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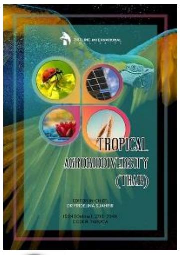

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RESEARCH ARTICLE

COMPARATIVE EFFICACY OF SOME INSECTICIDES AGAINST MAIZE APHID (*Rhopalosiphum maidis*) AND ITS INFLUENCE ON NATURAL ENEMIES IN MAIZE ECOSYSTEM

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ABSTRACT

The maize aphid, *Rhopalosiphum maidis* is one of the most serious pests of maize crop in Bangladesh. Nowadays, it becomes a major barrier for production of maize due to create hamper of pollination. In the present research investigation, the field efficacy of some insecticides was evaluated against maize aphid infestation and their toxic effects were also studied on some natural enemies in the maize ecosystem. To achieve the research goal, a field experiment was conducted on maize at the Entomology Field Laboratory, Department of Entomology, Bangladesh Agricultural University (BAU), Mymensigh during *Rabi season* of 2017-18. The experiment was set up in Randomized Complete Block Design (RCBD) with five treatments (Imidagold 20SL@ 0.1, 0.3 & 0.5ml/L; Ambush 1.8EC@ 1.5, 2.5 & 3.0ml/L; Hadhak 45WP@ 0.2, 0.4 & 0.6g/L; Suspend 5SG@ 0.5, 1.0 & 1.5 g/L and Heron 5EC @ 0.5, 1.0 & 1.5ml/L) and three replications for each treatment. Maize *viz.* BARI Hybrid Butta-09 was used as experimental crop. Data were collected on percent reduction of plant infestation & population of natural enemies, yield attributes and benefit cost ratio (BCR). Result clearly indicated that these mentioned parameters were highly significant with the application of insecticides. However, Imidagold 20SL@ 0.5ml/L resulted in the greatest (77.27%) percent reduction of maize plant infestation, the highest (623.51) number of grain per cob, the maximum (39.74g) 100 grain weight, the highest (10.02 t/ha) grain yield, the highest (63.27%) percent grain yield over control and maximum (1.56) benefit cost ratio compared to others tested insecticides which was statistically similar with the dose of 0.3ml/L of Imidagold 20SL. And then, this result was followed by Ambush 1.8EC, Hadhak 45WP, Suspend 5SG and Heron 5EC, respectively. Besides, the highest (93.67%) percent cumulative mean of maize plant infestation, the lowest (330.45) number of grain per cob, minimum (13.43g) 100 grain weight, the lowest grain yield (3.68 t/ha) and the lowest benefit cost ratio (0.95) were obtained from untreated control. With a view to know the toxic effect of different insecticides, the percent reduction of population of natural enemies was counted at 2 days, 5 days and 7 days after spraying. In all field trials, the harmful effects of the five insecticides were in the following rank order (least harmful to most harmful): Imidagold 20SL<Ambush 1.8EC< Hadhak 45WP<Suspend 5SG < Heron 5EC. Hence, based on the percent reduction of plant infestation, yield attributes, benefit cost ratio and compatibility with natural enemies, Imidagold 20SL@ 0.3ml/L proved to be the best among all the tested insecticides.

KEYWORDS

Maize, *Rhopalosiphum maidis,* infestation, insecticide, natural enemy, yield

1. INTRODUCTION

Maize (*Zea mays* L.) also known as "corn" is the most versatile rising cash and food crop. Maize is the second most important cereal crops after rice in Bangladesh (Ahmed, 2016). It is a plant belonging to the family of grasses (Poaceae). In Bengali called as "Bhutta". *Zea* is an ancient Greek word which means "sustaining life" and *Mays* is a word from Taino language meaning "life giver." The word "maize" is from the Spanish connotation "maiz" which is the best way of describing the plant. Various other synonyms like zea, silk maize, makka, barajovar, etc. are used to recognize the plant (Kumar and Jhariya, 2013). It is considered as a staple food in many countries of the world. In Bangladesh, the production of

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maize is about 2.81 MT in 2018-2019 (BBS, 2020). About 90% of the home grown maize is feeding a burgeoning poultry and fish feed industry and rests are used as human food (Alam et al., 2019a, c).

There are approximately 11.1g protein, 3.6g fat, 2.7g fibre, 348mg phosphorus, 15.9mg of total sodium, 114mg of total sulphur, 1.78mg of total amino acid, 1.5g of total minerals, 66.2g of total carbohydrates, 10mg of total calcium, 2.3mg of total iron, 286mg of total potassium, 90ug of carotene and 0.12mg of total vitamin C contain in 100g of dry maize grain (Gopalan et al., 2012 and Alam et al., 2020b, d). In country, maize is produced less than 30% in *kharif season* and more than 70% in *Rabi season* (Alam et al., a, b, c, d). Maize is a photo-insensitive & C_4-cycle crop and it is also cross-pollinating but self-fertile crop. Therefore, it can be grown throughout the year (Alam et al., 2019a). It can be processed into a variety of food and industrial products, including starch, sweeteners, oil, beverages, glue, industrial alcohol, and fuel ethanol. Its grain contains about 45-50% of oil that is used in cooking (Alam et al., 2020d).

