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Research Article

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Insecticide Induced Resurgence of Brown Planthopper, *Nilaparvata lugens* (Stål) on Rice

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ABSTRACT
The research was undertaken in the entomological field of Bangladesh Agricultural University (BAU), Mymensingh during the Boro crop of 2015-16 and 2016-17. Fourteen generic of single-molecule insecticide along with control were used separately in this experiment. Among the 14 single-molecule insecticides, four generics were synthetic pyrethroid group insecticide. Causes of resurgence were determined in the form of a resurgence ratio. More resurgence of brown planthopper, *Nilaparvata lugens* (Stål) on rice was induced by the application of all synthetic pyrethroids i.e., Cypermethrin, Deltamethrin, Fenvalerate, and Lambda cyhalothrin along with Acetamiprid, Chlorpyrifos, Phenthoate, and Thiamethoxam (resurgence ration 1.0 or above) compared to Pymetrozine 50WG (0.26), Dinotefuran 20SG (0.29), Isoprocarb/MIPC 75WP (0.43), Cartap 50SP (0.76) and Imidacloprid 20SL (0.91). Commonly used recommended insecticides i.e., Imidacloprid 20SL, Cartap 50SP, Isoprocarb/MIPC 75WP, Pymetrozine 50WG, and Thiamethoxam 25WG were used in 3 different doses (i.e., low, recommended, and high) and found that all recommended insecticides were induced higher resurgence ratio (≥1.0) except Pymetrozine 50WG when applied at sub-lethal dose. A positive correlation was found between resurgence ratio and yield loss.
Keywords: Brown planthopper, insecticide, resurgence ratio, yield loss.

INTRODUCTION
Brown planthopper (BPH), *Nilaparvata lugens* (Stål.) (Homoptera: Delphacidae) is serious insect pest in several Asian countries including Bangladesh. Introduction of high yielding and BPH-susceptible rice varieties, use of high level of nitrogen fertilizer, continuous cropping, staggered planting, and indiscriminate use of insecticides are reported for causes of increased BPH population in Bangladesh. It induces complex plant responses and potentially dramatic losses in yield, ultimately leading to plant death. Feeding by a large number of planthoppers causes drying of the rice leaves and wilting of the tillers, a phenomenon called 'hopper burn' (Tan et al., 2004). Sometimes the damage may be so great that growers have to abandon the crop. The loss in grain yield ranges from 10% in moderately affected fields to 70% in those fields which are severely affected (Liu and Sun, 2016; Kumar et al., 2012; Srivastava et al., 2009). The control of this insect pest has always been emphasized and largely relied on insecticides in most rice-producing countries (Alam, 2013; Ali et at., 2019; Gao et al., 1987; Hasan et al., 2015; Sivasubramaniam and Imthiyas, 2018; Seni and Naik, 2017; Wojciechowska et al., 2016) especially in countries where commercial, resistant varieties are not available. In Bangladesh, insecticides are being used to control the BPH (Uddin et al., 2019). All the insecticides have different types of effects on the BPH which may lead to the differential development of the next generation of the pest. Indiscriminate uses of broad-spectrum chemicals also reduce the biodiversity of natural enemies, lift the natural control, induce an outbreak of secondary pests and disrupt the eco-system (Ali et al., 2019; Hong-xing et al., 2017). Continuous use of insecticides has resulted in BPH resistance to insecticides (Khoa et al., 2018; Wu et al., 2018). BPH control by insecticides is often effective because inappropriate insecticide use, time of application, and incorrect dosage cause the BPH resurgence. Chelliah and Heinrichs (1980) reported that field application of certain pesticides has been shown to induce the resurgence of the target pest. Synthetic organic insecticides provide effective insect control, but the wider use has resulted in toxicity to natural pest enemies, toxic residues in plants and the environment, and induces insect resistance. The resurgence of some pests after insecticide application on rice is becoming common. Such an abnormal increase of pest population after insecticide application often far exceeds the economic injury level.

To manage the pest successfully we need to find out the causes of the outbreak of the pest. Resurgence is one of the major causes of the brown planthopper outbreak. After the application of insecticides, BPH resurgence was reported in Bangladesh (Alam, 2013), India (Ghosal and Chatterjee, 2018), Indonesia (Oka, 1991), the Philippines (Heong and Hardy, 2009), Poland (Wojciechowska et al., 2016) and the Solomon Islands (Stapley et al., 1979). Most of the hopper burn fields reported or observed in India, Indonesia, the Philippines, and Sri Lanka received insecticides before the outbreak. Hopper burns commonly occur in insecticide-treated plots while the untreated field remains relatively lower infestation. The same results were also found in the present study while surveyed done in the farmer's field of Tanore, Rajshahi (Uddin et al., 2019). Entomologists and plant protection specialists at home and abroad have taken much attention to know the resurgence of insect pests after the application of insecticides (Wojciechowska et al., 2016; Alam, 2013). There is an urgent need to determine the role of insecticides on BPH resurgence in Bangladesh. In the current study, we evaluated the induced responses of rice plants to several commonly used insecticides in Bangladesh and their effects on brown planthopper resurgence. This evaluation study might reduce insecticide application in brown planthopper control.

