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INSECTICIDAL ACTIVITIES OF RAKTA KOMOL *ADENANTHERA PAVONINA* (l.) PLANT EXTRACT AGAINST PULSE BEETLE *CALLOSOBRUCHUS CHINENSIS* (L.) ADULTS

Abdul Matin[1], Omar Ali Mondal[1*], Wehedul Islam[1], Farjana Binta Omar[1] and Ataur Rahman Khan[3]
[1]Institute of Biological Sciences, University of Rajshahi, Bangladesh
[2]Department of Genetic Engineering and Biotechnology, University of Rajshahi, Bangladesh
[3]Department of Zoology, University of Rajshahi, Bangladesh
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Research article

Research article
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DIVERSITY OF INSECT PESTS IN THE BRINJAL FIELD DURING THE SUMMER SEASON

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ABSTRACT

A study was conducted to know the prevalence, abundance and diversity of insect pests in the brinjal field at Babugonj, Barisal during May to September 2024. Eleven insect pests namely brinjal mealy bug, *Coccidohystrix insolita* Green (Margarodidae: Hemiptera); cotton aphid, *Aphis gossypii* Glover (Aphididae: Hemiptera); green leafhopper, *Amrasca biguttula biguttula* Ishida (Cicadellidae: Hemiptera); whitefly, *Bemisia tabaci* Gennadius (Aleyrodidae: Hemiptera); plant hopper, *Siphanta acuta* Walker (Flatidae: Hemiptera); squash bug, *Anasa tristis* De Geer (Coreidae: Hemiptera); epilachna beetle, *Henosepilachna vigintioctopunctata* Fabricius (Coccinellidae: Coleoptera); leaf beetle, *Monolepta signata* Olivier (Chrysomelidae: Coleoptera); flea beetle, *Phyllotreta cruciferae* Goeze (Chrysomelidae: Coleoptera); brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenée (Pyralidae: Lepidoptera); and cutworm moth, *Agrotis ipsilon* Hufnagel (Noctuidae: Lepidoptera) were recorded in the field. Among the insect pests, cotton aphid (6.93 insects plant^{-1} observation^{-1}), green leafhopper (5.60 insects plant^{-1} observation^{-1}), mealy bug (5.28 insects plant^{-1} observation^{-1}) and whitefly (0.82 insects plant^{-1} observation^{-1}) were more abundant while the others were less abundant in the field. The relative abundance of the insect pests was cotton aphid (36.31%) > green leafhopper (29.33%) > mealybug (27.65%) > whitefly (4.29%) > leaf beetle (0.56%) > brinjal shoot and fruit borer (0.49%) > epilachna beetle (0.42%) > flea beetle (0.35%) > plant hopper (0.24%) > squash bug (0.21%) > cutworm moth (0.14%). Among the prevalent 11 insects, 6 insects belong to the order Hemiptera, 3 insects belong to the order Coleoptera and 2 insects belong to the order Lepidoptera. Hemipteran insects belong to the suborder Sternorrhyncha (3), Auchenorrhyncha (2) and Heteroptera (1). All Coleopteran insects belong to Polyphaga and all Lepidopteran insects belong to Heterocera suborder. Therefore, Hemipteran insect of the suborder Sternorrhyncha were most prevalent and abundant in the brinjal field.

Keywords: Brinjal, insect pest diversity, prevalence, abundance, relative abundance

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INTRODUCTION

Brinjal (*Solanum melongena* Lin.) is a popular vegetable in Bangladesh because of its palatability. In Bangladesh, brinjal is cultivated in 115,000 hectares of land producing 619,000 metric ton fruit with a yield ranging from 20-30 t ha^{-1} (BBS 2023). Brinjal fruit is rich in vitamin, mineral, protein and bioactive compounds including flavonoid, isoflavone, anthocyanin, antioxidant and polyphenol (Agregan *et al.* 2021) like the different cereal grains (Khatun and Mollah 2024) and legume crops including soybean (Khatun and Kim 2021). These bioactive compounds have anti-inflammatory and anti-obesity properties (Khatun *et al.* 2023). In Bangladesh, brinjal is successfully cultivated throughout the country both in the winter and summer season (Mollah 2025, Das *et al.* 2023). However, summer season is most suitable for brinjal cultivation providing sufficient yield (Mollah *et al.* 2023, Mollah *et al.* 2022).

Insect pests are the main constraint against the successful cultivation of brinjal in Bangladesh. Infestation of insects started at the seedling or early vegetative stage and continued up to last harvest of fruit (Latif *et al.* 2010). Brinjal is reported to be infested by many insect pests including brinjal shoot and fruit borer, *Leucinodes orbonalis* G. (Haque 2024); green leafhopper, *Amrasca biguttula biguttula* I. (Mollah 2024); cotton aphid, *Aphis gossypii* G. (Mollah and Khatun 2024); whitefly, *Bemicia tabaci* Genn. (Uddin *et al.* 2025); leaf roller, *Anobata olevacea* (Das *et al.* 2023); epilachna beetle, *Epilachna vigintioctopunctata* Fab. (Khan *et al.* 2023); mealybug, *Coccidohystrix insolita*; leaf beetle, *Monolepta signata* Oliv. and green leafhopper, *Nephotettix virescens* (Ghosh *et al.* 2021).

However, all these insects are not prevalent and abundant in all seasons and in all areas of Bangladesh. For example, brinjal shoot and fruit borer are most prevalent and abundant in the summer season (Mollah *et al.* 2022, Ara *et al.* 2007) compared to the winter season (Das *et al.* 2023). However, brinjal shoot and fruit borer are prevalent and abundant as major pest both in winter and summer season in Jashore region (Ghosh *et al.* 2021) and Dhaka (Ghosh *et al.* 2022) but as minor pest in Sylhet (Das *et al.* 2023). The sucking pests including aphid and green leafhopper are more prevalent and abundant in the winter season (Mollah and Khatun 2024, Mollah 2024, Ghosh *et al.* 2021) than the summer season (Kadgonkar *et al.* 2018). Mealybug appeared as a major pest in the summer season in the coastal area of Bangladesh

(Khan 2020) while in winter as minor pest in Dhaka (Ghosh *et al.* 2022). Very few or no information on the diversity of insect pests in the Brinjal field of Barisal is available. Therefore, the present study aimed to know the variation in prevalence and abundance of insect pests in brinjal field of Barisal during summer season.

MATERIALS AND METHODS

This study was conducted at Bangladesh Institute of Nuclear Agriculture (BINA), Barisal during May to September 2024. This area is situated at the latitude of 22.8162 ^{o}N and longitude of 90.3137^{o}E with an elevation of 2 meters from the sea level (Khatun *et al.* 2025). The study area is under the Agro-Ecological Zone of Active Ganges Floodplain (AEZ 10) with calcareous brown floodplain soil characterized by low organic matter and nitrogen content (Khatun and Mollah 2023). The experimental field was prepared well following the agronomic practices. One-month aged seedlings were planted in the field keeping 80 cm distance. The experiment was laid out in randomized complete block design (RCBD) with three replications. Total number of brinjal seedling transplanted in the field were thirty (30). Irrigation, weeding, mulching, fertilization and other intercultural operations were carried out as needed. After ten days of seedling transplanting, data collection on insect pest prevalence and abundance were started. Data on the prevalence of insect was recorded by visual search following Mollah *et al.* (2017). For this, all the leaves of all the plants were checked regularly once a week and the prevalent insect pests were recorded. Picture of the leaves infested by the specific pests were also collected for pictorial representation and validation. For the abundance of insect pests, number of the specific insect pests in the infested leaves or infested plants were recorded. During the process of data collection, the unknown insects were collected in the 15 ml falcon tube and brought to the laboratory for detailed study on their morphological characteristics. Identification of the collected insects were performed by matching with pictures, literature study or taking help from the experts. The collected data were inputted and analysed using Microsoft excel and graphically presented with sigma plot 12.5 software. Pictorial representation of the insect pests was carried out using the Microsoft PowerPoint software. Relative abundance of the insect pests was determined following Mollah and Rahman (2012):

$$\text{Relative abundance (\%) of insect pests} = \frac{\text{Number of specific insect pest}}{\text{Total number of insect pests}} \times 100$$

RESULTS

Prevalence of insect pests in the brinjal plant: Eleven insect pests were found in the brinjal field during summer season (Fig. 1). The prevalent insect pests were: brinjal mealybug, green leafhopper, cotton aphid, epilachna beetle, brinjal shoot and fruit borer, leaf beetle, flea beetle, plant hopper, whitefly, cutworm moth and squash bug (Fig. 1). Among these insect pests, mealybug, epilachna beetle and brinjal shoot and fruit borer were recorded from both leaf and fruits (Fig. 1).

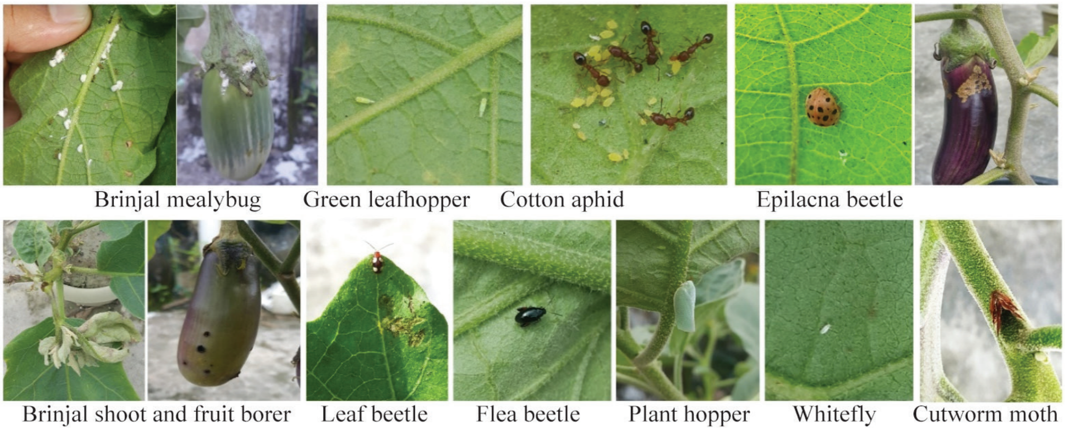

Fig. 1. Pictorial representation of insect pests infesting brinjal plant and fruit.

Taxonomic status of the prevalent insect pests: Among the insect pests, mealybug (*Coccidohystrix insolita* Green), cotton aphid (*Aphis gossypii* Glover) and whitefly (*Bemisia tabaci* Gennadius) belongs to the family Margarodidae, Aphididae and Aleyrodidae, respectively (Table 1). All these three families belong to the suborder Sternorrhyncha. Green leafhopper (*Amrasca biguttula biguttula* Ishida) and planthopper (Siphanta acuta Walker) belongs to the family Cicadellidae and Flatidae, respectively. These two families belong to the suborder Auchenorrhyncha (Table 1). Squash bug (*Anasa tristis* De Geer) belongs to the family Coreidae under the suborder Heteroptera (Table 1). The suborders Sternorrhyncha, Auchenorrhyncha and Heteroptera belongs to the order Hemiptera

(Table 1). Epilachna beetle (*Henosepilachna vigintioctopunctata* Fabricius) belongs to the family Coccinellidae (Table 1). Leaf beetle (*Monolepta signata* Olivier) and Flea beetle (*Phyllotreta cruciferae* Goeze) belongs to the family Chrysomelidae (Table 1). Both Coccinellidae and Chrysomelidae family belongs to the suborder Polyphaga under the order Coleoptera. Brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenée) and Cutworm moth (*Agrotis ipsilon* Hufnagel) belongs to the family Pyralidae and Noctuidae, respectively (Table 1). These two families belong to Heterocera suborder of the order Lepidoptera (Table 1). So, eleven brinjal pests belongs to ten families, five suborders and three orders (Table 1).