Green cobs of maize are also used as a salad for increasing test of foods. Colorful kernel of maize is used as different purpose, such as a dent, flint, waxy, flour, sweet, pop and pod corn. It can be grown all year round in Bangladesh and can therefore be fitted in the gap between the main cropping seasons without affecting the major crops (Alam et al., 2020a, b, c, d). Infestation caused by insects on maize is increasing day by day due to continuous cultivation. Of different insect pests, maize aphid, *Rhopalosiphum maidis* is one of the important insect. It is a main constrain for producing of maize (Alam et al., 2018; 2019a, c; 2020a, b, c, d). *R. maidis* is a major agricultural pest and polyphagous in nature (Alam et al., 2014). It can attack more than 182 plant species. Nymphs and Adult are very much aggressive and cannibalistic in nature, that's why they suck cell sap from all parts of the plant (Alam et al., 2014). As a result, it causes hamper on pollination and also introduces various fungi into the cobs and plant.

Annual yield loss ranged from 5-7% in a field (Alam et al., 2018, 2020a, b). Like maize, this species of aphid infested causes 0.876% yield loss in bean, sorghum, barley, cotton and mustard (Alam et al., 2015a, b, c). However, insecticides are considered essential tools for management of aphid infesting maize in Bangladesh. Farmers usually use a lot of insecticides indiscriminately and frequently as result abatement in biodiversity of natural enemies, outbreak of secondary pests, development of resistance to pesticides, pesticide induced resurgence and contamination of food and eco-system (Alam et al., 2020c). Maize grower in Bangladesh or other countries are adopted with the use of synthetic chemical insecticides of different groups like organophosphate, organocarbamate, pyrethroids, nicotinoids to control this pest (Patil et al., 2018). It causes the environmental pollution and food adulteration which creates versatile disease in human body.

Therefore, to reduce the environmental pollution and to conserve the eco-system, a bio-remediation is necessary to develop & adopt eco-friendly and sustainable management system of maize production. Of the many options, use of new generation insecticides is the alternative to manage the pest and develop the eco-system so that farmers can get a satisfactory yield, as well as consumers can get fresh and safe food. From the above scenario, in this present research, we have managed several new generation insecticides that are available in the local market from different groups for the management of maize aphid, *R. maidis* under field conditions and their effect on maize grain yield.

2. Materials and Methods

2.1 Experimental location, site, soil and weather

The research experiment was conducted on maize at the Entomology Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh during *Rabi season* of 2017-18. The site of the study located at 24.75^0 N latitude and 90.50^{0}E longitudes at a mean altitude of 18m above the mean sea level. The soil of the research area was the dark grey floodplain soil type under belonging to the Old Brahmaputra Floodplain under the Agro-Ecological Zone (AEZ)-09 (Alam et al., 2019a, b). The climate is subtropical, characterized by heavy rainfall during the month of April to September and scanty rainfall from October to March. The field was a medium high land with well drained silty-loam texture having pH value 6.5 and moderate fertility level with 1.67% organic matter content and other nutrient components well (Alam et al., 2019b; 2020d).

2.2 Development of crop

The Experimental plots were prepared well through six (06) ploughing with mini power tiller. After ploughing, the land was cleaning and then applied fertilizers in land properly. Except urea and Muriate of Potash (MOP), all of fertilizers were mixtured into soil before final land preparation. One-fourth of urea and MOP were applied at the time of final land preparation. The recommended doses of N-P-K-S-Zn (260-80-140-50-4.5 kg ha^{-1}) were applied in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate (FRG, 2012). Maize *var.* BARI Hybrid Butta-09 variety was used as experimental crop. The seed of maize was sown on 1st week of November, 2017 in line with raise bed. Remaining urea and MOP were applied at three equal installments at pre-vegetative stage, full vegetative stage and early corn formation stage. Weeding, irrigation and other intercultural operation were done properly as and when necessary for better growth and development of maize plants.

2.3 Experimental design and plot size

The field experiment was laid out in Randomized Complete Block Design (RCBD) with three replications of each treatment including control where the unit plot size of 10 m^2 (4m×2.5m), spacing of 60×30cm between row to row and plant to plant, respectively, and the distance was 70cm between the two plots to facilitate cultural operations and insecticide applications. Total number of plots was 48.

2.4 Treatments specification and application

Five insecticides as treatments are depicted in Table 1 with their doses and other specifications. All selected insecticides were collected from the local market of Sadar, Mymensingh. Calculated quantities of insecticides and combinations were measured with the help of micropipettes and mixed well with required quantities of water to get the desired dilution. Applications of mentioned five insecticides were sprayed with the help of a hand compression knapsack sprayer at the three stages of crop production i.e. vegetative, inflorescence and cob formation stage, when considerable plants, inflorescences and cobs were found to be infested. Spraying was started at morning time to avoid bright sunshine and drift caused by strong wind. All the selected insecticides were applied with their mentioned doses. A total of three sprays were given at the mentioned three stages of crop production. The data were collected at 2, 5 and 7 days after treatment (DAT) application of each spray.