MATERIALS AND METHODS

The research was undertaken in the entomological field of Bangladesh Agricultural University (BAU), Mymensingh, located at 24.750N latitude and 90.50E longitudes at the mean elevation of 18 meters above the sea level. Studies were done during the Boro crop of 2015-16 and 2016-17 and average data of both seasons were used in the results. Rice variety BRRI dhan29 was used in the experiment. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications following the methods described by Gomez and Gomez (1984). The whole experimental plot was divided into three equal blocks. Each block was divided according to the number of treatments where treatments were allocated at random. The unit plot size was 4 x 2.5 m^2. The distance between block to block was 0.60m. The border between the plots was 0.60 m to facilitate different intercultural operations. The plant spacing was followed as 25 x 15 cm^2. Standard agronomic practices were done when necessary. BPH population was reared and multiplied in the greenhouse at BAU, Mymensingh. Different earthen pots (19.05 ×60.96 cm^2) consisting of three hills/pots of 35–40-day old rice plants that were used for egg-laying and population development of BPH. After that, a pot contained on an average 1000 BPH population including about 300 females were placed at the center of each plot 30 days after transplanting (DAT) for population build-up in each plot.

Effect of different insecticides and doses on the development of BPH resurgence: After 15 days of BPH release in the field 14 single-molecule insecticides were applied separately with the recommended dose (Table 1). Another five most commonly used insecticides were applied at the rate of low, recommended, and high doses to study the resurgence development (Table 2). One control plot was maintained in both experiments and sprayed with freshwater only.

Data collection: Data on the BPH population were collected from 20 randomly selected hills at pretreatment, 72 hours, and 30 days after insecticide application. The resurgence ratio of brown planthopper was calculated by the following equation (Heinichs et al., 1981):

$$\textbf{Resurgenc ratio} = \frac{\text{Population after application of treament}}{\text{Population in check field at the same interval}}$$

The status of hopper burn was also measured by the percentage of total damaged plants. During harvesting, hopper burn was recorded from each experiment and yield was recorded from each plot. The following equation was used to calculate the % hopper burn:

$$\%\ \textbf{Hopper burn} = \frac{No.of\ burn\ hill\ per\ plot}{Total\ no.of\ hill\ per\ plot} \times 100$$

Yield loss was calculated by deducting the yield of healthy plants from the expected yield of the total plant. The following equation was used to cboldste the yield loss:

$$\textbf{Yield loss} = \text{Expected yield of total plant} - \text{yield of a healthy plant}$$

Statistical analysis: The software program STATISTIX 10 (Statistix, 2013) was used to analyze the data. The mean difference among the treatments was determined by the least significant difference (LSD) test.

RESULTS AND DISCUSSION

The population development of BPH with single-molecule insecticide application:

The population of BPH/hill was not significantly different at pretreatment (Table 1). The ranged of the population was 78.10 to 72.57 BPH/hill at pretreatment. A significant difference in population was observed at 72 hours after spray (HAS). The range was 5.30 to 52.17 BPH/hill in different treatments (Table 1). But control treatment contained the highest population (81.20 BPH/hill) at 72 HAS. The population of BPH in T_3, T_5, T_6, and T_{12} was not significantly different (18.47 to 19.33 BPH/hill). The lowest population was found in T_{13}, T_8, T_{10} (5.30 to 9.87 BPH/hill) followed by T_4 and T_2 (13.4 to 15.43 BPH/hill) at 72 HAS. But 30 days after spray (DAS) highest population of BPH was found in T_1, T_9, T_6, and T_{11} (99.10, 97.30, 96.63, and 93.9 BPH/hill respectively), and those were not significantly different followed by T_7, T_5, and T_{12} treatments (Table 1). The differences among treatments T_5, T_7, T_{12} were also insignificant at 30 DAS. BPH populations in T_2 (65.53), T_{14} (64.13), and T_3 (58.30) were identical with control T_{15} (64.00 BPH/hill) at 30 DAS (Table 1). The lowest

BPH was found in T_{13} and T_8 (16.67 and 18.53 BPH/hill respectively) followed by T_{10} and T_4 (27.63 and 48.63 BPH/hill respectively) at 30 DAS.

