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Influence of certain insecticides on the resurgence of rice brown planthopper, *Nilaparvata lugens* (Stal)

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Abstract
Influence of certain insecticides *viz*., chlorpyriphos, profenophos, cypermethrin, deltamethrin, bifenthrin, lambda cyhalothrin and imidacloprid on growth and reproductive physiology of rice brown planthopper, *Nilaparvata lugens* (Stal) was investigated. Bifenthrin, cypermethrin, lambda cyhalothrin and deltamethrin resulted in enhancement of fecundity of brown planthopper (227.67, 218.33, 199.00 and 191.00 nymphs vs 131.00 nymphs in control) and consequently resurgence ratio ranged from 1.18 to 1.74. Application of chlorpyriphos, profenophos and imidacloprid on rice plants did not influence the reproductive rate of brown planthopper. Chlorpyriphos, cypermethrin, deltamethrin, bifenthrin and lambda cyhalothrin significantly increased the nymphal survival (86.67 per cent to 96.00 per cent against 80.67 per cent in control) and growth index (6.34 to 7.11 vs 5.63 in control). Cypermethrin, deltamethrin, bifenthrin and lambda cyhalothrin resulted in a sex ratio in favour of more number of females.

Keywords: Brown planthopper, resurgence, reproductive rate, fecundity, nymphal survival, nymphal duration, growth index and sex ratio

1. Introduction
Among the insect pests infesting rice, brown planthopper (BPH), *Nilaparvata lugens* (Stal) (Hemiptera: Delphacidae) is a typical resurgent pest that threatening the rice production during post green revolution period. It is considered as the major yield limiting factor in all rice growing countries both in tropics and temperate regions (Krishnaiah, 2014) [1]. The BPH has become a major insect pest of rice in almost all rice growing tracts of India (Krishnaiah and Jhansilakshmi, 2012) [2]. The high population density of brown planthopper may result upto 60 per cent yield loss (Panda and Khush, 1995) [3]. Both nymphs and adults of the brown planthopper suck plant sap from phloem cells resulting in "hopper burn" symptoms and it can cover large circular patches in the rice fields under heavy pest pressure. In addition to direct damage, it is a vector for Rice Grassy Stunt Virus and Rice Ragged Stunt Virus.

Farmers rely solely on insecticides for management of brown planthopper but their repeated applications often result in problems such as induction of resurgence, development of resistance and residues on farm produce besides environmental concern.

Detailed investigations have been made on insecticide induced resurgence of brown planthopper in rice (Chelliah and Heinrichs, 1980; Heinrichs *et al*., 1982; Heinrichs *et al*., 1982; Krishnaiah and Kalode, 1987) [4-7] and reported that the suppression of natural enemies following intensive broad spectrum insecticidal application; the increased feeding rate of BPH at sub-lethal doses of some resurgence inducing insecticides; stimulation of growth and reproduction by the pest following insecticidal application; changes in the nutrient contents of the plant following insecticidal application are important factors contributing to resurgence in BPH.

To enhance field life of an insecticide, the knowledge relating to risks associated with the insecticides such as resurgence or resistance is of paramount importance. Having recognized the significance of the use of insecticides in rice-ecosystem, the present study was undertaken to assess the influence of some insecticides being used for management of rice insect pests on growth and reproduction of brown planthopper infesting rice.

2. Materials and Methods
Experiments were conducted in poly house of the Department of Entomology, Regional Agricultural Research Station, Maruteru, West Godavari District of Andhra Pradesh during 2017.

2.1 Test insect and insecticides
Brown planthopper (BPH), *Nilaparvata lugens* (Stal) was reared on the one month old potted plants of the susceptible rice variety, Taichung Native-1 (TN1) to obtain large number of nymphs and adults of brown planthopper of uniform size and age required for different experiments. Planthopper susceptible rice variety, Swarna (MTU7029) was used as test variety in the experimentation. The following insecticides (Table1) were used as foliar sprays to study their impact on growth and reproductive physiology of BPH.