Table 1: Details of insecticides tested against maize aphid

Trade name	Active ingredients	Nature of insecticides	Group	Doses	Company name/Manufacturer
Imidagold 20 SL	Imidacloprid 20SL	Systemic, contact & stomach	Insecticides	0.1, 0.3 & 0.5 ml/L	United Phosphorus (Bangladesh) Limited.
Ambush 1.8 EC	Abamactin 1.8EC	Contact & stomach	Miticides	1.5, 2.5 & 3.0 ml/L	Haychem (Bangladesh) Limited
Hadhak 45WP	Imidacloprid 25% + Thiram 20% 45WP	Contact & systemic	Insecticides	0.2, 0.4 & 0.6 g/L	Intefa
Suspend 5 SG	Emamectin benzoate 5 SG	Contact & non-systemic	Insect Growth Regulator	0.5, 1.0 & 1.5g/L	Haychem (Bangladesh) Limited
Heron 5EC	Lufenuron 5% 5EC	Contact & Stomach	Insect Growth Regulator	0.5, 1.0 & 1.5 ml/L	Haychem (Bangladesh) Limited

2.5 Procedure of data collection

Data were collected on percent reduction of plant infestation & population of natural enemies, yield attributes and benefit cost ratio (BCR). To get percent plant infestation, a total number of healthy and infested plants were counted per plot at 2, 5 and 7 days after treatment application and finally the percent infestation of plant was calculated by using the following formula (Alam et al., 2019a):

$$\text{Infestation of plant (\%)} = \frac{\text{Number of infested plants}}{\text{Total number of plants}} \times 100$$

And thereby, the percent reduction of infestation over control was calculated by using the following formula (Alam et al., 2020a, c):

% reduction of infested plant over control

$$=\frac{\text{Infestation (\%) in control} - \text{infestation (\%) in treatment}}{\text{Infestation (\%) in control}} \times 100$$

In the case of percent reduction of natural enemies like ladybird beetle and lynx spiders, percent abundance of total natural enemies before and after spray were counted by visual observation from the whole $10m^2$ plot. Proper care was taken to not disturb natural enemies while observations were being made. The natural enemies observed in experimental plots are listed in Table 2 and finally expressed as the percent reduction of natural enemies using the following formula (Alam et al., 2020a, c):

$$\% \text{ reduction of ladybird beetle} = \frac{A-B}{A} \times 100$$

Here, A=Total abundance of natural enemies before spray, B=Total abundance of natural enemies after spray

Moreover, after full matured of cob, cobs were harvested from the experimental plots. Thereby, the grain was received from each treated plot along with control. The harvested grains were sun-dried and then cleaned carefully to remove the straw and other debris. Freshly harvested grains contained approximately 22 to 23% moisture whereas normally dry grains have moisture content of 12% to 14%, therefore, the yield was adjusted to 14% moisture. Thereafter, these grains were weighted and recorded, and yield data were converted into ton per hectare according to treatment. All data of all stages were collected and compiled into average value. Hence, Grain yield (kg/ha) at 14% moisture content was calculated using fresh grain weight with the help of the below formula (Alam et al., 2020a, c, d):

$$\text{Grain yield } \left(\frac{Kg}{ha}\right) = \frac{\text{F.W. } \left(\frac{kg}{Plot}\right) \times (100-\text{HMP}) \times \text{S} \times 10000}{(100-\text{DMP}) \times \text{NPA}}$$

Where, F.W= Fresh weight of grain in kg per plot at harvest; HMP=Grain moisture percentage at harvest; DMP=Desired moisture percentage i.e. 14%; NPA= Net harvest plot area (m^2) and Shelling co-efficient i.e. 0.8. This formula was also adopted to adjust the grain yield (kg/ha) at 14% moisture content. This adjusted grain yield (kg/ha) was again converted to grain yield (t/ha) (Alam et al., 2020a, c, d).

The percentage increase of yield over control was calculated by using the following formula (Alam et al., 2019a):

$$\text{Yield increase over control (\%)} = \frac{\text{Yield in control} - \text{yield in treatment}}{\text{Yield in control}} \times 100$$

The benefit cost ratio (BCR) was calculated on the basis of prevailing market prices of maize grain, insecticides, spraying and cultivation cost etc. Benefit cost ratio was calculated using the following formula (Alam et al., 2019a):

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return}}{\text{Total variable cost}}$$

Table 2: List of natural enemies recorded in maize field

Category	Common name	Scientific name	Family	Order
Predator	Ladybird beetle	*Cycloneda sanguinea*	Coccinellidae	Coleoptera
	Lynx spider	*Oxyopes quadrifasciatus*	Oxyopidae	Araneae

2.6 Data analysis

The recorded data were compiled and tabulated for statistical analysis. Analysis of variance (ANOVA) was done by the computer package R statistics software version 3.5.3. And then, the mean differences were adjudged with the help of Duncan's Multiple Range Test (DMRT) and Least Significant Different (LSD) test, when necessary (Gomez and Gomez, 1984).