Table 1. Taxonomic identity of the prevalent insect pests.

Common name	Scientific name	Family	Suborder	Order
Brinjal mealybug	*Coccidohystrix insolita* Green	Margarodidae	Sternorrhyncha	Hemiptera
Cotton aphid	*Aphis gossypii* Glover	Aphididae		
Whitefly	*Bemisia tabac*i Gennadius	Aleyrodidae		
Green leafhopper	*Amrasca biguttula biguttula* Ishida	Cicadellidae	Auchenorrhyncha	
Planthopper	*Siphanta acuta* Walker	Flatidae		
Squash bug	*Anasa tristi*s De Geer	Coreidae	Heteroptera	
Epilachna beetle	*Henosepilachna vigintioctopunctata* Fabricius	Coccinellidae	Polyphaga	Coleoptera
Leaf beetle	*Monolepta signata* Olivier	Chrysomelidae		
Flea beetle	*Phyllotreta cruciferae* Goeze			
Brinjal shoot and fruit borer	*Leucinodes orbonalis* Guenée	Pyralidae	Heterocera	Lepidoptera
Cutworm moth	*Agrotis ipsilon* Hufnagel	Noctuidae		

Abundance of the insect pests: Number of insects were variable in the field. Field observations revealed that cotton aphid (208) was most abundant which was followed by green leafhopper (168), mealybug (158.4) and whitefly (24.6) while cutworm moth (0.8) was least abundant followed by squash bug (1.2), plant hopper (1.4), flea beetle (2), epilachna beetle (2.4), brinjal shoot and fruit borer (2.8) and leaf beetle (3.2) (Fig. 2).

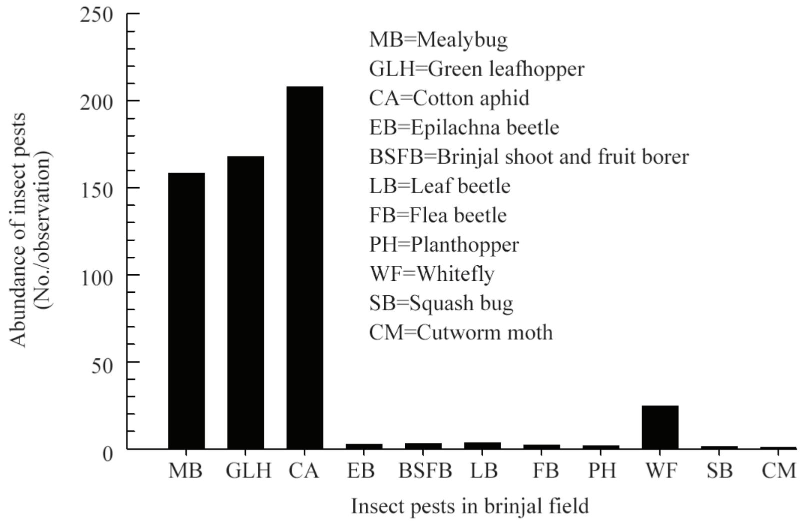

Fig. 2. Abundance of insect pests in the brinjal field. The number represent insect pests from each observation conducted in 30 plants.

Considering the number of insect pest plant^{-1} observation^{-1}, cotton aphid (6.93 insect plant^{-1} observation^{-1}) was most abundant which was followed by green leafhopper (5.6 insect plant^{-1} observation^{-1}), mealybug (5.28 insect plant^{-1} observation^{-1}) and whitefly (0.82 insect plant^{-1} observation^{-1}) among the major insect pests (Fig. 3).

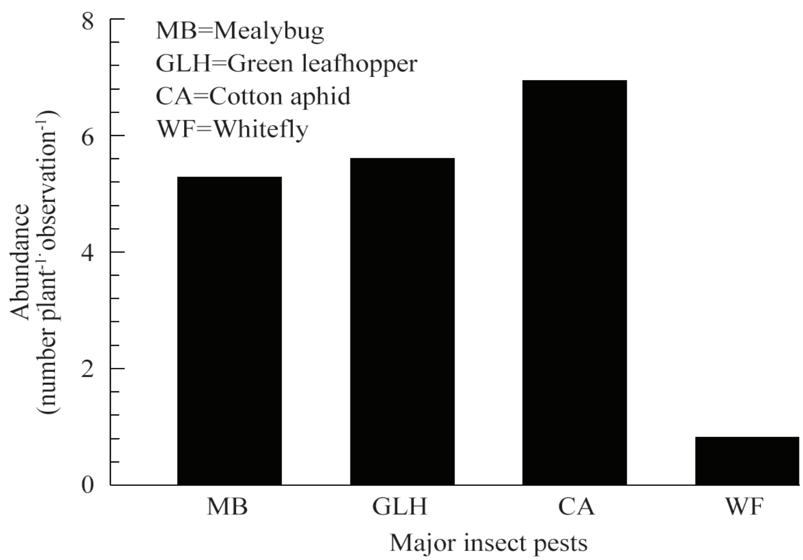

Fig. 3. Abundance (number plant^{-1} observation^{-1}) of major insect pests in the brinjal plants.

Among the minor pests, cutworm was least abundant (0.027 insect plant^{-1} observation^{-1}) which was followed by squash bug (0.04 insect plant^{-1} observation^{-1}), plant hopper (0.047 insect plant^{-1} observation^{-1}), flea beetle (0.067 insect plant^{-1} observation^{-1}), epilachna beetle (0.08 insect plant^{-1} observation^{-1}), brinjal shoot and fruit borer (0.093 insect plant^{-1} observation^{-1}) and leaf beetle (0.107 insect plant^{-1} observation^{-1}) (Fig. 4). Therefore, cotton aphid, green leafhopper, mealybug and whitefly can be considered as major pest and epilachna beetle, brinjal shoot and fruit borer, leaf beetle, flea beetle, plant hopper, squash bug and cutworm moth can be treated as minor pests.

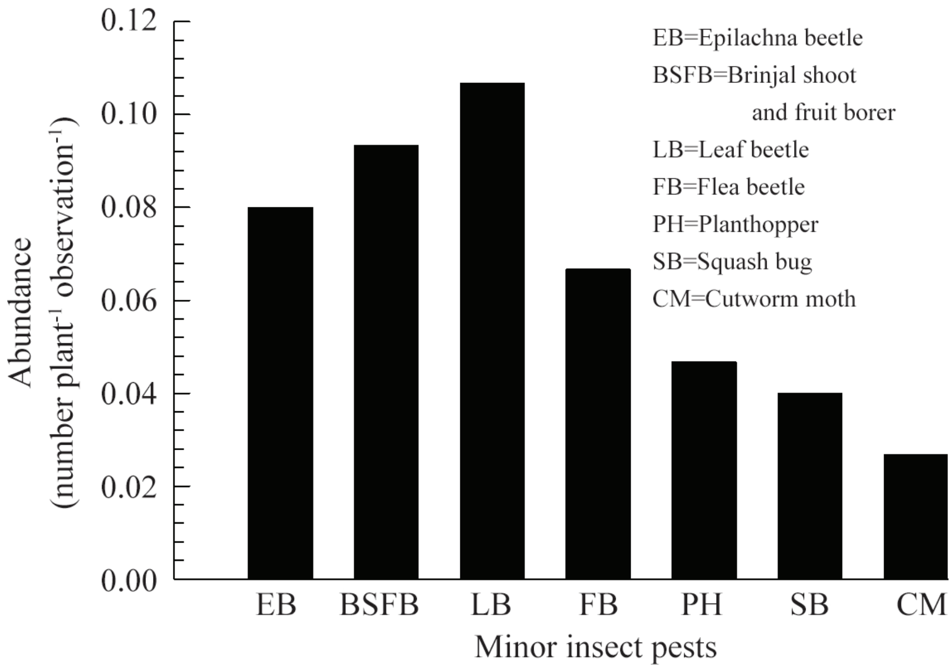

Fig. 4. Abundance (number/plant/observation) of minor insect pests in the brinjal plants.

Relative abundance of insect pests in the field: From the prevalent insect pests, relative abundance (%) was determined. Maximum relative abundance was recorded for cotton aphid (36.31%) which was followed by green leafhopper (29.33%), mealybug (27.65%), whitefly (4.29%), leaf beetle (0.56%), brinjal shoot and fruit borer (0.49%), epilachna beetle (0.42%), flea beetle (0.35%), plant hopper (0.24%), squash bug (0.21%) and cutworm moth (.14%) (Fig. 5). So, based on the abundance, the insect pests can be arranged as cotton aphid > green leafhopper > mealybug > whitefly > leaf beetle > brinjal shoot and fruit borer > epilachna beetle > flea beetle > plant hopper > squash bug > cutworm moth.

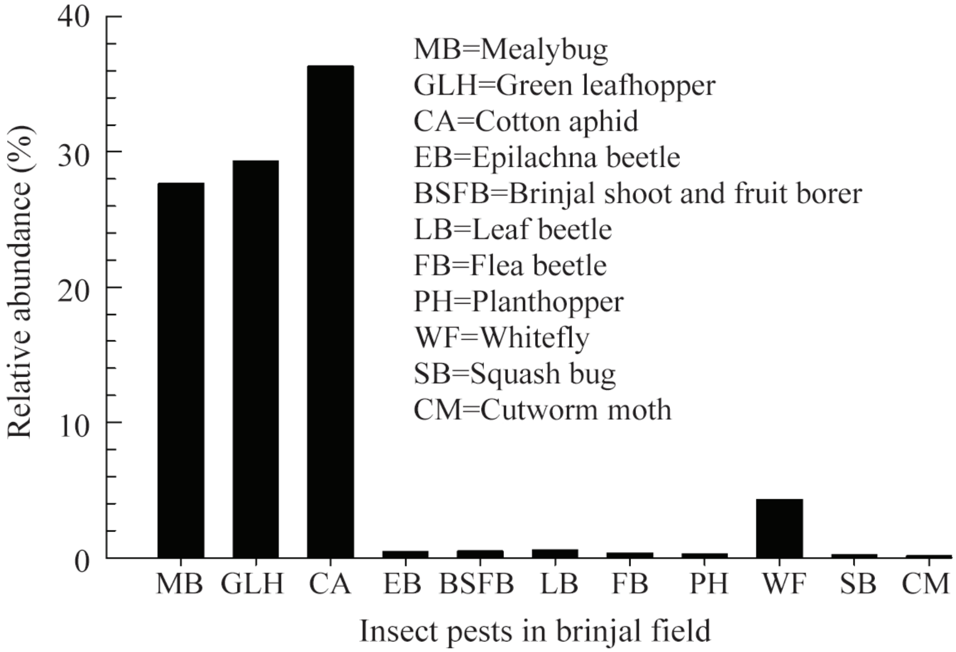

Fig. 5. Relative abundance (%) of insect pests in the brinjal field.