Emulsions of these insecticides were prepared from the commercial formulations by adding required quantities of water. The test insecticides were used at two dosages (half of the field recommended concentration and recommended field concentration) and replicated thrice. A pot with two rice plants represented one replication and there were three replications per insecticide treatment. Insecticides were applied thrice at 10 days interval to the potted plants starting from 20 days after planting. The plants were sprayed with water alone in control. Insecticide treated potted plants were covered with cylindrical mylar film cages of 75 cm tall and 15 cm diameter and were maintained in a poly house (Heinrichs *et al*., 1981) [8].

2.2 Influence of insecticides on reproductive rate (fecundity) of BPH
At fifteen days after third spray of insecticides, two pairs of the adult BPH were released per pot, confined therein for seven days for oviposition and later the insects were removed (Plate 1).to assess the impact of insecticides on reproductive rate (fecundity) of BPH, The nymphs that hatched in each pot were counted daily and removed with aspirator. This process was continued until hatching terminated. The cumulative numbers of the nymphs that emerged on plants treated with insecticides serves as an indirect measure of fecundity of the brown planthopper.

The resurgence of brown planthopper following three applications of each test insecticide was assessed from the comparison of reproductive rates on the treated and control plants as per the formula given by Heinrichs *et al.*, 1981 [8, 18].

$$\text{Resurgence ratio} = \frac{\text{Number of nymphs on treated plants}}{\text{Number of nymphs on control plants}}$$

2.3 Influence of insecticides on the biological parameters of brown planthopper
At fifteen days after third spray, twenty five freshly hatched nymphs were released on rice plants enclosed in cylindrical mylar film cages to study the effect of test insecticides on biological parameters i.e. nymphal duration, survival, growth index and sex ratio of BPH (Plate 2).

2.4 Nymphal duration
The duration (days) of the nymphal stage of brown planthopper was estimated from the date of release of freshly hatched nymph to the date of adult emergence.

2.5 Nymphal survival (%)
Nymphal survival represents the number of nymphs that survived and developed into adults and it was calculated using the formula given below.

$$\text{Nymphal survival (\%)} = \frac{\text{Number of nymphs becoming adults}}{\text{Number of nymphs released}} \times 100$$

2.6 Growth index
Growth index is an indicator of suitability of a cultivar for growth and development of an insect and it was estimated by the formula given by Saxena *et al*. (1974) [9].

$$\text{Growth index} = \frac{\text{Per cent nymphs becoming adults}}{\text{Mean growth period (days)}}$$

2.7 Sex ratio (female: male)
Female: male ratio was assessed from the adults that emerged in the above experiment.

2.8 Statistical analysis
Data recorded on different biological parameters were suitably transformed (arc-sine and square root transformations) before analysis. Transformed data were analyzed using analysis of variance technique given by Gomez and Gomez (1984) [10] in completely randomized design (CRD). Means were compared by Duncan's Multiple Range Test (DMRT) (Duncan, 1955) [11].

3. Results and Discussion
3.1 Reproductive rate (Fecundity) of BPH
Data presented in Table 2 revealed that insecticides significantly influenced reproductive rate of *N. lugens* adults when they were allowed to feed and oviposit on the treated plants. The highest reproductive rate of BPH was observed on bifenthrin (0.50 ml l^{-1}) and cypermethrin (0.50 ml l^{-1}) treated plants with 227.67 and 218.33 nymphs emergence per two pairs of adult hoppers, respectively, which were on par with each other (Table 2). Lambda cyhalothrin (1.0 ml l^{-1}) and cypermethrin (1.0 ml l^{-1}) treated plants also had higher progeny production and stood next with a mean progeny production of 199.00 and 191.00, respectively. It was followed by deltamethrin (1.00 ml l^{-1}), lambda cyhalothrin @ 0.50 ml l^{-1}, bifenthrin @ 1.0 ml l^{-1} and deltamethrin @ 1.00 ml l^{-1} with mean reproductive rates of 177.67, 160.33, 154.67 and 153.67, respectively. All these insecticidal treatments recorded significantly higher rates of BPH reproduction over control (131.00).