3. Results

3.1 Effects of different insecticides on the percent reduction of maize plants infestation

The performance of five insecticides on the percent reduction of maize plants infestation as affected by maize aphid presented in Table 3. The effect of different insecticides was observed up to 7 days after the application of treatments. It was found that the application of insecticides showed significant ($P \leq 0.01$, $P \leq 0.001$ and $P \leq 0.05$) reduction of percent plant infestation compared to control (Table 3). The mean percentage of plant infestation was recorded in the range of 4.34 to 96.79. The results clearly revealed that different insecticides had a significant effect on the reduction of plant infestation and the effect was also clearly dose and time dependent. A significant level of plant infestation was found at 2 DAT which was further increased at 5 DAT and reached to the peak level by 7 DAT.

3.1.1 Two days after spraying

The results of this experiment were presented in Table 3. The results showed that, the selected insecticides had significant ($P \leq 0.01$) effect on the reduction of plant infestation compared to untreated control. In case of control condition (T_{16}), plant infestations were gradually increased to 90.80%, 93.32% and 96.79% after 2nd, 5th and7th days of observations, respectively. But this infestation level significantly reduced when maize plants were treated with different new generation insecticides. Among the different insecticides, Imidagold 20SL@ 0.5ml/L showed the best efficacy which reduced plant infestation at the level of 42.22% at 2DAS. This result was statistically at par with the dose of 0.3ml/L of Imidagold 20SL where the level of plant infestation was 42.81%. They were followed by 46.70%, 50.30%, 58.74%, 60.11%, 60.74%, 71.37%, 73.31%, 73.35%, 73.44%, 77.37%, 77.40%, 81.36% and 81.38% in T_6, T_9, T_1, T_5, T_8, T_4, T_{12}, T_{15}, T_7, T_{11}, T_{14}, T_{10} and T_{13}, respectively.

Table 3: Efficacy of different insecticides on the percent reduction of maize plant infestation

Treatments	Doses	ST	BS	Mean percentage of infested plants at			CM	Reduction (%) of infested plants over control
				2DAS	5DAS	7DAS		
Imidagold 20SL	0.1 ml/L	T_1	86.02 a	58.74 g	43.38g	20.26gh	40.79g	56.45
	0.3 ml/L	T_2	86.00 a	42.81 j	18.02 j	4.95j	21.93j	76.58
	0.5 ml/L	T_3	86.01 a	42.22 j	17.30 j	4.34j	21.29j	77.27
Ambush 1.8EC	1.5 ml/L	T_4	86.02 a	71.37 e	52.57e	28.35 e	50.76e	45.81
	2.5 ml/L	T_5	85.90 a	60.11fg	45.52fg	21.54 g	42.39f	54.75
	3.0 ml/L	T_6	86.00 a	46.70 i	24.79 i	9.69i	27.06i	71.11
Hadhak 45WP	0.2 g/L	T_7	86.01 a	73.44d	64.05cd	30.26 d	55.92d	40.30
	0.4 g/L	T_8	86.00 a	60.74 f	46.23f	24.31f	43.76f	53.28
	0.6 g/L	T_9	85.90 a	50.30 h	30.08h	19.65h	33.34h	64.41
Suspend 5 SG	0.5 g/L	T_{10}	86.02 a	81.36 b	68.63b	41.31b	63.77b	31.92
	1.0 g/L	T_{11}	86.10 a	77.37 c	64.53c	34.55c	58.82c	37.21
	1.5 g/L	T_{12}	85.99 a	73.31de	61.64d	29.22de	54.72d	41.58
Heron 5EC	0.5 ml/L	T_{13}	86.02 a	81.38b	68.66b	41.35b	63.79b	31.89
	1.0 ml/L	T_{14}	86.00 a	77.40cd	64.55cd	34.56c	58.84cd	37.18
	1.5 ml/L	T_{15}	85.98 a	73.35de	61.66d	29.25de	54.75d	41.55
Control		T_{16}	86.12 a	90.80 a	93.42 a	96.79a	93.67a	
Level of significance			NS	**	*	***	*	
CV (%)			12.52	5.84	6.28	5.19	6.90	
LSD			0.03	1.93	2.60	1.53	1.58	
SE(±)			1.83	1.10	1.20	0.76	1.05	

In column, means followed by different letters are significantly different, In column, means followed by same letters are not significantly different, *means at 5% level of probability, **means at 1% level of probability, ***means at 0.1% level of probability, NS means non-significant, CV= Coefficient of variation, LSD= Least significant difference, SE (±)= Standard error, ST= Symbol of treatments, BS= Before spray, DAS=Days after spraying of treatments, CM=Cumulative mean

3.1.2 Five days after spraying

All insecticides significantly ($P \leq 0.05$) had reduced percent plant infestation (Table 3). The lowest percentage of plant infestation (17.30%) was observed in T_3, which was at par with T_2 (18.02%). They were followed by T_6(24.79%), T_9(30.08%), T_1(43.38%), T_5(45.52%), T_8(46.23%), T_4(52.57%), T_{12}(61.64%), T_{15}(61.66%), T_7(64.05%), T_{11}(64.53%), T_{14}(64.55%), T_{10}(68.63%) and T_{13}(68.66%), respectively, whereas the highest (93.42%) percentage of plant infestation was recorded in T16.