DISCUSSION

This study was conducted during May to September 2024 at Babugonj of Barisal district and recorded 11 insect pests from brinjal field. Among these, cotton aphid (6.93 insects plant^{-1} observation^{-1}), green leafhopper (5.60 insect plant^{-1} observation^{-1}), mealybug (5.28 insects plant^{-1} observation^{-1}) and whitefly (0.82 insect plant^{-1} observation^{-1}) were major while epilachna beetle (0.08 insect plant^{-1} observation^{-1}), brinjal shoot and fruit borer (0.093 inset plant^{-1} observation^{-1}), leaf beetle (0.11 insect plant^{-1} observation^{-1}), flea beetle (0.07 insect plant^{-1} observation^{-1}), plant hopper (0.05 insect plant^{-1} observation^{-1}), squash bug (0.04 insect plant^{-1} observation^{-1}) and cutworm moth (0.03 insect plant^{-1} observation^{-1}) were minor. However, green leafhopper and whitefly were also recorded in dwarf bean field in this area during summer season (Mollah and Khatun 2026).

Ghosh *et al.* (2022) conducted research at Sher-e-Bangla Agricultural University, Dhaka during November 2018 to April 2019 and recorded 7 insect pests of which brinjal shoot and fruit borer, epilachna beetle, whitefly, aphid and jassid were major insect pests but mealy bug and green leafhopper was minor insect pests. Das *et al.* (2023) conducted a study at Sylhet during October 2019 to March 2020 and recorded 6 insect pests and their relative abundance was: aphid > epilachna beetle > leaf roller > jassid > whitefly > brinjal shoot and fruit borer.

Another study at Jashore conducting during November 2018 to April 2019 reported 9 insect pests in the brinjal field of which brinjal shoot and fruit borer, epilachna beetle and jassid were major insect pests while whitefly, aphid, mealybug, green leafhopper, leaf roller and leaf beetle were minor insect pests (Ghosh *et al.* 2021). From the above information, it can be concluded that brinjal shoot and fruit borer, aphid, jassid/green leafhopper, whitefly and epilachna beetle were common in all locality and season although the level of abundance and severity varied among them. However, mealybug appeared as a major insect pest in summer season only in Barisal while infestation of brinjal shoot and fruit borer was relatively less in Barisal compared to Jashore and Dhaka.

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ECO-FRIENDLY MANAGEMENT APPROACHES OF MAJOR INSECT PESTS IN CAULIFLOWER

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ABSTRACT

In Bangladesh, the cultivation of cauliflower (*Brassica oleracea* L. *var. botrytis*) faces critical challenges from insect pest infestations, which lead to substantial reductions in both marketable yield and curd quality. This study aimed to evaluate the efficacy of five eco-friendly management approaches against major cauliflower pests and their impact on natural enemies and economic returns. The field experiment was conducted at Gazipur Agricultural University during the *Rabi season* (November 2023 to January 2024) using a Randomized Complete Block Design (RCBD) with three replications. Treatments included Vermitec 1.8 EC (Abamectin) @ 1.2 mL L^{-1} of water, Tracer 45 SC (Spinosad) @ 0.4 ml L^{-1} of water, Bio-Action 1.5 SL (Matrine) @ 1.5 mL L^{-1} of water, Phytoclean (Potassium salt of fatty acid 40%) @1.5 mL L^{-1} of water, Proclaim 5 SG (Emamectin Benzoate) @ 1 mL L^{-1} of water as an untreated control. Among the treatments, Tracer 45 SC (Spinosad) @ 0.4 ml L^{-1} was the most effective, resulting in the lowest number of diamondback moth (1.7 ± 0.0/head) and prodania caterpillar (1.5 ± 0.0 $head^{-1}$), lowest head infestation rates (3.9% by number and 3.5% by weight), highest yield (29.9 ± 0.4 t ha^{-1}), and maximum MBCR (8.3). Three applications of Tracer 45 SC (Spinosad) @ 0.4 ml L^{-1} was found as an effective, economically viable, and environmentally sustainable strategy for managing major cauliflower pests in Bangladesh, ensuring high productivity and conserving beneficial arthropods.

Keywords: Biopesticides, Diamondback moth, Prodania caterpillar, Eco-friendly management, Spinosad, BARI Fulkopi-1

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INTRODUCTION

Cauliflower (*Brassica oleracea* L. *var. botrytis*) is a globally significant cruciferous vegetable, prized for its high nutrient density, including dietary fiber, folate, and essential vitamins (A, C, and K). In Bangladesh, it is a cornerstone of winter vegetable production, ranking ninth globally and contributing significantly to the rural economy (FAOSTAT 2021, BBS 2023). Beyond its nutritional value, cauliflower contains bioactive compounds like Indole-3-carbinol, which offer protective benefits against chronic diseases and certain cancers (Fageria *et al*. 2010).

Despite its economic and nutritional importance, cauliflower yields in Bangladesh remain below potential. The primary constraint is a complex of approximately 24 insect pest species that can cause marketable yield losses ranging from 50% to 80% (Shankar *et al*. 2016). Among these, the tobacco caterpillar (*Spodoptera litura* Fab.) and the diamondback moth (DBM) (*Plutella xylostella* L.) are the most devastating. *S. litura* is a highly polyphagous pest capable of complete defoliation, resulting in yield losses of up to 100% under severe outbreaks (Tuan *et al*. 2014). Similarly, *P. xylostella* larvae cause characteristic "windowing" damage, which can compromise up to 90% of global brassica production (Verkerk and Wright 1996). Additionally, sap-sucking pests like aphids act as vectors for viral diseases, further reducing crop vigor and quality.

Historically, farmers have relied almost exclusively on synthetic chemical insecticides to manage these pests. However, indiscriminate application has led to the development of insecticide resistance, environmental degradation, and significant health risks due to chemical residues (Abbas *et al*. 2014). The disruption of natural enemy populations and pollinators further highlights the unsustainability of current chemical-intensive practices.

Consequently, there is an urgent need for bio-rational or eco-friendly management strategies that prioritize environmental safety and consumer health without sacrificing efficacy. Integrated management packages using bio-control agents and bio-pesticides offer a sustainable alternative. The present study was therefore conducted to evaluate the effectiveness of selected bio-rational approaches against major cauliflower pests and to determine their economic viability through benefit-cost ratio analysis.

MATERIALS AND METHODS

Experimental design and cultivation of crop: The study was set in the field under the Department of Entomology, Gazipur Agricultural University (GAU), Gazipur during the month of November 2023 to January 2024. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of equal size. The Seed of BARI Fulkopi-1(Rupa) was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur for this experiment. Seeds were sown in the seed bed measuring 3m x1m was at the nursery bed. Around thirty to forty days old seedlings were transplanted. The unit plot size was 3m×2m and plant to plant distance was 60 cm and row to row distance was 45 cm.

Treatments and methods of application: Five treatments viz., Vermitec 1.8 EC (Abamectin) @ 1.2 mL L^{-1} of water, Tracer 45 SC (Spinosad) @ 0.4 ml L^{-1} of water, Bio-Action 1.5 SL (Matrine) @ 1.5 mL L^{-1} of water, Phytoclean (Potassium salt of fatty acid 40%) @1.5 ml L^{-1} of water, Proclaim 5 SG (Emamectin Benzoate) @ 1 mL L^{-1} of water was an untreated control (application of tap water only) were evaluated on the basis of pest infestation and reduction of cauliflower production.

All the insecticides were collected from local market of Gazipur district. The insecticide mixture in the spray machine was shaken well and covered spray by a knapsack sprayer. Before spraying, the spray machine was calibrated to find out the required quantity of spray material for 3 plots. During the entire cropping season, a total of 3 sprays of insecticides was done, among them 2 were applied at vegetative stages and another 1 was applied after head formation. The spraying was done early in afternoon to avoid bright sunlight and drift caused by strong wind and adverse effect on pollinating bees.

Data collection and analysis: Data were collected some pre-selected parameters, such as insect pests and natural enemies with seasonal fluctuation, rate of leaf infestation by insect pests, number of infested, healthy and total heads, Yield (t ha^{-1}) and marginal benefit cost ratio analysis for different treatments. The observations on the incidence of insect pests and their natural enemies were counted visually with the help of magnifying lens at 10 days interval recorded from their appearance on plants till harvest. Sample was taken from 5 plants randomly and then converted to 18 plants (3×2 m^2) for expressing rate of plant infestation and number of arthropods pests per plot. For obtaining head yield (t ha^{-1}), the weights of healthy, infested, and total curd of all harvests were taken plot-wise. The yield of healthy, infested, and total curds obtained were transformed into curds yield in ton per hectare. The weight of infested pods was recorded from the total weight of the harvested curd for each plot and the percent yield loss was calculated.

The economic analysis or Marginal Benefit Cost Ratio (MBCR) was calculated on the basis of total expenditure of the respective treatment along with the total return from that particular treatment (Ali *et al*. 1996). Data were analyzed by using SPSS software for analysis of variance. ANOVA was done by F variance test (Gomez and Gomez 1984) and the mean comparisons were performed by Tukey HSD posthoc statistics.

RESULTS AND DISCUSSION

The infestation rates of sucking pests as affected by eco-friendly management approach: From Table 1, the highest rate of leaf infestation by jassid was recorded in the untreated control plot (71.7±3.4%) at both 3 and 7 days after treatment (DAT), indicating a severe infestation in the absence of any pest control. Among the treated plots, Bio-Action 1.5 SL showed a comparatively high jassid infestation (38.7±0.3%) and was significantly lower than the untreated control. In contrast, the lowest and statistically similar jassid infestations were recorded in Phytoclean (9.6±0.1%), Vermitec 1.8 EC (9.7±0.1%), Tracer 45 SC (11.3±0.1%), and Proclaim 5 SG (17.0±0.2%) at treated plot both 3 and 7 DAT and all showing effective suppression of jassid infestation. In case of aphid infestation, the untreated control again exhibited the highest rate of plant infestation, with 26.6±1.2% at 3 DAT and 29.2±1.2% at 7 DAT. The lowest and statistically similar infestations were observed in Phytoclean (1.0±0.0% at 3 DAT and 0.7±0.0% at 7 DAT), Bio-Action 1.5 SL (4.3±0.1% at 3 DAT and 3.0±0.1% at 7 DAT), Tracer 45 SC (5.3±0.1% at 3 DAT and 4.0±0.1% at 7 DAT), and Proclaim 5 SG (7.0±0.1% at 3 DAT and 5.6±0.1% at 7 DAT) treated plots. Vermitec 1.8 EC showed moderate control of aphids, with 11.3±0.2% and 9.9±0.2% infestation at 3 and 7 DAT, respectively, which was significantly lower than the untreated control.

In terms of overall effectiveness against both jassid and aphid infestations, Phytoclean and Tracer 45 SC demonstrated consistently superior performance across both observation periods. Partially similar findings were reported by Ghosh & Chakraborty (2015), who found that Spinosad 45 SC achieved 79.77% suppression of jassid, with efficacy comparable to Imidacloprid. Likewise, Ghosh *et al*. (2009) observed 71.76% suppression of aphid on lady's finger by Spinosad 45 SC at 1.0 ml per 3 L, followed by Polygonum extract (7.0%) with 59.00% suppression.