Chlorpyriphos, imidacloprid (at both doses) and profenophos (2.00 ml l^{-1}) applications on the rice plants did not interfere the reproduction of the brown planthopper rather recorded lower multiplication over the control. It was evident from the data that among the treatments, reproductive stimulation was observed in the insecticides belonged to synthetic pyrethroid group.

Resurgence ratio of BPH feeding on bifenthrin @ 0.50 ml l^{-1}, cypermethrin @ 0.50 ml l^{-1}, lambda cyhalothrin @ 1.00 ml l^{-1}, cypermethrin @ 1.00 ml l^{-1}, deltamethrin @ 1.00 ml l^{-1}, lambda cyhalothrin @ 0.50 ml l^{-1}, bifenthrin @ 1.00 ml l^{-1}, deltamethrin @ 0.50 ml l^{-1} and profenophos @1.00 ml l^{-1} treated plants was 1.74, 1.67, 1.52, 1.46, 1.36, 1.22, 1.18, 1.17 and 1.08, respectively indicating the risk associated with use of these insecticides leading to failure in field control of the hopper. Other test insecticides recorded a resurgence ratio of less than one.

Stimulatory influence of insecticides on reproduction of planthoppers and several other sucking pests of crops is a common phenomenon known as harmoligosis. The present findings of higher reproductive rate of *N. lugens* on rice plants treated with cypermethrin, deltamethrin, bifenthrin and lambda cyhalothrin is endorsed by observations of several workers, who reported reproductive stimulation as an important factor for causing resurgence in populations of BPH and WBPH Heinrichs *et al.* (1982a) [5, 19]; Salim and Heinrichs (1987) [12]; Zhu *et al*. (2004) [13]; Suri and Singh (2011) [14]; Zhang *et al*. (2014) [15]; Suri *et al.* (2015) [16]. This increase in fecundity might be attributed to stimulation of hopper reproduction by the insecticide residues or their metabolites, chemical changes in the host plant receiving insecticides, or a combination of these two factors.

All insecticides do not have stimulatory influences, even if applied at sublethal doses. The results of the present investigation revealed that chlorpyriphos, imidacloprid and profenophos did not influence the reproduction of *N. lugens.* This indicates that all the insecticides applied even at sub-lethal doses may not show stimulatory influence on the insect reproduction. The present findings are in agreement with observations of Suri and Singh (2011) [14, 20], who reported that chlorpyriphos, endosulfan and imidacloprid (0.0018%) applications on the rice plants did not affect the reproduction of WBPH

3.2 Nymphal duration

Nymphal duration was not significantly influenced when freshly hatched nymphs of *N. lugens* were allowed to feed and develop on insecticide-treated rice plants (Table 3). Nymphal duration ranged from 13.33 to 14.33 days showing statistical parity among the values. However, hoppers completed their nymphal stage 0.66 to 1.00 day earlier on insecticide treated plants than on untreated plants.

Inference of the present study that the test insecticides applied to rice plants did not affect the nymphal duration of *N. lugens*. This observation was endorsed by findings of Salim and Heinrichs (1987) [12, 21], who reported that deltamethrin, monocrotophos and diazinon applications to susceptible and resistant rice cultivars did not affect the nymphal duration of WBPH. Suri *et al.* (2015) [16, 22] also observed that there was no significant difference in the nymphal duration of *N. lugens* on rice plants treated with chlorpyriphos, quinalphos, methyl parathion, imidacloprid, deltamethrin, chlorantraniliprole and buprofezin.

3.3 Nymphal survival (%)

Data presented in Table 3 revealed that mean survival of BPH nymphs on both tested doses of chlorpyriphos (90.67% and 86.67%), cypermethrin (86.67% and 94.67%), deltamethrin (92.00% and 93.33%), bifenthrin (96.00% and 93.33%) and lambda cyhalothrin (89.33% and 89.33%) treated plants was significantly greater than that of the control (80.67%). Survival of the nymphs reared on the rice plants exposed to profenophos (82.67% and 81.33%) and imidacloprid (84.00% and 82.67%) insecticides showed statistical parity with that of nymphs in control (80.67%).