3.1.3 Seven days after spraying

The data in Table 3 indicated that the treatment T_3 (Imidagold 20 SL@ 0.5ml/L) recorded the lowest percentage of plant infestation (4.34%) on seven days after spraying which was statistically at par with Imidagold 20SL@ 0.3ml/L(T_2) where the level of plant infestation of (4.95%) at the 0.1 % level of significance. They were followed (considering combine efficacy only) by 28.35, 21.54 & 9.69% in Ambush 1.8EC@ 1.5, 2.5 & 3.0ml/L; 30.26, 24.31 & 19.65% in Hadhak 45WP@ 0.2, 0.4 & 0.6g/L; 41.31, 34.55 & 29.22% in Suspend 5SG@ 0.5, 1.0 & 1.5g/L and 41.35, 34.56 & 29.25% in Heron 5EC@ 0.5, 1.0 & 1.5ml/L, respectively. Untreated control found the highest plant infestation (96.79%).

From the result of the cumulative mean of plant infestation, the doses of 0.5ml/L(T_3) noticed the minimum plant infestation (21.29%) which was statistically similar with T_2 (21.93%) at the 5% level of probability. They were followed by T_6(27.06%), T_9(33.34%), T_1(40.79%), T_5(42.39%), T_8(43.76%), T_4(50.76%), T_{12}(54.72%), T_{15}(54.75%), T_7(55.92%), T_{11}(58.82%), T_{14}(58.84%), T_{10}(63.77%) and T_{13}(63.79%), respectively, whereas the highest (93.67%) percentage of plant infestation was recorded in T16. On the other hand, With a view of the overall insecticidal effect on maize aphid, percent reduction of plant infestation over control was also calculated is shown in Table 3. It was observed that, the application of Imidagold 20SL@ 0.5ml/L has reduced the highest percent plant infestation (77.27%) over control than other insecticides. Imidagold 20SL@ 0.3ml/L (76.58%), which was statistically similar with Imidagold 20SL @ 0.5ml/L. The result was followed by 45.81, 54.75 & 71.11% in Ambush 1.8EC@ 1.5, 2.5 & 3.0ml/L; 40.30, 53.28 & 64.41% in Hadhak 45WP@ 0.2, 0.4 & 0.6g/L; 31.92, 37.21 & 41.58% in Suspend 5SG@ 0.5, 1.0 & 1.5g/L and 31.89, 37.18 & 41.55% in Heron 5EC@ 0.5, 1.0 & 1.5ml/L, respectively, whereas the lowest (31.89%) percent reduction of plant infestation was observed in T_{13}. Considering the above evaluation of efficacy of all tested insecticides under laboratory and field condition, the following rank orders (The highest to lowest efficacy only) were: Imidagold 20SL>Ambush 1.8 EC> Hadhak 45WP> Suspend 5SG>Heron 5EC.

3.2 Effect of different insecticides on yield attributes and benefit cost ratio

3.2.1 Number of grain per cob

All new generation pesticides significantly ($P \leq 0.05$) had reduced percent plant and cob infestation and the percent of number of grain per cob increased (Table 4). Of different tested insecticides, the highest (623.51) number of grain was counted from the plants treated with the doses of 0.5ml/L Imidagold 20SL which was statistically as well as T_2(620.86)=Imidagold 20SL@ 0.3ml/L. The 3rd highest (610.26) number of grain per cob was obtained in T_6 followed by T_9(602.45), T_1(596.47), T_5(585.33), T_8(580.62), T_4(560.27), T_{12}(520.37), T_{15}(490.82), T_7(440.19), T_{11}(410.19), T_{14}(400.38), T_{10}(382.22) and T_{13}(360.59), respectively. The minimum (330.45) number of grain per cob was found T_{16} (untreated control).

3.2.2 100 grain weight

Weights of 100 grains were measured regarding the treatment specification. The results presented in Table 4 and noticed that the tested treatments significantly ($P \leq 0.01$) increase the 100 grain weight compared to untreated control. A statistically significant maximum 100 grain weight (39.74g) of maize recorded from the use of Imidagold 20SL@ 0.5ml/L which statistically at par with Imidagold 20SL@ 0.3ml/L (39.62g). And then, there were followed by (37.86g), (34.99g), (31.74g), (38.63g), (25.12g), (23.45g), (20.38g), (18.97g), (17.35g), (16.23g), (15.90g), (15.45g) and (15.24g) in T_6, T_9, T_1, T_5, T_8, T_4, T_{12}, T_{15}, T_7, T_{11}, T_{14}, T_{10} and T_{13}, respectively, while the lowest (13.43g) weight of 100 grain was recorded from T_{16} (untreated control).