Table 1. Effect of different eco-friendly management approaches against aphid and jassid of cauliflower grown during *Rabi season* 2023-24

Treatment	Rate of leaf infestation (%) by jassid		Rate of plant infestation (%) by aphid	
	3 DAT	7 DAT	3 DAT	7 DAT
Vermitec 1.8 EC	9.7±0.1c	9.7±0.1c	11.3±0.2b	9.9±0.2b
Tracer 45 SC	11.3±0.1c	11.3±0.1c	5.3±0.1c	4.0±0.1c
Bio-Action 1.5 SL	38.7±0.3b	38.7±0.3b	4.3±0.1c	3.0±0.1c
Phytoclean	9.6±0.1c	9.6±0.1c	1.0±0.0c	0.7±0.0c
Proclaim 5 SG	17.0±0.2c	17.0±0.2c	7.0±0.1c	5.6±0.1c
Untreated control	71.7±3.4a	71.7±3.4a	26.6±1.2a	29.2±1.2a

Means within a column followed by same letter(s) are not significantly different ($P=0.05$) according to Tukey HSD posthoc statistic at < 0.05.

The infestation rates of chewing pests as affected by eco-friendly management approach: Table 2 showed the highest number of DBM (5.8±0.0 larvae head^{-1}) and was recorded in untreated control plot, followed by Vermitec 1.8 EC (4.0±0.0 larvae head^{-1}), Bio-Action 1.5 SL (3.9±0.0 larvae head^{-1}) and Phytoclean (3.5±0.0 larvae head^{-1}) treated plots. Proclaim 5 SG and Tracer 45 SC treated plots showed the lowest and statistically similar larval abundance per head of cauliflower (1.5±0.0 and 1.7±0.0 larva head^{-1}, respectively). The highest number of *Spodoptera litura* (Prodania caterpillar) larvae (3.6±0.0 head^{-1}) was also recorded in the untreated control plot. In contrast, the lowest and statistically similar numbers of caterpillars were observed in Tracer 45 SC (1.5±0.0) and Proclaim 5 SG (1.8±0.0) treated plots. The plots treated with Vermitec 1.8 EC (2.7±0.0), Phytoclean (2.5±0.0), and Bio-Action 1.5 SL (2.4±0.0) showed statistically similar but significantly lower caterpillar abundance compared to the untreated control (Table 2).

The highest rate of head infestation (33.3±0.4%) was recorded in the untreated control plot, while the lowest infestation rate was observed in the Tracer 45 SC treated plot (6.1±0.0%). The treatments with Bio-Action 1.5 SL (23.7±0.2%), Phytoclean (21.2±0.2%), and Vermitec 1.8 EC (19.4±0.2%) resulted in statistically similar head infestation rates, which were significantly higher than that of Proclaim 5 SG (16.3±0.2%) but considerably lower than the untreated control.

The present findings are supported by Hasan *et al.* (2023), who also obtained that the treatment using Tracer 45 SC (Spinosad) @ 0.4 g L^{-1} of water showed the best results, resulting in the lowest number of diamondback moths (0.4 per head) and tobacco caterpillars (0.2 $head^{-1}$) as well as the lowest rate of head infestation in cabbage.

Table 2. Effect of different eco-friendly management approaches on percent head infestation and number of diamondback moth (DBM) and Prodania caterpillar on cauliflower grown during *Rabi season* 2023-24

Treatment	No. of DBM larvae/head	No. of Prodania caterpillar $head^{-1}$ or $plant^{-1}$	Rate (%) of head infestation (n/n)
Vermitec 1.8 EC	4.0±0.0b	2.7±0.0b	19.4±0.2b
Tracer 45 SC	1.7±0.0c	1.5±0.0c	6.1±0.0d
Bio-Action 1.5 SL	3.9±0.0b	2.4±0.0b	23.7±0.2b
Phytoclean	3.5±0.0b	2.5±0.0b	21.2±0.2b
Proclaim 5 SG	1.5±0.0c	1.8±0.0c	16.3±0.2c
Untreated control	5.8±0.0a	3.6±0.0a	33.3±0.4a

Means within a column followed by same letter(s) are not significantly different (P=0.05) according to Tukey HSD posthoc statistic at < 0.05.

Effect of eco-friendly management approach on natural enemies: The highest and statistically similar abundance of lady bird beetle was recorded in the untreated control plot (33.8±1.4), followed by Vermitec 1.8 EC (32.7±1.3), Proclaim 5 SG (31.2±1.1) and Tracer 45 SC (25.0±1.4%) treated plots (Table 3). The lowest and statistically similar numbers were observed in Bio-Action 1.5 SL (22.9±0.9) and Phytoclean (20.6±0.9) treated plots.

In case of syrphid fly, there was no significant variation among the treatments, including the untreated control. The abundance ranged from 1.7±0.0 to 3.0±0.0 per plot, indicating a uniform distribution across all plots. The highest and statistically similar abundance of black ant was found in the untreated control (107.9±5.6), Vermitec 1.8 EC (101.7±4.2), and were statistically similar to Tracer 45 SC (96.7±3.4) and Proclaim 5 SG (96.2±3.7) treated plots. The lowest abundance was recorded in Bio-Action 1.5 SL (88.6±3.1) and Phytoclean (87.4±2.9) treated plots, which were statistically similar and significantly lower than the untreated control. For spiders, no significant variation was observed among the treatments, with population ranging from 5.3±0.0 to 8.6±0.0 per plot across all treated and untreated plots. In the case of mirid bug, although the highest abundance was found in Proclaim 5 SG and the untreated control (both 2.3±0.0) and all treatments showed statistically similar populations, ranging from 1.0±0.0 to 2.3±0.0 per plot. These results suggest that eco-friendly treatments, especially Vermitec 1.8 EC, proclaim 5 SG, and Tracer 45 SC, were able to suppress pests while conserving beneficial arthropod populations like lady bird beetles, black ants, and mirid bugs during the *Rabi season*.

The present findings were in agreement with Efad *et al*. (2021) who found that Azadirachtin, Spinosad and Abamectin were bio-rational with the beneficial arthropods like lady bird beetle, syrphid fly, black ant and spider's presence on field during entire season in brinjal. In their study, the abundance of lady bird beetles and black ants showed no significant statistical difference between Spinosad- and Abamectin-treated plots and the untreated control, while no statistical variation was found in syrphid fly and spider populations across all treatments.

Table 3. Effect of different eco-friendly management approaches on abundance of beneficial arthropods per plot (3×2m^2) during entire cropping season (Mean of 12 observations)

Treatments	No. of lady bird beetle plot^{-1}	No. of syrphid fly plot^{-1}	No. of black ant plot^{-1}	No. of spider's plot^{-1}	No. of mirid bug plot^{-1}
Vermitec 1.8 EC	32.7±1.3a	2.3±0.0a	101.7±4.2a	8.6±0.0a	1.7±0.0a
Tracer 45 SC	25.0±1.4a	2.3±0.0a	96.7±3.4ab	7.6±0.0a	1.7±0.0a
Bio-Action 1.5 SL	22.9±0.9b	1.7±0.0a	88.6±3.1b	6.0±0.0a	1.0±0.0a
Phytoclean	20.6±0.9b	1.7±0.0a	87.4±2.9b	5.3±0.0a	1.0±0.0a
Proclaim 5 SG	31.2±1.1a	3.0±0.0a	96.2±3.7ab	6.6±0.0a	2.3±0.0a
Untreated control	33.8±1.4a	2.3±0.0a	107.9±5.6a	8.0±0.0a	2.3±0.0a

Means within a column followed by same letter(s) are not significantly different (P=0.05) according to Tukey HSD posthoc statistic at < 0.05

Effect of eco-friendly management approach on cauliflower head quality: The lowest number of healthy heads per plot (12.0±0.2) was recorded from the untreated control plot. On the other hand, the highest number of healthy heads per plot (17.3±0.3) was obtained from the Tracer 45 SC treated plot. The plots treated with Proclaim 5 SG (15.7±0.3), Vermitec 1.8 EC (15.0±0.3), Phytoclean (14.7±0.3), and Bio-Action 1.5 SL (14.3±0.3) showed statistically similar results and had a higher number of healthy heads per plot than the untreated control (Table 4). In terms of the number of infested heads per plot, the highest number (6.0±0.0) was found in the untreated control plot, whereas the lowest (0.7±0.0) was observed in the Tracer 45 SC treated plot. The plots treated with Proclaim 5 SG (2.3±0.0), Vermitec 1.8 EC (3.0±0.0), Phytoclean (3.3±0.0), and Bio-Action 1.5 SL (3.7±0.0) showed statistically similar results and were significantly lower than the untreated control.

The lowest weight of healthy heads per plot (18.5±0.3 kg) was recorded in the untreated control plot, while the highest weight (29.9±0.4 kg) was obtained from the Tracer 45 SC treated plot. This was followed by Proclaim 5 SG (26.1±0.4 kg), Vermitec 1.8 EC (23.8±0.3 kg), Phytoclean (23.2±0.4 kg), and Bio-Action 1.5 SL (22.4±0.4 kg) and all were statistically similar but significantly the higher weights of healthy heads compared to the untreated control plot.

For the weight of infested heads per plot, the lowest (1.1±0.0 kg) was recorded in the Tracer 45 SC treated plot. The treatments Proclaim 5 SG (3.9±0.1 kg), Vermitec 1.8 EC (4.7±0.1 kg), Phytoclean (5.2±0.1 kg), and Bio-Action 1.5 SL (5.7±0.1 kg) resulted in statistically similar weights of infested heads, all of which were lower than the untreated control plot. The highest weight of infested heads (9.2±0.3 kg) was observed in the untreated control (Table 4).

Effect of eco-friendly management approach on yield and yield contributing traits: The effect of different eco-friendly management approaches on yield and yield contributing characters of cauliflower was presented in Table 5. The highest yield (29.9±0.4 t ha^{-1}) was recorded from the Tracer 45 SC treated plot, followed by Proclaim 5 SG (26.1±0.4 t ha^{-1}) and Vermitec 1.8 EC (23.8±0.3 t ha^{-1}) treated plots. The lowest yield (18.5±0.5 t ha^{-1}) was observed in the untreated control plot.

Table 4. Effect of different eco-friendly management approaches on number and weight of cauliflower head per plot (3×2 m^2) grown during *Rabi season* 2023-24

Treatment	Number of healthy head plot^{-1}	Number of infested head plot^{-1}	Weight of healthy head plot^{-1} (kg)	Weight of infested head plot^{-1} (kg)
Vermitec 1.8 EC	15.0±0.3ab	3.0±0.0b	23.8±0.3b	4.7±0.1b
Tracer 45 SC	17.3±0.3a	0.7±0.0c	29.9±0.4a	1.1±0.0c
Bio-Action 1.5 SL	14.3±0.3ab	3.7±0.0b	22.4±0.4b	5.7±0.1b
Phytoclean	14.7±0.3ab	3.3±0.0b	23.2±0.4b	5.2±0.1b
Proclaim 5 SG	15.7±0.3ab	2.3±0.0b	26.1±0.4b	3.9±0.1b
Untreated control	12.0±0.2b	6.0±0.0a	18.5±0.3c	9.2±0.3a

Means within a column followed by same letter(s) are not significantly different (P=0.05) according to Tukey HSD posthoc statistic at < 0.05

The weight of single head was not statistically different in the plots treated with different insecticides including untreated control plot which ranged from 1.5±0.0 kg to 1.7±0.0 kg (Table 5). Regarding head diameter, the lowest diameter of cabbage head was recorded in untreated control plot (15.1±0.0cm) which was not statistically different from the diameter of cauliflower head obtained from plots treated with Tracer 45 SC (19.9±0.0cm), Proclaim 5 SG (18.8±0.0cm), Phytoclean (17.0±0.0cm) and Bio-Action 1.5 SL (18.6±0.0cm).

