.80, 2.10 and 3.80 folds resistance to malathion (50% EC) at LC_{50} when compared to the laboratory susceptible population. At LC_{50}, Ghantasala, Maruteru, Nalgonda, Jangamaheswarapuram and Bapatla populations of *R. dominica*, revealed one fold resistance to deltamethrin (2.8% EC) and ranged from one to two folds, respectively when compared with laboratory susceptible population. It can be concluded from this study that populations of *R. dominica* have developed resistance against malathion and deltamethrin and these cannot be controlled by this insecticides. Higher doses or other pesticides are required to control resistant population. Secondly, development of resistance and the susceptibility in insects is a biochemical phenomenon which is evident from number of macromolecular derangements in resistant and susceptible populations of *R. dominica.* Future direction of the study to demonstrates the importance of research on insecticide resistance and the constant need to develop new tools, new insecticides, and innovative strategies to prevent the development of insecticide resistance.

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