3.2.3 Grain yield (t/ha)

All insecticides significantly had reduced plant and cob infestation, and the yield of grain had differed significantly ($P \leq 0.05$) among the tested insecticides. The results of grain yield has depicted in the Table 4. The grain yield was recorded in the range of 3.68 to 10.02 t/ha. Imidagold 20SL@ 0.5ml/L showed the the maximum (10.02 t/ha) grain yield than other treatments which was statistically at par with T_2 (Imidagold 20SL@ 0.3ml/L) where the value of yield was 9.97 t/ha. There were followed by T_6(9.42 t/ha), T_9(8.70 t/ha), T_1(8.11 t/ha), T_5(7.63 t/ha), T_8(7.61 t/ha), T_4(7.14 t/ha), T_{12}(7.12 t/ha), T_{15}(7.09 t/ha), T_7(6.26 t/ha), T_{11}(5.93 t/ha), T_{14}(5.89 t/ha), T_{10}(5.65 t/ha) and T_{13}(5.60 t/ha), respectively, whereas the minimum (3.68 t/ha) grain yield was found T_{16} (untreated control).

Table 4: Efficacy of different insecticides on yield attributes and benefit cost ratio

Treatments	Doses	ST	No. of grain cob^{-1}	100 grain wt. (g)	Yield (t/ha)	YI (%) over control	BCR
Imidagold 20SL	0.1 ml/L	T_1	596.47bc	31.74d	8.11cd	54.62	1.40
	0.3 ml/L	T_2	620.86a	39.62a	9.97a	63.09	1.55
	0.5 ml/L	T_3	623.51a	39.74a	10.02a	63.27	1.56
Ambush 1.8EC	1.5 ml/L	T_4	560.27f	23.45fg	7.14ef	48.46	1.32
	2.5 ml/L	T_5	585.33d	28.63de	7.63d	51.77	1.38
	3.0 ml/L	T_6	610.26b	37.86b	9.42b	60.93	1.47
Hadhak 45WP	0.2 g/L	T_7	440.19i	17.35j	6.26i	41.21	1.21
	0.4 g/L	T_8	580.62de	25.12f	7.61e	51.64	1.35
	0.6 g/L	T_9	602.45b	34.99bc	8.70bc	57.70	1.43
Suspend 5 SG	0.5 g/L	T_{10}	382.22l	15.45lm	5.65l	34.87	1.12
	1.0 g/L	T_{11}	410.61j	16.23jk	5.93ij	37.94	1.17
	1.5 g/L	T_{12}	520.37g	20.38h	7.12g	48.31	1.30
Heron 5EC	0.5 ml/L	T_{13}	360.59lm	15.24m	5.60lm	34.28	1.09
	1.0 ml/L	T_{14}	400.38jk	15.98l	5.89k	37.52	1.14
	1.5 ml/L	T_{15}	490.82h	18.97hi	7.09gh	48.09	1.25
Control		T_{16}	330.45n	13.43n	3.68n		0.95
Level of significance			*	**	*		
CV (%)			7.12	6.65	5.33		
LSD			5.56	1.14	0.034		
SE(±)			1.12	1.08	0.95		

In column, means followed by different letters are significantly different, *means at 5% level of probability, **means at 1% level of probability, CV= Coefficient of variation, LSD= Least significant difference, SE (±)= Standard error, ST= Symbol of treatments, YI (%) = Percent yield Increase over control and BCR= Benefit cost ratio

3.2.4 Percent increase of grain yield over control

The results of percent increase of grain yield over control are presented in Table 4. It was evident that grain yield was affected by different insecticides for controlling the plant infestation when used as treatments.

Based upon the percent increase of grain yield over control, the maximum percentage increase of grain yield (63.27%) over control was found in T_3(Imidagold 20SL@ 0.5ml/L) which was statistically similar to T_2(63.09%). The 3rd highest percent increase of grain yield over control was observed in T_6(60.93%) followed by T_9(57.70%), T_1(54.62%),

T_5(51.77%), T_8(51.64%), T_4(48.46%), T_{12}(48.31%), T_{15}(48.09%), T_7(41.21%), T_{11}(37.94%), T_{14}(37.52%) and T_{10}(34.87%), respectively. The minimum (34.28%) percent grain yield of maize over control was found T_{13}.

3.2.5 Benefit cost ratio (BCR)

The competence of the selected tested insecticides on the cobs caused by aphid for calculating benefit cost ratio and their results are presented in Table 4. The benefit cost ratio (BCR) in treated plots ranging from 0.95 to 1.56. Imidagold 20SL treated plots was noticed the highest benefit cost ratio (1.56) followed by 1.32, 1.38, 1.47 in Ambush 1.8EC@1.5, 2.5, 3.0ml/L; 1.21, 1.35, 1.43 in Hadhak 45WP@ 0.2, 0.4, 0.6g/L; 1.12, 1.17, 1.30 in Suspend 5SG@0.5, 1.0, 1.5g/L and 1.09, 1.14, 1.25 in Heron 5EC@ 0.5, 1.0, 1.5ml/L, respectively. The lowest (0.95) benefit cost ratio was found in T_{16} (Control).