A similar finding was reported by Shapla (2021) and found that the statistically significant highest yield of cauliflower (51.48 t ha^{-1}) was recorded from Spinosad 45SC treatment followed by Abamectin 1.8EC (47.26 t ha^{-1}), Cypermethrin 10EC (43.58 t ha^{-1}) and Sevin 85SP (41.41 t ha^{-1}) respectively and the lowest yield of cauliflower was obtained from untreated control plot (38.5 t ha^{-1}). The yield of cauliflower per hectare reported by Shapla (2021) was comparably higher than in this present study which could be attributed to differences in environmental conditions, variety, or agronomic practices.

The higher yields in case of Spinosad have also been showed by Gautam (2022). Similarly, Sapkota *et al*. (2020) reported that Spinosad @ 0.5 mL/L resulted in the largest curd diameter (16.10 cm) and the highest yield (22.02 t ha^{-1}) among all treatments. This was followed by Emamectin benzoate @ 0.6 g/L, which recorded a curd diameter of 14.77 cm and a yield of 19.29 t ha^{-1}. Treatments with BEFCU @ 1:5 and Neemix @ 3 mL/L produced moderate curd sizes of approximately 14.49 cm and 14.17 cm, with corresponding yields of 16.04 t ha^{-1} and 16.19 t ha^{-1}, respectively. The control treatment had the smallest curd diameter (13.37 cm) and the lowest yield (13.76 t ha^{-1}). These findings further reinforce the efficacy of Spinosad in improving both curd quality and yield of cauliflower.

Table 5. Effect of different eco-friendly management approaches on yield and yield contributing character of cauliflower grown during *Rabi season* 2023-24

Treatments	Single head weight (kg)	Diameter of head (cm)	Yield (t ha^{-1})
Vermitec 1.8 EC	1.6±0.0a	18.4±0.0a	23.8±0.3bc
Tracer 45 SC	1.7±0.0a	19.9±0.0a	29.9±0.4a
Bio-Action 1.5 SL	1.5±0.0a	18.6±0.0a	22.4±0.3c
Phytoclean	1.6±0.0a	17.0±0.0a	23.2±0.3c
Proclaim 5 SG	1.7±0.0a	18.8±0.0a	26.1±0.4b
Untreated control	1.5±0.0a	15.1±0.0a	18.5±0.5d

Means within a column followed by same letter(s) are not significantly different (P=0.05) according to Tukey HSD posthoc statistic at < 0.05

The percent increase in cauliflower yield over the untreated control under different eco-friendly management approaches were presented in Fig. 1. Among the treatments, the highest yield increase (61.6%) was observed in plots treated with Tracer 45 SC, followed by Proclaim 5 SG (41.1%) and Vermitec 1.8 EC (28.6%). Phytoclean and Bio-Action 1.5 SL also showed positive effects with 25.4% and 21.1% yield increases, respectively. The untreated control had no increase in yield (0.0%). These results indicate that all eco-friendly treatments improved yield over the untreated control, with Tracer 45 SC showing the most effective performance.

A similar trend was reported by Sapkota *et al*. (2020), who observed that Spinosad @ 0.5 mL/L resulted in the highest 60.03% increase over the untreated control, followed by Emamectin benzoate @ 0.6 g/L with a 40.19% increase over control. Moderate yield increases were recorded from Neemix @ 3 mL L^{-1} (17.66% over the untreated control) and BEFCU @ 1:5 (16.57% increase over the untreated control). which is consistent with the findings of the present study. This agreement strengthens the reliability of the present results and highlights the efficacy of eco-friendly insecticides, particularly Spinosad (Tracer 45 SC), in enhancing cauliflower yield. Similarly, Hasan *et al.* (2023), in a study on cabbage, reported that Tracer 45 SC resulted in the highest yield increase over untreated control (61.3%), followed by Proclaim 5 SG, Abom 1.8 EC, Fytomax PM, and NSKE which further supporting the efficacy of Spinosad-based treatments across cruciferous crops.

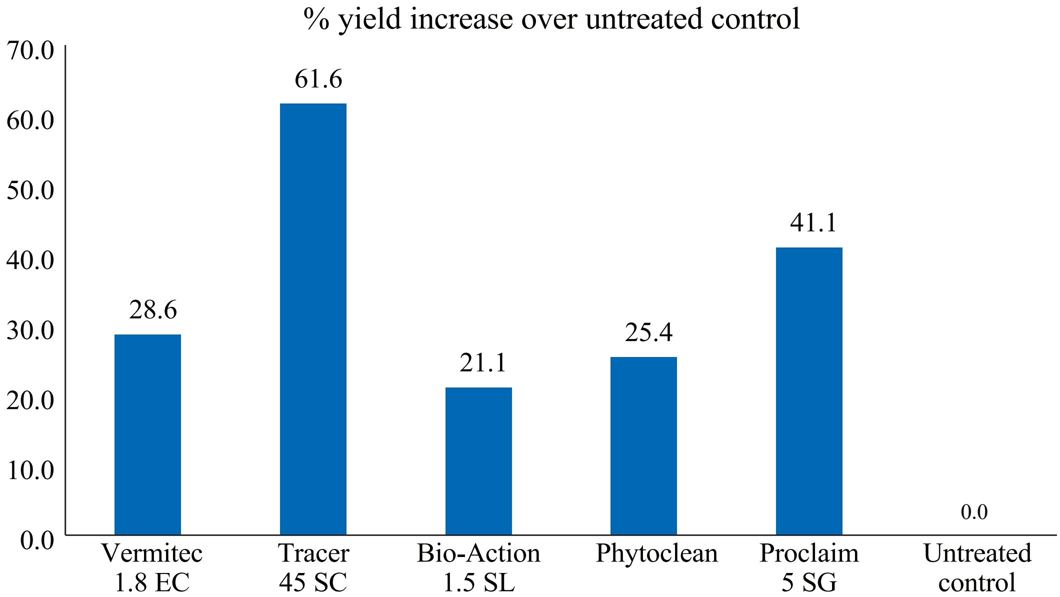

Fig. 1. Effect of different eco-friendly management approaches on % yield increase over untreated control of cauliflower grown during *Rabi season* 2023-24.

Economic analysis of different environment friendly approaches against insect pests in cauliflower: The details of the cost of pest management (Tk. ha^{-1}) under different eco-friendly approaches against arthropod pests in cauliflower grown during *Rabi season* 2023–24 is presented in Table 6. Management cost was the highest (Tk. 24,480.0) in Tracer 45 SC, followed by Bio-Action 1.5 SL with Tk. 19,080.0, and Vermitec 1.8 EC with Tk. 18,480.0. The lowest management cost (Tk. 17,880.0) was recorded in both Phytoclean and Proclaim 5 SG sprayed ones. As expected in Untreated control having no expenditure on pest management inputs or operations. The highest gross return was obtained from the treatment with Tracer 45 SC (Tk.

598,000.0 ha^{-1}), followed by Proclaim 5 SG (Tk. 522,000.0 ha^{-1}). In contrast, the lowest gross return was recorded in the untreated control (Tk. 370,000.0 ha^{-1}). Among the other treatments, Bio-Action 1.5 SL, Phytoclean, and Vermitec 1.8 EC yielded gross returns of Tk. 448,000.0 ha^{-1}, Tk. 464,000.0 ha^{-1}, and Tk. 476,000.0 ha^{-1}, respectively (Table 6). The highest net return (Tk. 573520.0 ha^{-1}) was recorded in Tracer 45 SC, followed by Tk. (504120.0 ha^{-1}) in Proclaim 5 SG and the lowest (Tk. 370000.0 ha^{-1}) in Untreated control, followed by Tk. 428920.0 ha^{-1} in Bio-Action 1.5 SL, Tk. 446120.0 ha^{-1} in Phytoclean and Tk. 457520.0 ha^{-1} in Vermitec 1.8 EC treatments (Table 6). The highest adjusted net return (Tk. 203520.0 ha^{-1}) was recorded in Tracer 45 SC followed by Tk. 134120.0 ha^{-1} in Proclaim 5 SG and the lowest (Tk. 58920.0 ha^{-1}) in Bio-Action 1.5 SL followed by Tk. 76120.0 ha^{-1} in Phytoclean and Tk. 87520.0 ha^{-1} in Vermitec 1.8 EC (Table 6).

The highest MBCR of 8.3 was obtained from the plots treated with Tracer 45 SC and the second highest benefit cost ratio (7.5) was recorded from the plot treated with Proclaim 5 SG, followed by Vermitec 1.8 EC sprayed plot (4.7) and Phytoclean sprayed plot (4.3). The lowest benefit cost ratio (3.1) was found with the Bio-Action 1.5 SL treated plot (Table 6).

Table 6. Marginal benefit cost ratio (MBCR) analysis of selected eco-friendly management approaches against arthropod pests in cauliflower grown during *Rabi season* 2023-24

Treatments	Management cost (Tk)	Gross return (Tk)	Net return (Tk)	Adjusted net return (Tk)	MBCR
Vermitec 1.8 EC	18480.0	476000.0	457520.0	87520.0	4.7
Tracer 45 SC	24480.0	598000.0	573520.0	203520.0	8.3
Bio-Action 1.5 SL	19080.0	448000.0	428920.0	58920.0	3.1
Phytoclean	17880.0	464000.0	446120.0	76120.0	4.3
Proclaim 5 SG	17880.0	522000.0	504120.0	134120.0	7.5
Untreated control	0.0	370000.0	370000.0	0.0	-

Market value of Cauliflower= Tk. 20.0 Kg^{-1}; cost of Vermitec 1.8 EC per spray= 5000.0 Tk ha^{-1}, Tracer 45 SC per spray = 7000.0 Tk ha^{-1}, Bio-Action 1.5 SL per spray = 5200.0 Tk ha^{-1}, Phytoclean per spray = 4800.0 Tk ha^{-1}, Proclaim 5 SG per spray = 4800.0 Tk ha^{-1}, Labor cost= 550.0 Tk day^{-1}, No. of spray=3, sprayer rent= 30.0 Tk day^{-1}.

CONCLUSION

The comparative evaluation of five eco-friendly management approaches demonstrated that the lowest number of diamondback moth (1.7 ± 0.0 per head), tobacco caterpillar (1.5 ± 0.0 per head); and the lowest rate of head infestation by tobacco/prodania caterpillar and/or diamondback moth (3.9% by number and 3.5% by weight); as well as the highest yield (29.9±0.4 t ha^{-1}) and Marginal benefit cost ratio (MBCR) (8.3) was recorded with the eco-friendly management approach comprising 3 spays of Tracer 45 SC (Spinosad) @ 0.4 g L^{-1} of water. Therefore, management approach comprising 3 spays of Tracer 45 SC (Spinosad) @ 0.4 g L^{-1} of water can be considered an effective, economically viable, and eco-friendly tool for suppressing diamondback moth, tobacco caterpillar as well as other cauliflower pests such as flea beetle, aphid, and jassid and also ensuring reduced head infestation and higher profitability.