Salim and Heinrichs (1987) [12, 21, 23] observed significantly increased survival of *Sogatella furcifera* from 88 to 95 per cent on deltamethrin treated plants of the susceptible variety, TN1. Suri and Singh (2011) [14, 20, 24] have reported the significant increase in the nymphal survival of *S. furcifera* on methyl parathion and deltamethrin treated rice plants. Suri *et al.* (2015) [16, 22, 25] reported that deltamethrin significantly increased the nymphal survival (91.10% against 81.11% in the control) of the brown planthoppers. The observations of earlier workers support the present findings of increased survival of BPH on chlorpyriphos, cypermethrin, deltamethrin, bifenthrin and lambda cyhalothrin treated plants.

3.4 Growth-index

Growth index is an indicator of suitability of a cultivar for growth and development of an insect. The higher the growth index, the more suitable is the cultivar for growth and development of an insect.

Data on growth index of *N. lugens* from the Table 3 revealed that insecticide applied to rice plants significantly influenced growth indices of the hoppers feeding on them. The mean values of growth indices in different insecticides tested is as follows, 6.81 and 6.34 for chlorpyriphos, 6.35 and 7.11 for cypermethrin, 6.91 and 7.01 for deltamethrin, 7.03 and 7.01 for bifenthrin, 6.71 and 6.54 for lambda cyhalothrin at their half and field recommended doses and 6.31 for imidacloprid @ 0.125 ml l^{-1} treated plants was significantly higher while that of profenophos (6.21 and 5.96) and imidacloprid @ 0.25 ml l^{-1} (field recommended dose) (6.06) are on par with corresponding value in the control (5.63).

Chlorpyriphos, cypermethrin, deltamethrin, bifenthrin, lambda cyhalothrin influenced the growth index of BPH at two treatment doses. Imidacloprid (0.125 ml l^{-1}) influenced the growth index of brown planthopper at half of the recommended dose only. Both the doses of profenophos and imidacloprid @ 0.25 ml l^{-1} did not influence the growth index of the brown planthopper. The lower value of growth index in case of profenophos and imidacloprid was attributed to a decrease in nymphal survival and increase in duration of the nymphal stage.

The present findings are endorsed by observations of Salim and Heinrichs (1987) [12, 21, 23, 26], who reported a significant increase in the growth index of the white backed planthopper (WBPH) following the foliar application of deltamethrin on a susceptible rice variety, TN1. Suri and Singh (2011) [14, 20, 24, 27] reported that methyl parathion and deltamethrin significantly increases the growth index of WBPH. Suri *et al.* (2015) [16, 22, 25, 28] also stated that deltamethrin significantly increased the growth index (5.17 vs 4.58 in the control) of the brown planthopper.

3.5 Sex ratio

Data presented in Table 3 revealed that the sex ratio of BPH adults emerging from nymphs confined on insecticide treated plants ranging from 1.07 to 1.84 and differ significantly when compared to control. Cypermethrin (1.00 ml l^{-1}), bifenthrin (1.00 ml l^{-1}), deltamethrin (0.50 ml l^{-1}), cypermethrin (0.50 ml l^{-1}) and lambda cyhalothrin (1.00 ml l^{-1}) applications significantly influenced the sex ratio of emerging adults with a sex ratio of 1.84, 1.80, 1.76, 1.71 and 1.48, respectively which were on par with each other and significantly greater than the untreated control (1.07). While, the plants treated with other insecticides *viz*., deltamethrin @ 1.00 ml l^{-1}(1.41), chlorpyriphos @ 0.80 and 1.60 ml l^{-1} (1.43 and 1.32), lambda cyhalothrin @ 0.50 ml l^{-1} (1.39), bifenthrin @ 0.50 ml l^{-1} (1.40), profenophos @ 1.00 and 2.00 ml l^{-1} (1.38 and 1.35) and imidacloprid @ 0.125 and 0.25 ml l^{-1} (1.25 and 1.30) recorded the sex ratio on par with each other and also on par with untreated control (1.07).