From the results of benefit cost ratio, both Imidagold 20SL@ 0.5ml/L and 0.3ml/L might be more effective for reducing the infestation of maize plants. The percent reduction of plan infestation of this insecticide with two doses were in the following order Imidagold 20Sl@ 0.5ml/L (77.24%)>Imidagold 20SL@ 0.3ml/L (76.57%), which was statistically similar (Table 4). Although, Imidagold 20SL@ 0.5ml/L showed good result, but consideration of the benefit cost ratio, Imidagold 20SL@ 0.3ml/L exhibited better performance. Imidagold 20SL@ 0.3ml/L may, therefore, be recommended for the effective and economic control of *R. maidis* in maize field.

3.3 Percent population reduction of ladybird beetle, *Cycloneda sanguinea* and lynx spider, *Oxyopes quadrifasciatus*

Toxic effects of selected insecticides were evaluated by counting the abundance of different insecticides like ladybird beetle, *Cycloneda sanguinea* and lynx spider, *Oxyopes quadrifasciatus* and results were presented in Table 5 and 6. However, all the insecticides were found significantly toxic to *C. sanguinea* and *O. quadrifasciatus* as compared to control after different intervals of spraying of insecticides. In case of ladybird beetle, Imidagold 20SL was found relatively safe to ladybird beetle, *C. sanguinea* with the minimum percent reduction (51.12%) after seven days of spray while Hadhak 45WP was found highly toxic with 76.66% population reduction. Ambush 1.8EC, Suspend 5SG and Heron 5EC showed moderate toxicity with, 67.89%, 62.53% and 58.42% reduction in the adult population of ladybird beetle, respectively (Table 5). On the other hand, Hadhak 45WP was found highly toxic to *Oxyopes quadrifasciatus* as it showed maximum percent reduction (78.23%) after seven days of spray application whereas imidagold 20SL was safe and showed minimum percent reduction (54.80%) after seven days of spraying. Ambush 1.8EC, Suspend 5SG and Heron 5EC were moderately toxic with 71.45%, 65.55% and 60.25% reduction in the *Oxyopes quadrifasciatus* population (Table 6).

Table 5: Efficacy of different insecticides on the percent reduction of *Cycloneda sanguinea* under field condition

Insecticides		Reduction (%) of *C. sanguinea* after different spray intervals		
Common Name	Trade Name	2 DAS	5 DAS	7 DAS
Imidacloprid 20SL	Imidagold 20SL	55.68 de	58.17 c	51.12 d
Abamactin 1.8EC	Ambush 1.8 EC	75.34 b	79.28 a	67.89 b
Imidacloprid 25% + Thiram 20% 45WP	Hadhak 45WP	84.14 a	80.47 a	76.66 a
Emamectin benzoate 5SG	Suspend 5SG	73.52 bc	69.53 b	62.53 bc
Lufenuron 5% 5EC	Heron 5EC	65.37 d	68.79 b	58.47 cd
	Control	10.45 f	9.16 d	11.33 e
Level of significance		*	*	**
CV (%)		6.96	7.35	5.29
LSD		5.68	4.23	3.56
SE(±)		1.43	1.22	1.04

Here, DAS= Day after spay, In column, means followed by different letters are significantly different, *means at 5% level of probability, **means at 1% level of probability, CV= Coefficient of variation, LSD= Least significant difference, SE (±)= Standard error

Table 6: Field efficacy of different insecticides on the percent reduction of *Oxyopes quadrifasciatus*

Insecticides		Reduction (%) of *O. quadrifasciantus* after different spray intervals		
Common Name	Trade Name	2 DAS	5 DAS	7 DAS
Imidacloprid 20SL	Imidagold 20SL	65.84c	62.45d	54.80d
Abamactin 1.8EC	Ambush 1.8 EC	75.68b	84.37a	71.45b
Imidacloprid 25% + Thiram 20% 45WP	Hadhak 45WP	81.35a	82.54a	78.23a
Emamectin benzoate 5SG	Suspend 5SG	66.66c	68.75b	65.55bc
Lufenuron 5% 5EC	Heron 5EC	74.57bc	65.49bc	60.25c
	Control	8.43d	7.72e	9.24e
Level of significance		**	*	*
CV (%)		7.34	5.48	6.78
LSD		2.47	3.12	5.67
SE(±)		1.34	1.15	1.13

Here, DAS=Days after spray, In column, means followed by different letters are significantly different, *means at 5% level of probability, **means at 1% level of probability, CV= Coefficient of variation, LSD= Least significant difference, SE (±)= Standard error