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OPTIMIZATION OF REARING PROTOCOL FOR EGG AND LARVAL PARASITOIDS WITH THEIR ASSOCIATED HOSTS AND EVALUATING THE EFFICACY OF *BRACON HEBETOR* AGAINST FALL ARMYWORM IN MAIZE

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ABSTRACT

The Fall Armyworm (FAW), *Spodoptera frugiperda,* poses a significant threat to maize production in Patuakhali and other regions globally. To mitigate this problem, the present study focused on developing a rearing protocol for two potential biological control agents: the larval parasitoid, *Bracon hebetor*, and the egg parasitoid, *Trichogramma chilonis* and the efficacy of *Bracon hebetor* was carried out in the bio-control laboratory of Entomology department, PSTU during October 2022 to September 2023. Laboratory trials were conducted to evaluate the efficacy of the reared parasitoids against FAW larvae of different instars. The rearing protocols of *B. hebetor* were established utilizing the associated hosts, *Galleria mellonella* (wax moth) and *Corcyra cephalonica* (rice moth), respectively. The rearing protocol development involved optimizing environmental conditions, nutritional requirements, and host-rearing methods to ensure large parasitoid populations. Observations on parasitism rates, and FAW population suppression were recorded to assess the effectiveness of the biological control strategy. The results demonstrated the potential for *Bracon hebetor* as biological control agent against FAW. The highest parasitism was found in 5th instar larvae which was about 96% while the lowest parasitism was found in 3rd instar larvae which was about 33%. In 4th instar mean parasitization was 6.33±1.52 which is about 63%. The parasitism of FAW by *B. hebetor* ranged from 20-40 % in net cage trial. The length and breadth of 6th instar larva of wax moth were 1.215 ± 0.13cm and 0.371 ± 0.03cm, respectively while the length and breadth of pupa were 2.13 ± 0.14cm and 0.33 ± 0.03cm, respectively. The length and breadth of 5th instar larva of fall armyworm were 3.66 ± 0.23cm and 0.372 ± 0.02cm while the length and breadth of pupa were 1.46 ± 0.05cm and 0.5 ± 0.00cm, respectively. Overall, the protocol development for rearing of larval and egg parasitoids and their efficacy against FAW provide valuable biological control strategies for managing FAW in maize fields and offer a sustainable alternative to chemical pesticides.

Keywords: Fall Armyworm, *Bracon hebetor, Corcyra cephalonica, Galleria mellonella,* maize, *Trichogramma chilonis*

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INTRODUCTION

Fall armyworm (FAW), *Spodoptera frugiperda* (Lepidoptera: Noctuidae), is an indigenous to the tropical and subtropical continents of South and North America. It was first discovered outside of its natural range in January 2016 in the Nigeria region of West Africa (Goergen *et al*. 2016). It is highly polyphagous insect pest that has invaded over 40 countries in Africa and Asia since 2016. FAW damaged 353 host plant species from 76 different plant families, with the Poaceae family being its preferred host (Montezano *et al.* 2018). The first report of FAW in Bangladesh was in November 2018. FAW larvae were first observed in a cabbage field on November 8, 2018 and adults were trapped in a maize field on November 23, 2018 (Alam *et al*. 2018). In recent years, the fall armyworm (FAW) has become a significant threat to maize production in Bangladesh. It is highly invasive pest that can cause significant damage to maize crops, leading to substantial economic losses. The FAW infestation had a devastating impact on maize production. The larvae feed on the leaves and stalks of maize plants, reducing yield and quality. In some cases, entire fields have been destroyed. The infestation has also led to increased costs for farmers, who have to spend more on pesticides and other control measures. Farmers are facing a number of challenges in controlling the pest infestation. In the absence of pesticides, FAW reduces maize production's profitability by an average of 37.7%. Bangladesh intends to stop importing maize by 2030, although its output still trails that of imports because of the growth of Bangladesh's chicken feed business, around 74% of the country's maize is currently farmed locally, with the remaining 26% imported at an annual cost of USD 0.4 billion to meet demand (Ullah *et al*. 2023). Pesticides are used by all farmers to suppress this pest. The use of chemical pesticides is one of the most common methods for controlling FAW. But the effectiveness of chemical pesticide is too much poor and there is no well-known chemical pesticide for controlling this pest in Bangladesh. However, use of chemicals has several drawbacks, including the development of resistance in pests, environmental pollution, and health hazards for humans and animals. These moth species have developed resistance to pesticides. In addition, because they leave residue in food products and in processing facilities where employees are exposed, pesticides pose a direct risk to human health and the environment (Fields and White 2002).

Thus, for sustainable pest management, tried-and-true agroecological techniques and bio-control agents are required. Biological control is an alternative method that has been gaining popularity in recent years. The use of parasitoids is one such method that has shown promising results in controlling FAW. Natural enemies like parasitoids are essential for controlling insect populations. The larval parasitoid *Bracon hebetor* and the egg parasitoid *Trichogramma chilonis* are two significant parasitoids are using in the management of lepidopteran pests. The need for pest management strategies that are environmentally benign was driven by the rising concern for environmental safety and the desire for pesticide-free food on a global scale. As a result of these varied pesticide-related environmental effects and emerging global trends that support conservation and the sustainable use of biological resources, interest in biological control has significantly increased (Farag *et al*. 2015). The development of non-chemical insect control strategies, such as cultural, physical, biological, varietal, biorational, and genetic control measures in place of conventional pesticides for the management of field pests and stored product insects, has received a lot of attention in recent years (Phillips 2006). The employment of natural enemies, such as parasitoids and predators, is one of these tactics that is crucial to IPM and offers numerous benefits over chemical control (Scholler and Flinn 2000). One of the potential biological control agents is *Bracon hebetor*, an ectoparasitoid that is gregarious and feeds primarily on Pyralidae (Lepidoptera) larvae to complete its larval development. A highly polyphagous parasitoid known as *B. hebetor* is found worldwide. It is simple to grow in a lab on fictitious hosts like *galeria menolella*. It has been successfully incorporated into IPM programmes. A productive gregarious larval parasitoid of numerous lepidopteran storage and vegetable pests is *Bracon hebetor* Say (Hymenoptera: *Bracon*idae). This parasitoid can be artificially released to control a variety of destructive pests, including *Leucinodes orbonalis*, *Spodoptera* sp., *Helicoverpa armigera*, *Maruca vitrata*, *Corcyra cephalonica*etc (Thanavendan and Jeyarani 2010, Amir-Maafi and Chi 2006) but can also parasitize hosts that are phylogenetically distant, like Coleoptera (Lopez *et al*. 2011). This parasitoid species can also parasitize a variety of pyralids from the family Crambidae and subfamily Galleriinae, such as the grass moth *Laetitia coccidivora*, the greater wax moth *Galleria mellonella*, and the rice moth *Corcyra cephalonica*, as well as non-pyralid moth larvae like the angoumois grain moth *Sitotroga cerealella* and the potato tuberworm (Krombein *et al*. 1979).

The greater wax moth (GWM) and other pyralid moth larvae in their fourth and fifth stages are attacked by the ecto-parasite *Bracon hebetor* Say (Hymenoptera: *Braconidae*). *Galleria mellonella* (L.) Pyralidae Lepidoptera (Awadallah *et al*.

1985). Variable quantities of eggs are then placed on or near the surface of the paralysed hosts by *Bracon hebetor* females after they have first paralyzed their host larvae by stinging them (Antolin *et al*. 1995). For the parasitoid to be released at the appropriate moment, pupae must be stored. This knowledge is particularly beneficial for mass-producing insects, especially for bio-control agents (Ashfak *et al*. 2011). So, there is need to be developed a rearing protocol of larval parasitoid, *Bracon hebetor* and its host wax moth, *Galaria melonella*. Considering above facts, this research work has been undertaken to develop rearing protocols for *B. hebetor* and *Trichogramma chilonis* with their associated host, wax moth (*Galeria mellonella*) and Rice moth (*Corcyra cephalonica)* and to evaluate the efficacy of *B. hebetor* against FAW.

MATERIALS AND METHODS

Mass rearing of larval parasitoid, *Bracon hebetor*: Techniques such as controlled temperature and humidity, suitable host provision, and monitoring of parasitoid development were implemented to enhance rearing efficiency. Mass rearing of *B. hebetor* parasitoid was done at Biocontrol lab, Entomology Department of Patuakhali Science and Technology and 5th to 6th instars wax moth, *Galleria mellonella* larvae were used as the host of *B. hebetor*.

Procedure of wax moth rearing: At first a parent stock of wax moth was developed in honeycomb in glass jars. Honeycomb wax was sterilized by electric autoclave at 125°C at 15 PSI for 60-70 minutes. The autoclaved wax is placed on a tray for cooling, then warm wax was given in ball shape and kept this ball for room temperature. About 200 to 250 g wax was taken in a glass jar and 20 to 30 adult male and female wax moth was released on this wax containing jar for egg laying then closed its mouth by black cloth. Adult wax moth was mate in jar and lay egg on wax. After 8 to 10 days first to second instar larvae of wax moth were release in the artificial diet (made with definite proportion of wheat flour, maize flour, milk, animal fat, sugar and yeast (Table 1) and autoclaved at 125°C and 1.5 PSI for 70 min).

Milk 1L, sugar 800gm, fat 250g and wax 300g were boiled together and made syrup. This solution was then mixed to the mixture of wheat 2kg and maize flour 2kg and

Table 1. Preparation of artificial diet for rearing wax moth

Name of ingredients	quantity
Wheat flour	2 kg
Maize flour	2 kg
Milk	1 L
Fat (mutton)	250 g
Sugar	800 g
Wax	300 g
Yeast	1.5 tea spoon full

yeast 1.5 tea spoon. Then the whole mixtures were autoclaved at 125°C temperature and 15 PSI for one hour. Then this diet kept in a bowl for room temperature then 1st to 2nd instar wax moth larvae were released on this.

Described amount of milk, sugar, fat and wax were boiled together and made syrup. This solution was then mixed to the mixture of wheat and maize flour and yeast. Then the whole mixtures were autoclaved at 125°C and 15 PSI for one hour. Then this diet kept in a bowl for room temperature then 1st to 2nd instar wax moth larvae were released on this. The larvae will attain full growth at 20 to 25 days later.

Procedure for mass rearing of *Bracon hebetor*: The full-grown larvae were transferred in a sterilized 3-4 litters plastic bottle (200 larvae /bottle) with a corrugated paper sheet. The full-fed larvae took position on the corrugated paper sheet for pupation. Then 100 adult *B. hebetor* (60 female and 40 male) were released in the plastic bottle with 10% honey solution as food. The opening end of the jar was closed with black cloth by a rubber band. Then the whole pot was covered with a black cloth to increase its parasitizing capacity. The wax moth larvae and *B. hebetor* were then kept in rack for 8-10 days for parasitism, egg laying, pupation and adult emergence of *B. hebetor*. The female parasitoids lay 8-12 eggs on ventral surface of the host larvae after paralyzing by stinging. It was observed that 100% parasitism of wax moth larvae occurred by *B. hebetor*. The duration of the egg stage of *B. hebetor* on host larva was 3-4 days, larval stage inside the host larva was 6-8 days, pupal stage outside the host larva was 5-6 days. Total adult longevity in the laboratory was 20-25 days (with honey as food). However, in nature adult *B. hebetor* can survive up to 45 days.