Among different insecticides, more number of female was emerged from the nymphs fed on cypermethrin, deltamethrin, bifenthrin and lambda cyhalothrin treated plants. The present findings are in agreement with the observations of Raman and Uthamasamy (1983) [17], who reported a sex ratio in favour of females, when *N. lugens* were reared on plants treated with deltamethrin, methyl parathion, quinalphos, cypermethrin, permethrin and fenvalerate. Suri and Singh (2011) [14, 20, 24, 27, 29] also reported that the sex ratio of adults of WBPH emerging on methyl parathion and deltamethrin-treated rice plants increased in favour of females.

Table 1: Insecticides used to study induction of resurgence in rice brown planthopper

Treatment No.	Treatment	Formulation Dose (ml l^{-1})
T_1	Chlorpyrifos 50 EC	0.80 ml*
T_2	Chlorpyrifos 50 EC	1.60 ml#
T_3	Profenophos 50 EC	1.00 ml*
T_4	Profenophos 50 EC	2.00 ml#
T_5	Cypermethrin 10EC	0.50 ml*
T_6	Cypermethrin 10EC	1.00 ml#
T_7	Deltamethrin 2.8 EC	0.50 ml*
T_8	Deltamethrin 2.8 EC	1.00 ml#
T_9	Bifenthrin 10 EC	0.50 ml*
T_{10}	Bifenthrin 10 EC	1.00 ml#
T_{11}	Lambda Cyhalothrin 2.5 EC	0.50 ml*
T_{12}	Lambda Cyhalothrin 2.5 EC	1.00 ml#
T_{13}	Imidacloprid 17.8 SL	0.125 ml*
T_{14}	Imidacloprid 17.8 SL	0.25 ml#
T_{15}	Untreated Control	Water Spray

*Half of the field recommended dose; # Field recommended dose

Table 2: Effect of insecticides on the reproductive rate of *Nilaparvata lugens* feeding on rice variety, Swarna (MTU 7029)

T. No.	Treatment	Dose (ml l^{-1})	Reproductive rate (No. of nymphs emerged)**	Resurgence Ratio #
T_1	Chlorpyrifos 50 EC	0.80 ml	111.33* (10.55)^{a}	0.85
T_2	Chlorpyrifos 50 EC	1.60 ml	118.67 (10.89)^{ab}	0.91
T_3	Profenophos 50 EC	1.00 ml	141.33 (11.86)^{cd}	1.08
T_4	Profenophos 50 EC	2.00 ml	123.33 (11.10)^{ab}	0.94
T_5	Cypermethrin 10EC	0.50 ml	218.33 (14.77)^{h}	1.67
T_6	Cypermethrin 10 EC	1.00 ml	191.00 (13.82)^{fg}	1.46
T_7	Deltamethrin 2.8 EC	0.50 ml	153.67 (12.40)^{de}	1.17
T_8	Deltamethrin 2.8 EC	1.00 ml	177.67 (13.33)^{f}	1.36
T_9	Bifenthrin 10 EC	0.50 ml	227.67 (15.02)^{h}	1.74
T_{10}	Bifenthrin 10 EC	1.00 ml	154.67 (12.44)^{de}	1.18
T_{11}	Lambda Cyhalothrin 2.5 EC	0.50 ml	160.33 (12.66)^{e}	1.22
T_{12}	Lambda Cyhalothrin 2.5 EC	1.00 ml	199.00 (14.10)^{g}	1.52
T_{13}	Imidacloprid 17.8 SL	0.125 ml	119.33 (10.92)^{ab}	0.91
T_{14}	Imidacloprid 17.8 SL	0.25 ml	118.33 (10.88)^{ab}	0.90
T_{15}	Untreated Control	Water Spray	131.00 (11.44)^{bc}	-

*Mean of three replication; ** from eggs laid by 2 females in 7 days figures in parentheses are square root transformed values.

$$\# \text{ Resurgence ratio} = \frac{\text{Mean number of } N.lugens \text{ nymphs in the treatment}}{\text{Mean number of } N.lugens \text{ nymphs in the control}}$$

In a column, means followed by a common letter are not significantly different at 1per cent level by DMRT.