4. Discussion

From the finding of this study, it was found that the five new generation insecticides showed variable efficacy in reducing plants, inflorescences and cobs over the control. Among tested insecticides, Imidagold 20SL@ 0.5ml/L was the most effective treatment against maize aphid, where returned maximum yield, benefit cost ratio and low toxic effect on natural enemies (Suchail et al., 2001; David et al., 2009 and Gaikwad et al., 2012). This result was statistically at par with the dose of 0.3ml/L of Imidagold 20SL. Thus, Imidagold 20SL@ 0.3ml/L could be the best performance against maize aphid in field level for considering the benefit cost ratio with returned higher yield (Patil et al., 2018). The main mechanism of this result was Imidagold 20SL (Imidacloprid 20SL) is a systemic, contact and stomach barrier insecticides (Alam et al., 2019a) so it acts as both contact and systemic on insect. That is why it causes block the receptor, nervous system and stomach system of aphid directly (Kumar et al., 2019 and Ahmed et al., 2017).

Moreover, it is a systemic in nature of mode of action, when insects suck the cell sap from treated plants, this insecticides cause disrupt the cell and block the ingestion activity of insect (Alam et al., 2019a, 2020a, b, c, d; Preetha et al., 2012 and Gaikwad et al., 2014). The present findings of newer insecticides against maize aphid are in conformity with the result of who also reported imidacloprid 20SL was found best insecticide in reducing aphid (Zewar and Zahoor, 2007; Suchail et al., 2001; Alam et al., 2020a, b, c). Furthermore, in our study, Ambush 1.8EC (Abamectin 1.8EC) found to be the second best than others considering all the parameters studied like reduction the infestation of plants, inflorescence & cobs, abundances of natural enemies and yield (t/ha) (Zewar and Zahoor, 2007 and Patil et al. 2018). This result was close followed by Hadhak 45WP, Suspend 5SG and Heron 5EC, respectively. Heron 5EC showed the least efficacy compared to other insecticides i.e. this insecticide is the highest toxic to natural enemies and lowest yield and benefit cost ratio follower by Suspend 5SG>Hadhak 45WP>Ambush 1.8EC>Imidagold 20SC, respectively.

Similar results were also observed from the studies stated that the infestation of aphid was effectively checked by Imidacloprid 20SC and others insecticides (Ahmed et al., 2017; Kumar, et al., 2019). In all field trial and considering the efficacy of all tested insecticides, the efficacy of tested insecticides followed the order Imidagold 20SL>Ambush 1.8 EC>Hadhak 45WP>Suspend 5SG>Heron 5EC. As in known, Imidagold 20 SL was the best performance for controlling the maize aphid than other tested insecticides where returned maximum yield and benefit cost ratio through doing safe the maximum natural enemies (Zewar and Zahoor, 2007). In case of doses, 0.5ml/L and 0.3ml/L of Imidagold 20SL might be more effective for reducing the maize plant infestation, exhibition the highest yield and benefit cost ratio by saving largest amount of natural enemies (Suchail et al., 2001). The percent reduction of plan infestation and percent increased of yield over control of this insecticide with two different doses were in the following order Imidagold 20 SL@ 0.5ml/L (77.27%) & (63.27%)>Imidagold 20SL@ 0.3ml/L (76.58%) & (63.09%), which was statistically similar (Table 3). Although, Imidagold 20SL@ 0.5ml/L showed good result but consideration of benefit cost ratio and safe natural enemies, Imidagold 20SL@ 0.3ml/L exhibited better performance (Kumar et al., 2019). Therefore, Imidagold 20SL@ 0.3ml/L may be recommended for the effective and economic control of *R. maidis* in maize field. Ambush 1.8EC was the second best (Ahmed et al., 2017; David et al., 2009; Alam et al., 2020a, b, c, d; Preetha et al., 2012).

5. Conclusion

In summary, the results of the present research revealed that the application of Imidagold 20 SL@ 0.5ml/L and 0.3ml/L is more effective together for controlling maize aphid returning the maximum yield and minimum infested plant of maize. However, based on the benefit cost ratio, Imidagold 20 SL@ 0.3ml/L is the best. Additionally, Imidagold 20SL was relatively safe to *C. sanguinea* and *Oxyopes quadrifasciatus* as compared to other tested insecticides. On the whole summarizing, Imidagold 20 SL@ 0.3ml/L could be recommended to the maize grower for the effective management of *R. maidi* and as these are also safer to predators and other beneficial insects in the maize crop.

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Author's Contribution

Professor Dr. Kazi Shahanara Ahmed (KSA) and Principal Scientific Officer Dr. Md. Harun-or Rashid (MHR) conceptualized, designed, formulation and supervision of the experiment. Md. Jewel Alam performed the field experiment, collected, recorded and analyzed the data. Md Amzed Hossain Chowdhury and Quamrun Nahar collected materials, tools and helped to set up the experiments, and also helped to collect information of material method. Md. Jewel Alam drafted the manuscript which was critically reviewed by KSA and MHR.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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