Resurgence ratio: The highest resurgence ratio was found in T_1 and it was not significantly different from T_6, T_9, and T_{11} (resurgence ratio 1.47 to 1.55). The resurgence ratio was identical in T_5 (1.23) with T_{12} (1.20) and T_2 withT_{14} (1.0). The lowest resurgence ratio was observed in T_{13} (0.26) and T_8 (0.29) followed by T_{10} (0.43), T_4 (0.76), and T_3 (0.91) which differed significantly at a 5% level of significance (Table 1).

Hopper burns development: Maximum hopper burn was found in T_9 (43.86%) and it was not significantly different from T_1 (43.59%), T_{11} (43.21%), and T_6 (42.95%) treatments followed by T_7 (40.51%), T_5 (37.56%), and T_{12} (36.41%) treatments (Fig. 1). The lowest hopper burn was found in T_{13} (15.39%) and T_8 (15.77%) treatments followed by T_{10} (21.92%), T_4 (27.56%), and T_3 (29.74%) treatments (Fig. 1).

Yield: Yield of rice varied significantly due to single-molecule insecticide application to control BPH in field. Rice yield was irreversibly correlated with the development of hopper burn i.e., the lower the hopper burn higher the yield. Significantly higher yield was found in T_{13} (5.54 t/ha) and T_8 (5.52 t/ha) followed by T_{10} (5.11 t/ha), T_4 (4.74t/ha) and T_3 (4.60 t/ha) treatments then T_{14} (4.45 t/ha), T_2 (4.43 t/ha), and T_{15} (4.38 t/ha) treatments (Fig.1). The lowest yield was found in T_9 (3.67 t/ha) where hopper burn was the highest (43.85%) and it was significantly different from T_1 (3.69 t/ha), T_{11} (3.72 t/ha), and T_6 (3.74 t/ha) treatments followed by T_7 (3.90t/ha), T_5 (4.09 t/ha) and T_{12} (4.16 t/ha) treatments (Fig.2).

Table 1. Effect of single-molecule insecticides on resurgence development during Boro 2015-16, BAU farm, Mymensingh

Treatment		Dose/ha (kg or L)	No. of BPH/hill at different time intervals			Resurgence ratio
			Before spray	72 HAS*	30 DAS*	
T_1	**Acetamiprid** (Tundra 20 SP)	0.1	78.10a	52.17b	99.10a	1.55a
T_2	**Acephate** (Mimpahte 75 SP)	0.75	79.80a	15.43ef	65.53d	1.03d
T_3	**Imidacloprid** (Admire 20 SL)	0.125	78.27a	18.90de	58.30de	0.91de
T_4	**Cartap** (Suntap 50 SP)	1.2	81.57a	13.40fg	48.63e	0.76e
T_5	**Chlorpyrifos** (Dursban 20 EC)	1.0	79.03a	19.20de	78.53c	1.23c
T_6	**Cypermethrin** (Cymbaz 10 EC)	0.55	82.57a	18.47de	96.63a	1.51ab
T_7	**Deltamethrin** (Decis 2.5 EC)	0.5	78.43a	50.87b	86.63bc	1.36bc
T_8	**Dinotefuran** (Token 20SG)	0.15	81.43a	7.10gh	18.53fg	0.29fg
T_9	**Fenvalerate** (Fenfen 20 EC)	0.25	81.87a	41.41c	97.30a	1.52a
T_{10}	**Isoprocarb/MIPC** (Chabi 75 WP)	1.3	79.40a	9.87gh	27.43f	0.43f
T_{11}	**Lambda cyhalothrin** (Karate 2.5 EC)	500	81.50a	21.47d	93.90ab	1.47ab
T_{12}	**Phenthoate** (Kiron 50 EC)	1.0	79.87a	19.33de	76.90c	1.20c
T_{13}	**Pymetrozine** (Plenum 50 WG)	0.5	78.27a	5.30h	16.67g	0.26g
T_{14}	**Thiamethoxam** (Spike 25 WG)	0.06	79.40a	21.20d	64.13d	1.00d
T_{15}	Control (water)	-	81.67a	81.20a	64.00d	-
Level of significance			NS	**	**	**
$LSD_{0.05}$			10.92	4.74	9.89	0.16
CV%			8.15	10.76	8.93	9.47

**= Significant at 1% level of probability, *= Significant at 5% level of probability
NS= Non-Significant, Name in the parenthesis are different trade names of insecticide.
HAS*= Hour After Spray, DAS*= Days After Spray
Values in a column followed by different letters are significantly different