Mass rearing of egg parasitoids, *Trichogramma chilonis*: In the laboratory Rice moth *Corcyra cephalonica* (Table 2) were used as the host for mass rearing of *Trichogramma.* For mass rearing of *Trichogramma* spp. The following steps are followed

Table 2. Mass rearing of host insect rice moth, *Corcyra cephalonica*

At first artificial diet was made for rice moth *C. cephalonica* larvae.

Ingredient	Quantity
Maize flour	1 kg
Wheat flour	1 kg
Pea-flour (bason)	500 g

Described quantity of ingredient are mixed together then whole mixture was autoclaved at 125°C temperature at 15 PSI for 1 hour. After autoclaved this diet was kept at a bowl for room temperature. Then 2g or 3g eggs of rice moth were spread over the diet and covered the bowl with 64 meshes net.

This bowl was kept at untouched condition until adult emergence. After 4 to 5 days hatched and 28 to 33 days old adult rice moth come out (depends on temperature) then adult containing bowl kept inside a small net box for adult collection. 30 to 35 adult rice moths kept in a special plastic jar bottom of which was covered by a net. Then adult containing jar was kept on another jar, female moth lay eggs and these eggs fall down through the net and store at the jar. Eggs were collected and cleaned and were ready for rearing of *Trichogramma* spp.

Mass rearing of *Trichogramma* spp. preparation of trichocards: A coat of 10% gum arabic was applied on the cards and the eggs of *Corcyra* were sprinkled uniformly in a single layer with the aid of a strainer. The excess eggs pasted are removed gently by passing a brush over the card after sufficient air drying under fan. Label information on the species of the parasitoid and date of parasitizing are given in the leftover spaces. Very small amount of honey was placed on card for supplying food. The egg cards were placed into test tube/glass cylinder of suitable size and the nucleus card of *Trichogramma* was introduced in it. *Trichogramma* adults emerge from this card in 7-8 days after parasitization.

To delay the emergence of *Trichogramma*, these parasitized cards can be stored in refrigerator at 5-10°C and 65-70% RH for 10-15 days. On removing the cards to room temperature, the parasitoids emerge normally.

Maize flour 1 kg, wheat flour 1 kg, pea-flour 500 g are mixed together then whole mixture was autoclaved at 125°C temperature at 15 PSI for 1 hour. After autoclaved this diet was kept in a bowl for room temperature. Then 2 g or 3 g eggs of rice moth were spread over the diet and cover the bowl with 64 meshes net.

Female moth lay eggs, this egg falls down through the net and store at the jar. Eggs are collected and cleaned. thick color papers used as trichocard and the size of trichocard should fit to the test tube. Date and label are noted at one end of trichocard. A coat of 10% gum arabia was applied on the cards.

Eggs of Corcyra are sprinkled uniformly in a single layer with the aid of a strainer. The excess eggs pasted were removed gently by passing a brush over the card after sufficient air drying under fan. Label information on the species of the parasitoid and date of parasitization were given in the left-over spaces. Very small amount of honey was placed on the card for supplying food. The egg cards were placed into test tube/glass cylinder of suitable size and the nucleus card of *Trichogramma* was introduced in it. Black coloration of eggs indicated the presence of parasitoid.

Efficacy of *Bracon hebetor* against Fall Armyworm: Initial *B. hebetor* mother culture was procured from Patuakhali Science and Technology University laboratory, Dumki, Patuakhali. The method followed for efficacy studies was developed for *B. hebetor* rearing at PSTU. In this method for efficacy studies of 1 host, individual experiments were conducted with 3 replications. In the first experiment for each replication 20 *B. hebetor* adults were released in 3 jars and cotton dipped in 10% honey solution was placed at one side on inner wall of the jar to provide nutrition for the adult *B. hebetor*. The jars were covered on the top with a black cloth. In each jar 20 adults of *B. hebetor* were released and 10 *S. frugiperda* larvae were placed in corrugated paper sheet for parasitization. After 24 hours of exposure individual host larvae were transferred to Petri plates to observe number of *B. hebetor* larvae, pupae and adults per host larva. Each host larva was observed under magnifying glass one day after transfer to petri plate.

The second and third experiment was conducted as mentioned above and along with *S. frugiperda*. The host insects were exposed to *B. hebetor* for oviposition for 24 hours and the parasitized host larvae were transferred individually to petri plates with filter paper to note larval and pupal counts and adult emergence.

Statistical analysis: Each experiment was repeated 3 times. Mean of total data of particular treatment and standard deviation as a measure of data variability around mean (the average squared deviation from the mean) of a treatment was calculated and represented as mean ± SD.

RESULTS AND DISCUSSION

Optimized protocol for Mass rearing of larval parasitoid, *Bracon hebetor* in the bio-control laboratory: In this protocol development, controlled environment conditions were maintained for insect, like lab temperature was 26-28°C and relative humidity was 70-75%. Steps are given bellow (Fig. 1):

Parent stock of wax moth developed in honeycomb in glass jar
↓ First to second instars larvae of wax moth are reared in artificial diet
↓ 18-20 days later, full-fed 200 larvae transferred in a plastic bottle with a corrugated paper sheet
↓ 100 adults *B. hebetor* (60 female and 40 male) released in the plastic bottle with honey socked cotton pieces
↓ The wax moth larvae and *B. hebetor* containing whole bottle covered the with black cloth and kept on rack for parasitism, egg laying, pupation and adult emergence of *B. hebetor*
↓ 8-10 days later, adults B. hebetor emerged from the parasitized larvae and ready for field release.

Fig. 1. Mass rearing protocol of *B. hebetor*

Optimized protocol for Mass rearing of egg parasitoid, *Trichogramma chilonis* in the bio-control laboratory: In this protocol development, controlled environment conditions were maintained for insect, like lab temperature at 26-28°C and relative humidity of 70-75%. Steps are given bellow (Fig. 2)

Sterilized artificial diet infested with older eggs of *Corcyra cephalonica* and kept for 28-30 days
↓ After 28-30 days, adults were collected and kept in a jar for egg laying
↓ Eggs were brush up from the cylinder and sieved to get fresh eggs. Fresh eggs used for *Trichogramma* rearing while older eggs used for *Corcyra rearing*
↓ Eggs were spreads over the gum containing trichocard, then cards placed in a *Trichogramma* containing test tube for patasitization
↓ Next day parasitized trichocard replaced in a new test tube, after 7-8 days new adult was emerged and ready for release.

Fig. 2. Mass rearing protocol of *Trichogramma chilonis*

Efficacy of *Bracon hebetor* against different instar of FAW larvae: When the 3rd instar larvae of host insect was offered to *B. hebetor* mean ± SD of parasitized host larvae was 3.33 ± 0.57 and SE 0.33. Mean ± SD of egg, larvae, pupae and adults of *B. hebetor* were 14.67±1.52, 14.33±1.53,11±1 and 8.66±0.577, respectively per single *S. frugiperda* larva in jar 1. Mean ± SD number of eggs, larvae, pupae and adults of *B. hebetor* were 16.5±2.08,15±0.816,11.25±0.95 and 8±1.41 per larva, respectively in jar 2. Mean ± SD of egg, larvae, pupae and adults of *B. hebetor* were 15.33±2.52, 14±1.73, 9.33±2.15 and 6±1 on *S. frugiperda* larvae in jar became black, dead within 24 hours after exposure to *B. hebetor* (Table 3, Fig. 3).

Table 3. Parasitizing of *B. hebetor* on 3rd instar larvae of *Spodoptera frugiperda* under laboratory conditions

Experimental jar	Number of host (*Spodoptera frugiperda*)/ jar	Number of *B. hebetor*/ jar	Number of parasitized larvae/jar	No. of *B. hebetor* egg formed/ host larva (Mean±SD)	No. of *B. hebetor* larvae formed/ host larva (Mean ± SD)	No. of *B. hebetor* pupa formed/ host larva (Mean ± SD)	No. of *B. hebetor* adult formed/ host larva (Mean ± SD)
jar 1	10	20	3	14.67±1.52	14.33±1.53	11±1	8.66±0.577
jar 2	10	20	4	16.5±2.08	15±0.816	11.25±0.95	8±1.41
jar 3	10	20	3	15.33±2.52	14±1.73	9.33±2.15	6±1
Mean ± SD			3.33 ± 0.57				
SE			0.33				

Fig. 3. Efficacy of *B. hebetor* on 3rd instar larvae in three jars

When the 4th instar larvae of host insect was offered to *B. hebetor* mean ± SD of parasitized host larvae was 6.33 ± 1.53 and SE 0.88. Mean ± SD of egg, larvae, pupae and adults of *B. hebetor* were 18.6±1.67, 15.6±1.67,10.67±1.14 and 9.8±1.30, respectively per single S. *frugiperda* larva in jar 1. Mean ± SD of egg, larvae, pupae and adults of *B. hebetor* were 18.67±2.25,14.16±2.13,10±2.19 and 9.33±2.33 per larva, respectively in jar 2. Mean ± SD of egg, larvae, pupae and adults of *B. hebetor* were 18.85±3.23, 14±2.82, 12±2.38 and 11.28±2.28 on *S. frugiperda* larvae in jar became black, dead within 24 hours after exposure to *B. hebetor* (Table 4, Fig. 4).

Fig. 4. Efficacy of *Bracon hebetor* on 4th instar larvae in three jars

Table 4. Parasitization of *Bracon hebetor* on 4th instar larvae of *Spodoptera frugiperda* under laboratory conditions

Experimental Jar	No. of host (*Spodoptera frugiperda*)/ jar	No. of *Bracon hebetor*/jar	No. of parasitized larvae/jar	No. of *B. hebetor* egg formed/ host larva (Mean ± SD)	No. of *B. hebetor* larvae formed/ host larva (Mean ± SD)	No. of *B. hebetor* pupa formed/ host larva (Mean ± SD)	No. of *B. hebetor* adult formed/ host larva (Mean ± SD)
Jar 1	10	20	5	18.6±1.67	15.6±1.67	10.6±1.14	9.8±1.30
Jar 2	10	20	6	18.67±2.25	14.16±2.13	10±2.19	9.33±2.33
Jar 3	10	20	8	18.85±3.23	14±2.82	12±2.38	11.28±2.28
Mean ± SD			6.33 ± 1.53				
SE			0.88				

When the 5th instar larvae of host insect were offered to *B. hebetor* had mean ± SD of parasitized host larvae was 9.66 ± 0.57 and SE 0.33. Mean ± SD of egg, larvae, pupae and adults of *B. hebetor* were 22.44±2.79, 18.44±2.06,11.55±2.08 and 10.88±2.31, respectively per single *S. frugiperda* larva in jar 1. Mean ± SD of egg, larvae, pupae and adults of *B. hebetor* were 23.4±4.03,21±3.50,13.6±4.06 and 12.6±3.97 per larva, respectively in jar 2. Mean ± SD of egg, larvae, pupae and adults of *B. hebetor* were 25±4.54, 22.5±4.47, 17.9±4.33 and 16.1±4.04 in *S. frugiperda* larvae, respectively in jar where eggs became black, dead within 24 hours of exposure to *B. hebetor* (Table 5, Fig. 5).