Table 3: Effect of insecticides on nymphal duration, survival, growth index and sex ratio of *Nilaparvata lugens* feeding on rice variety, Swarna (MTU 7029)

T. No.	Treatment	Dose (ml l^{-1})	Nymphal Duration* (Days)	Nymphal Survival* (%)	Growth Index* (%)	Sex ratio* (F/M)
T_1	Chlorpyrifos 50 EC	0.80 ml	13.33^{a}	90.67 (72.33)^{cd}	6.81^{cde}	1.43 @ (1.56)^{abcde}
T_2	Chlorpyrifos 50 EC	1.60 ml	13.67^{a}	86.67 (68.66)^{bc}	6.34^{bcd}	1.32 (1.52)^{abc}
T_3	Profenophos 50 EC	1.00 ml	13.33^{a}	82.67 (65.46)^{ab}	6.21^{abc}	1.38 (1.55)^{abcd}
T_4	Profenophos 50 EC	2.00 ml	13.67^{a}	81.33 (64.46)^{ab}	5.96^{ab}	1.35 (1.53)^{abc}
T_5	Cypermethrin 10EC	0.50 ml	13.67^{a}	86.67 (68.66)^{bc}	6.35^{bcd}	1.71 (1.65)^{cdef}
T_6	Cypermethrin 10EC	1.00 ml	13.33^{a}	94.67 (76.87)^{ef}	7.11^{e}	1.84 (1.69)^{f}
T_7	Deltamethrin 2.8 EC	0.50 ml	13.33^{a}	92.00 (73.96)^{de}	6.91^{de}	1.76 (1.66)^{def}
T_8	Deltamethrin 2.8 EC	1.00 ml	13.33^{a}	93.33 (75.24)^{def}	7.01^{e}	1.41 (1.56)^{abcde}
T_9	Bifenthrin 10 EC	0.50 ml	13.67^{a}	96.00 (78.50)^{f}	7.03^{e}	1.40 (1.55)^{abcd}
T_{10}	Bifenthrin 10 EC	1.00 ml	13.33^{a}	93.33 (75.24)^{def}	7.01^{e}	1.80 (1.67)^{ef}
T_{11}	Lambda Cyhalothrin 2.5 EC	0.50 ml	13.33^{a}	89.33 (71.05)^{cd}	6.71^{cde}	1.39 (1.55)^{abcd}
T_{12}	Lambda Cyhalothrin 2.5 EC	1.00 ml	13.67^{a}	89.33 (71.05)^{cd}	6.54^{bcde}	1.48 (1.58)^{bcdef}
T_{13}	Imidacloprid 17.8 SL	0.125 ml	13.33^{a}	84.00 (66.56)^{ab}	6.31^{bcd}	1.25 (1.50)^{ab}

T_{14}	Imidacloprid 17.8 SL	0.25 ml	13.67[a]	82.67 (65.46)[ab]	6.06[ab]	1.30 (1.52)[ab]
T_{15}	Untreated Control	Water Spray	14.33[a]	80.67 (63.95)[a]	5.63[a]	1.07 (1.44)[a]

*Mean of three replication; figures in parentheses are arc sine transformed values.
@figures in parentheses are square root transformed (√X+1) values.
In a column, means followed by a common letter are not significantly different at 1per cent level by DMRT.

Plate 1: Experimental setup for reproductive rate (fecundity) of BPH

Plate 2: Experimental setup for nymphal duration, survival, growth index and sex ratio of BPH

4. Conclusion

From the present study on the impact of seven insecticides on growth and reproduction of brown planthopper, four insecticides *viz*., bifenthrin, cypermethrin, deltamethrin, and lambda cyhalothrin resulted in enhancement of fecundity of BPH and consequently resulted in higher resurgence, whereas the remaining insecticides i.e., chlorpyriphos, profenophos and imidacloprid did not influence the reproductive rate of BPH.

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