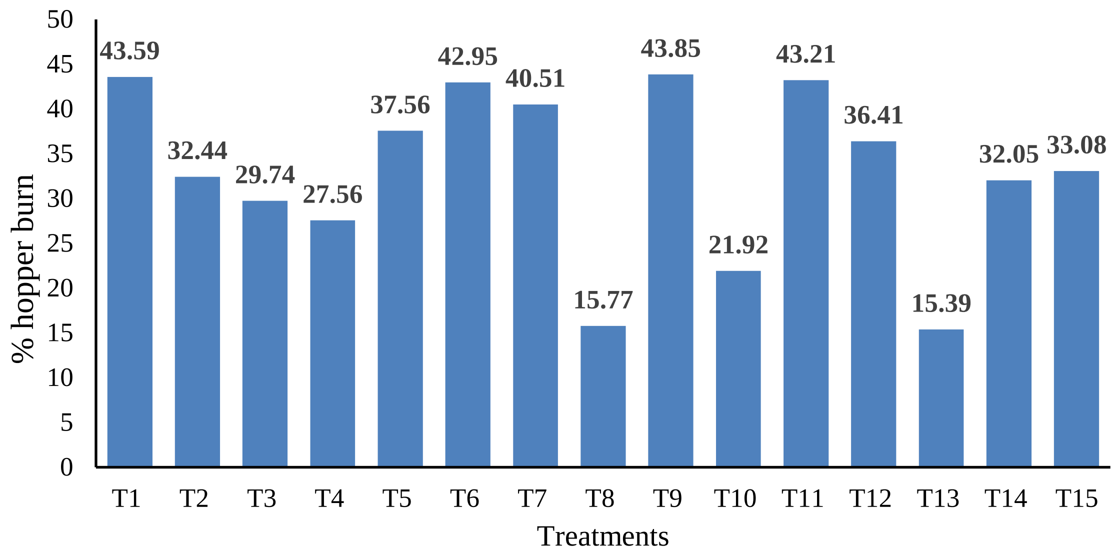

Fig. 1. Single-molecule insecticide induced hopper burn at BAU farm, Mymensingh

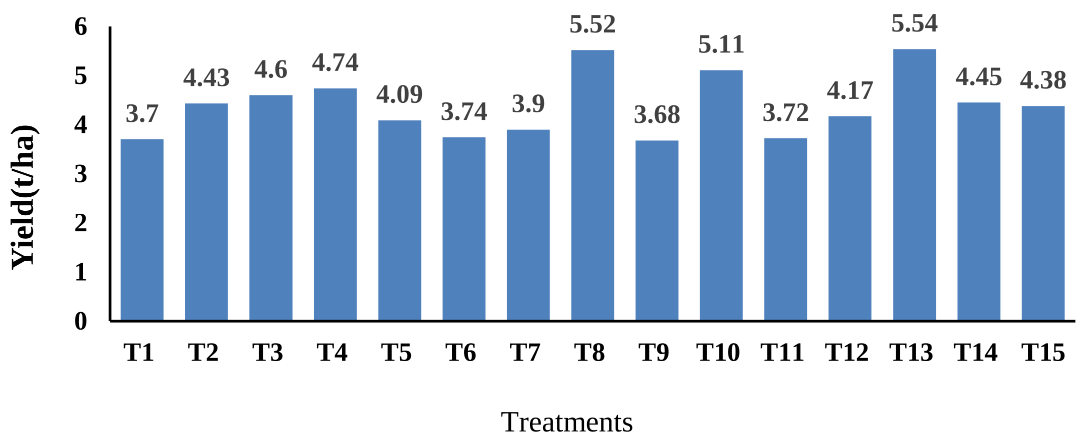

Fig. 2. Impact of BPH resurgence on yield as influenced by a different type of single-molecule insecticide

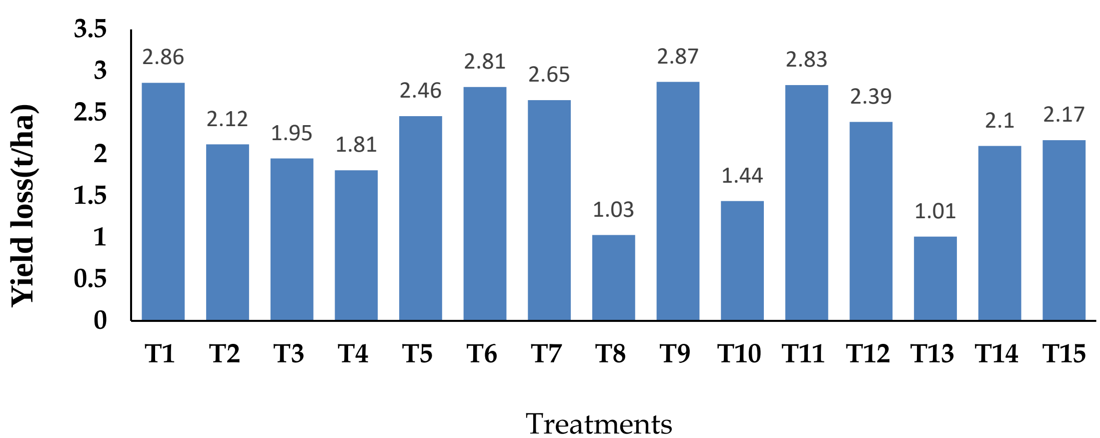

Fig. 3. Yield loss due to BPH attack in the form of a resurgence as developed after the application of single-molecule insecticide

Yield loss: The yield loss of rice varied significantly due to differential attack of BPH in different treatments. The highest yield loss was found in T9 (2.87 t/ha) treatment and it was not significantly different from T1 (2.86 t/ha, T11 (2.83 t t/ha), and T6 (2.81 t/ha) treatments followed by T7 (2.65 t/ha), T5 (2.46 t/ha) and T12 (2.39 t/ha) treatments (Fig. 3). The lowest yield loss was found in T13 (1.00 t) and T8 (1.03 t) treatments followed by T10 (1.44 t/ha), T4 (1.81 t/ha), and T3 (1.95 t/ha) treatments (Fig. 3).

Insecticide does induce BPH resurgence: The number of BPH per hill was not significantly different among the treatments and the range was 68.03 to 72.00 BPH/hill at pre-treatment (Table 2). Conversely, a significantly different population was found after 72 hours of spray. Significantly highest population was found in T_{16} (64.87 BPH/hill) i.e. control plot followed by T_1, T_{13}, T_4, and T_7 (35.33, 34.53, 29.50 and 26.50 BPH/hill respectively) treatments. The lowest population was found in T_{11} (5.30 BPH/hill) and it was identical with T_{12} (5.43 BPH/hill). Again, a significant difference was found in T_2, T_5, T_6, and T_8 (12.30, 12.90, 11.80, and 12.50 BPH/hill respectively).

Significantly, the highest population was found in T_{13} (85.00 BPH/hill) and lowest in T_{12} (7.67 BPH/hill) at 30 DAS (Table 2). The lowest population was identical to T_{11} (7.79 BPH/hill). There is no significant difference found in T_3, T_8, T_{10}, and T_{15} (31.60, 31.20, 35.0, and 31.40 BPH/hill respectively) at 30 DAS. Again treatment T_6 and T_9 were identical (25.0 and 24.60 BPH/hill respectively).

Signif maximum resurgence ratio was found in T_{13} (1.56) followed by T_1, T_4, T_7, and T_{14} (1.13, 1.10, 1.06, and 1.01 respectively) than T_2 and T_5 (0.79 and 0.77) treatments. The lowest resurgence ratio was observed in T_{12} (0.14) and it was identical with T_{11} (0.15) followed by T_9 and T_6 (0.45 and 0.46) treatments. There is no significant difference observed in treatment T_3, T_8, T_{10}, and T_{15}. Different dosages of insecticide induced BPH resurgence significantly at 30 DAS. All low doses of insecticide-induced resurgence except Pymetrozine 50 WG. The ranged of resurgence ratio was 1.06 to 1.56 in low doses of different insecticides at 30 DAS. The resurgence ratio was 0.64 at low doses of Pymetrozine 50WG. The resurgence ratio was <1.0 in the case of recommended and higher doses of different insecticide spray except for thiamethoxam 25 WG (T_{14}). Thiamethoxam 25WG showed a resurgence ratio >1.0 with a recommended dose of spray (Table 2).

Hopper burn development: Plants showed high burning symptoms (44.36%) in T_{13} followed by T_1 (37.18%) and then T_4, T_7, T_{16}, and T_{14} (34.74 %, 33.97 %, 33.59%, and 33.33% respectively) treatments (Fig. 4). Burning of plants by hopper in T_3, T_6, T_8, and T_9 were not significantly different and ranged from 21.54 to 22.69%. The lowest hopper burn was found in T_{11} (14.36%) treatment and it was similar to T_{12} (14.74%) treatment (Fig. 4).

Yield: The yield of rice varied significantly due to different doses of selected insecticides applied to control BPH in the field. The highest yield (5.61 t/ha) was obtained in T_{11} (Pymetrozine 50WG) treatment (Fig. 5). That indicated the highest yield found when Pymetrozine was used in a recommended dose which is identical with high doses of Pymetrozine (T_{12}). The significantly lowest yield was found in T_{13} (3.64 t/ha) followed by T_1, T_4, T_7, and T_{16} (4.11, 4.27, 4.32, and 4.35 t/ha respectively) treatments (Fig. 5).

Yield loss: Yield loss was maximum in T_{13} (2.91 t/ha) treatment followed by T_1, T_4, T_7, and T_{16} (2.44, 2.28, 2.23, and 2.20 t/ha respectively) treatments. The loss was identical in T_3, T_6, T_8, and T_9 treatments (yield loss ranged from 1.41 to1.49 t/ha). The lowest yield loss was found in T_{11} treatment and it was at per with T_{12} (0.94 and 0.97 t/ha) treatment (Fig. 6).

Almost all cases yield was similar in recommended and high doses of insecticide use. So, it is observed that more insecticide use didn't increase grain yield. Not only that when we used low doses of insecticides rather than recommended doses yield loss was found highest in all the 5 selected insecticides. So, it should not use high or low doses of insecticides rather than the recommended dose. In most of the cases similar yield was obtained in the control plot compared to low doses of insecticide spray plot. Moreover, a low dose creates a resurgence of BPH.

Insecticides induced brown planthopper resurgence: Chemical insecticides were embraced as part of the package of the technologies of the green revolution when modern improved rice varieties were introduced in the mid-1960s (Conway and Barbier, 1990). With the increased adoption of new high-yielding varieties, the use of insecticides also increased, and the destruction of predators and parasitoids that followed insecticide misuse resulted in the resurgence of several rice pests including the BPH, *Nilaparvata lugens* (Heinrichs and Mochida, 1984). The most commonly used method for controlling BPH is the use of insecticide (Islam *et al.*, 2001; Islam and Catling, 2012). Fourteen different generics of insecticides were used in the experiment to determine the effect of insecticide on BPH development and resurgence. Resurgence ratio of the insecticide showed that the insecticide acetamiprid, chlorpyrifos, cypermethrin, deltamethrin, fenvalerate, lambda-cyhalothrin, thiamethoxam, create a higher resurgence ratio compared to imidacloprid, cartap, dinotefuran, isoprocarb/MIPC, phenthoate and pymetrozine. Among the 14 generic of different single-molecule insecticide, we included 4 synthetic pyrethroid groups of insecticide i.e., cypermethrin, deltamethrin, fenvalerate, and lambda-cyhalothrin in the experiment and found the highest hopper burn (41-44%) with high resurgence ratio (>1.0) compared to other insecticides. This result is in agreement with Suri *et al.* (2015). They reported that out of seven insecticides deltamethrin produced a higher resurgence ratio compared to other insecticides.

Reissing *et al.* (1982) also found such type of findings and stated that synthetic pyrethroids insecticides were BPH resurgence inducing insecticides. Chelliah and Heinrichs (1980) also found a resurgence of BPH (*Nilaparvata lugens*) on rice was induced by the application of deltamethrin, methyl parathion, and diazinon. Heinrichs and Moshida (1984) found a severe outbreak of *Nilaparvata lugens* in tropical regions due to the resurgence of the pest after insecticide application. Population increases were due in part to stimulation of reproduction of the hopper, either by contact action of the insecticides or through increased plant growth. Reduction in the length of the nymphal stage and increased adult longevity resulting in a short life cycle and longer oviposition period respectively were additional factors contributing to resurgence.

Table 2. Effect of different doses of selected insecticides on resurgence development during Boro season, 2015, BAU farm, Mymensingh

Treatment		Dose/ha (kg or L)	No. of BPH/hill at different time intervals			Resurgence ratio
			Before spray	72 HAS	30 DAS	
T_1	Imidacloprid (Admire 20 SL)	0.1	70.40a	35.33b	62.00b	1.13b
T_2	Imidacloprid (Admire 20 SL)	0.125	68.07a	20.80f	43.33e	0.79d
T_3	Imidacloprid (Admire 20 SL)	0.150	68.57a	12.30h	31.60f	0.58e
T_4	Cartap (Suntap 50 SP)	1.00	72.00a	29.50c	60.00bc	1.10b
T_5	Cartap (Suntap 50 SP)	1.20	69.93a	12.90h	42.03e	0.77d
T_6	Cartap (Suntap 50 SP)	1.40	70.33a	11.80h	25.00g	0.46f
T_7	Isoprocarb/MIPC (Chabi 75 WP)	1.10	69.60a	26.50d	58.00cd	1.06bc
T_8	Isoprocarb/MIPC (Chabi 75 WP)	1.30	69.20a	12.50h	31.20f	0.57e
T_9	Isoprocarb/MIPC (Chabi 75 WP)	1.50	68.33a	8.80i	24.60g	0.45f
T_{10}	Pymetrozine (Plenum 50 WG)	0.30	71.10a	23.80e	35.00f	0.64e
T_{11}	Pymetrozine (Plenum 50 WG)	0.50	69.83a	5.30j	7.97h	0.15g
T_{12}	Pymetrozine (Plenum 50 WG)	0.70	69.57a	5.43j	7.67h	0.14g
T_{13}	Thiamethoxam (Spike 25 WG)	0.040	70.03a	34.53b	85.00a	1.56a
T_{14}	Thiamethoxam (Spike 25 WG)	0.060	68.43a	20.80f	54.97d	1.01c
T_{15}	Thiamethoxam (Spike 25 WG)	0.80	70.37a	16.87g	31.40f	0.58e
T_{16}	Control (Water)	-	69.23a	64.87a	54.67d	-
Level of significance			NS	**	**	**
$LSD_{0.05}$			11.74	2.49	3.96	0.08
CV%			10.1	6.98	5.81	6.43

**= Significant at 1% level of probability, *= Significant at 5% level of probability
NS= Non-Significant Name in parenthesis are different trade names of insecticide
Values in a column followed by different letters are significantly different

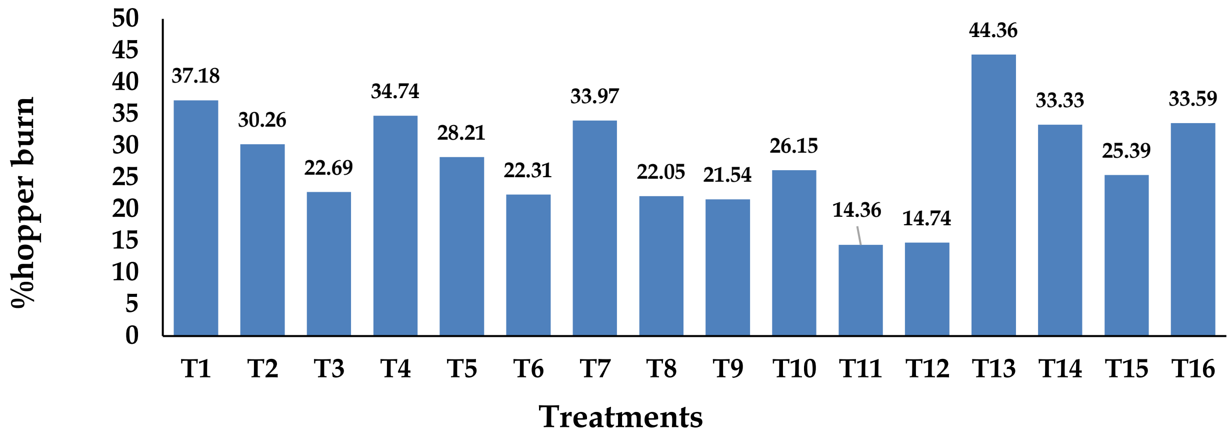

Fig. 4. Influence of resurgence of BPH on % hopper burn and yield after the application of different doses of selected insecticide

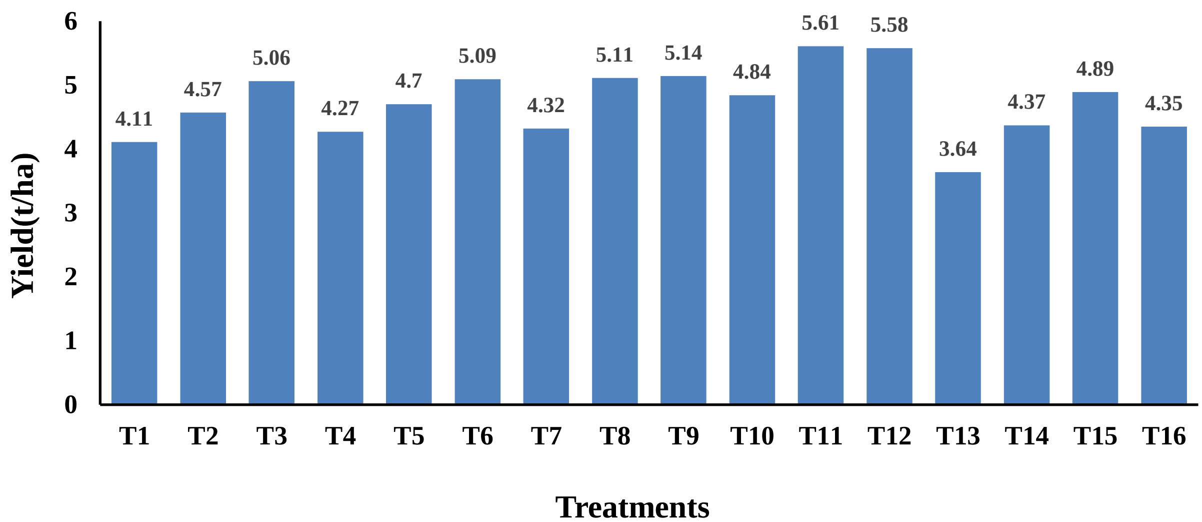

Fig. 5. Impact of the resurgence of BPH on yield after the application of different doses of selected insecticide

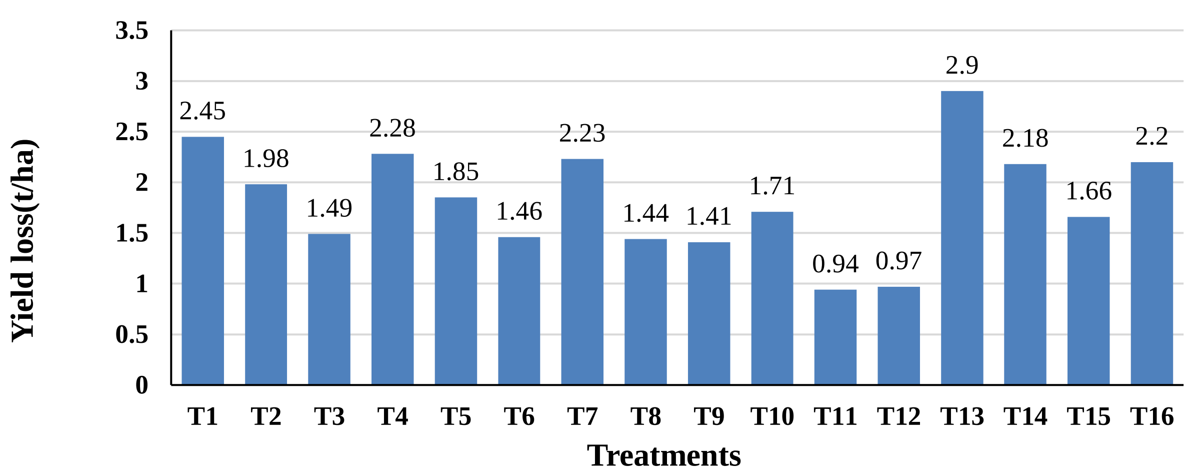

Fig. 6. Effect of the resurgence of BPH on yield loss after application of different doses of selected insecticide

Different doses of selected insecticides induced resurgence development of BPH: Use of insecticide at a lower dose is common in farmers to practice in Bangladesh as apparently, it saves some money. The practice of using a low dose combined with short residual toxicity of many commercial insecticides may often cause a sub-lethal effect to the pest. In the present studies, the dose of selected insecticide under field conditions showed that the sub-lethal dose developed more resurgence compared to the recommended dose and a higher dose of insecticide. The result conforms with the findings of Chelliah, 1979; Heinrichs et al., 1982; Krishnaiah and Kalode, 1987; Chelliah and Uthamasamy, 1986; Karns and Stewart, 2000. Heinrichs et al. (1982) reported high BPH populations (40-fold) in lower rates of application of FMC 3500 (0.2 kg ai/ha) as compared to a high rate (1.0 kg a. i./ha). Chelliah (1979) reported that low doses of resurgence-inducing insecticides increased the reproductive rate of the BPH and reduced the nymphal duration, eventually leading to resurgence. Heinrichs and Mochida (1984) reported that dose rates had a distinct effect on the degree of the resurgence in both the deltamethrin and methyl parathion treatments with higher rates permitting the higher BPH populations. There were 850 BPH per hill at the high and 210 BPH per hill at the low deltamethrin rate and 60 BPH per hill in the check. Present findings showed a 20-50% increase in the levels of a resurgence when the low dose was used. Further lower doses might increase the resurgence ratio to some higher degree.

The efficacy study of five popular insecticides i.e., imidacloprid 20SL, cartap 50SP, isoprocarb/MIPC 75WP, pymetrozine 50WG, and thiamethoxam 25WG showed effectiveness to control BPH. But found to develop resurgence when applied as a sub-lethal dose. It indicates that any recommended product or chemical could also be a cause of resurgence development for its improper use.

CONCLUSION

Fourteen insecticides of single molecules along with control were used separately in the resurgence study. Among 14 single-molecules insecticides four insecticides i.e., Cypermethrin, Deltamethrin, Fenvalarate, and Lamda Cyhalothrin were synthetic pyrethroids groups. All four synthetic pyrethroids insecticides along with acetamiprid, chlorpyrifos were found as high resurgence producing chemicals, resurgence ratio 1.0 or above. On the other hand, Imidacloprid 20SL, Cartap 50SP, Isoprocarb/MIPC 75W, Dinotefuran 20SG, and Pymetrozine 50WG showed low resurgence (resurgence ratio <1.0) producing chemicals. Many factors are involved in inducing BPH resurgence. Some insecticides contribute to a favorable environment in the rice eco-system for the BPH to alight feed and survive. This stimulates BPH reproduction leading to a high population build-up and severe damage. To prevent outbreaks, a more natural pesticide management program must thoroughly evaluate candidate insecticides to identify those causing BPH resurgence. Although identifying insecticides that induce resurgence is important in an insecticide evaluation program, their use for increasing the field population of rice insects in varietal screening is also valuable.

The recommended insecticide which produces low resurgence may have the potentia to cause high resurgence when it was applied at sub-lethall dose. Yield loss was high when the resurgence ratio was high.

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