Table 5. Parasitization of *B. hebetor* on 5th instar larvae of *Spodoptera frugiperda* under laboratory conditions

Experimental Jar	No. of host (*Spodoptera frugiperda*)/ jar	No. of *B. hebetor*/ jar	No. of parasitized larvae/jar	No. of *B. hebetor* egg formed/ host larva (Mean ± SD)	No. of *B. hebetor* larvae formed/ host larva (Mean ± SD)	No. of *B. hebetor* pupa formed/ host larva (Mean ± SD)	No. of *B. hebetor* adult formed/ host larva (Mean ± SD)
Jar 1	10	20	9	22.44±2.79	18.44±2.06	11.55±2.08	10.88±2.31
Jar 2	10	20	10	23.4±4.03	21±3.50	13.6±4.06	12.6±3.97
Jar 3	10	20	10	25±4.54	22.5±4.47	17.9±4.33	16.1±4.04
Mean ± SD			9.66 ± 0.57				
SE			0.33				

Fig. 5. Efficacy of *B. hebetor* on 5th instar larvae in three jars

Efficacy of *B. hebetor* on FAW larvae in net cage: The percent parasitism of FAW by *B. hebetor* ranged 20-40 % among three net cage trials where the highest percent was recorded in cage no. 2 and the lowest in cage no. 3 (Fig. 6, Plate 1). Causes of lowest parasitism in case no.3 may due to hiding of larvae inside maize plant and under soil clods.

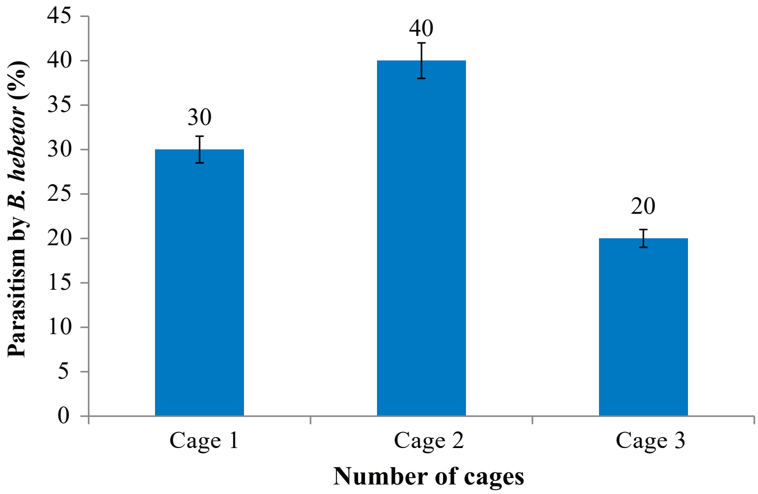

Fig. 6. Percentage of parasitized larvae of FAW by *B. hebetor* in net cage conditions

Plate 1 (A&B). Efficacy of *B. hebetor* on FAW larvae in net cage

The findings of the present study are supported by Ashley *et al*. (1982), Ashley (1983) and Pair *et al*. (1986). FAW reported recently in Bangladesh found as notorious insect with high dispersal ability, wide host range and high fecundity that make it one of the most severe economic pests. Braconids like egg-larval endoparasitoid *Chelonus insularis* Cresson (Braconidae, Cheloninae), and the larval endoparasitoids *Cotesia marginiventris* (Cresson) (Braconidae, Microgastrinae) were effective against FAW. Worldwide Braconids play crucial role in controlling fall armyworm. Egg Larval parasitoid *Chelonus* spp, Larval parasitoids like *Agathis stigmatera*, *Cotesia marginiventris* were reported from many FAW infested countries. According to Brower *et al*. (1996), *B. hebetor* is a highly effective biological control agent for stored-product insects of the Pyralidae family. *B. hebetor* females sting and inject paralytic venom to paralyze their host, which are often final stage larvae in a "wandering" phase. They then oviposit varying numbers of eggs on or around the paralyzed host. Paralyzed host larvae serve as food for growing wasp larvae and adult females. Invasive alien species pose a serious threat to agriculture and cost billions of dollars in terms of reduced production and productivity (Paini *et al*. 2018). Heimpel *et al*. (1997) suggest that the wasp species described in earlier research may be a different species than *B. hebetor*, capable of attacking Noctuidae moth larvae in the wild.

CONCLUSION

protocol for mass rearing of egg parasitoid, *Trichogramma* spp. and larval parasitoid *Bracon hebetor* has been optimized in the bio-control laboratory, PSTU. The larvae of *Spodoptera frugiparda* were parasitized after 24 hours of releasing *Bracon hebetor*. The recommended release rates for *Bracon hebetor* and *Trichogramma* spp. will vary depending on the specific pest species, crop, and environmental conditions. Using biological control agents like *Bracon hebetor* and *Trichogramma* can help reduce reliance on chemical insecticides, which can be harmful to human health and the environment. Both *Bracon hebetor* and *Trichogramma* spp. are sensitive to temperature and humidity. It's important to release them under environmental conditions that are favorable for their survival and activity. *Bracon hebetor* and *Trichogramma chilonis* may be incompatible with certain insecticides. It's important to check for compatibility before using them together.

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FARMERS' KNOWLEDGE OF INSECT PESTS IN BOTTLE GOURD (*LAGENARIA SICERARIA*) AND THEIR MANAGEMENT PRACTICES IN MAJOR BOTTLE GOURD PRODUCING DISTRICTS OF BANGLADESH

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ABSTRACT

Bottle gourd (*Lagenaria siceraria*) is a popular vegetable crop in Bangladesh including some other countries in Asia. The production of bottle gourd is hampered due to multiple insect pest infestation in recent years. For developing eco-friendly management, a survey among 150 farmers across three major districts of Bangladesh was performed to assess farmers' knowledge and perceptions on insect pest infestation of bottle gourd and management. Results showed that farmers identified a total of 7 insects in bottle gourd. Among them, all the farmers observed fruit fly and red pumpkin beetle as the major insect pest. Approximately 66.67% of farmers reported significant yield loss due to fruit fly infestation, while 22.0% experienced yield loss due to sap beetle infestation. Farmers employed chemical pesticides, pheromone trap, ash, soapy water and bio-pesticides for pest management in bottle gourd. Almost all the respondents (99.3%) applied pesticides more than 5 times in a single growing season. Most of the growers (62.7%) applied pesticides at 15-days interval. Majority farmers (68.67%) didn't receive any training on sustainable management of the insect complex of bottle gourd plant. Authors findings provide insight into the importance of developing sustainable pest management approaches for bottle gourd production in Bangladesh.

Keywords: Survey, insect complex of bottle gourd, eco-friendly & sustainable management

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INTRODUCTION

Bottle gourd is a monoecious annual vine plant that belongs to cucurbitaceae family, is a popular vegetable in Bangladesh (Barot *et al.* 2015, Christenhusz *et al.* 2016). This vegetable derived from African origins and now found in subtropics and the tropics throughout the world (Chimonyo and Modi 2013). It is a popular diet for preparing sweet curries, soups, jams, beverages, cakes, ice creams and tea (Barot *et al.* 2015). This vegetable contains vitamin C and niacin with essential minerals potassium, calcium and phosphorus which makes it nutritiously beneficial for human health (Sawate *et al.* 2009). High fiber content in bottle gourd helps protect the stomach from disorders like constipation and piles. Additionally, bottle gourd consumption helps to prevent diabetes and coronary heart diseases, mental stress, nervous dysfunction, insanity and epilepsy (Hassan *et al.* 2008, Mohale *et al.* 2008).

In Bangladesh, bottle gourd is widely consumed vegetable and locally known as “Lau” (Mohammad *et al.* 2015). Climatic condition of Bangladesh is favorable for growing bottle gourd. According to the Bangladesh Bureau of Statistics, the country produced approximately 0.314 million metric tons of bottle gourd from 0.02 million ha with an average yield of 15.45 million metric tons /ha (BBS 2025). But profitable production sometime hampered due to insect pest infestation (Parkash *et al.* 2023). The production of bottle gourd faces major damage from multiple insect pests including fruit fly (*Bactrocera cucurbitae*), Epilachna beetle (*Epilachna viginctiocpunctata*), white fly (*Bemisia tabaci*), sap beetle (*Epuraea* sp.), squash bug (*Anasa tristis*), leaf cutting caterpillar (*Spodoptera litura*), red pumpkin beetle (*Aulacophora foveicollis*), ash weevil (*Myllocerus subfasciatus*) and aphid (*Aphis gossypii*) (Haldhar *et al.* 2014, Bhowmik and Saha 2017, Parkash *et al.* 2023). In addition, sap beetle (*Epuraea* sp.) and mirid bugs (*Nesidiocoris cruentatus* and *Metacanthus pulchellus*) have emerged as new threat in bottle gourd production in Bangladesh and India, respectively (Mondal *et al.* 2022, Halder *et al.* 2021). Among these insects, fruit flies, red pumpkin beetles, and sap beetles can cause yield losses of over 50% in bottle gourd, while fruits affected by mirid bugs experience a significant reduction in market value (Sohrab and Prasad 2018, Abrol *et al.* 2019, Bhowmik and Saha 2017, Mondal *et al.* 2022, Halder *et al.* 2021).

Sustainable bottle gourd production demands urgent development of efficient management systems for controlling pest pressure. But before implementing any intervention, it is necessary to understand the current field data on insects in bottle gourd, and the effectiveness of existing management practices. Farmers traditional knowledge, perceptions and pest management strategies are necessary to develop successful pest management approaches (Olaniran *et al.* 2014). Besides, participatory farmer survey will help to design proper field monitoring tools, field guide and exploring potential approaches for pest protection (Litsinger *et al.* 2009, Midega *et al.* 2012). Still now, no studies investigate farmer viewpoints regarding insects of bottle gourd while the threat from these insect-pest continues to expand throughout Bangladesh. Therefore, this study aims to explore the farmers' knowledge and perceptions regarding insect pest infestation and their management strategies in bottle gourd field in some areas of Bangladesh.

MATERIALS AND METHODS

Survey: To assess the incidence and damage severity of different insect pests of bottle gourd and their managements, a comprehensive cross-sectional survey was conducted across the country. Before the survey, a pre-survey was conducted for the clarity of questions and identifying any potential biases or problems that might arise during the entire survey. Survey was performed in three most significant bottle gourd producing districts, namely Jashore, Sylhet and Chuadanga - between December, 2020 to February, 2021. Among these districts, three upazilas (sub-districts) such as Sylhet Sadar upazila (24.8917˚N 91.8833˚E) of Sylhet, Jashore Sadar upazila (23.1681˚N 89.2042˚E) of Jashore, Chuadanga Sadar upazila (23.6417˚N 88.8583˚E) of Chuadanga district were selected to complete the survey (Fig. 1).

Following Amon-Armah *et al.* (2023), a standardized, semi-structured questionnaire was developed, including both open-ended and closed-ended questions of different titles for effective survey (Table 1). The questionnaire contained 22 questions. The questions were written in English at first and then translated into Bengali for the farmers' convenience. Most of the data were collected when the farmers were in their field so that it would be easy to make them understand the question and answer. The questionnaires were divided into 4 parts. Socio-demographic characteristics and bottle gourd farming practices were

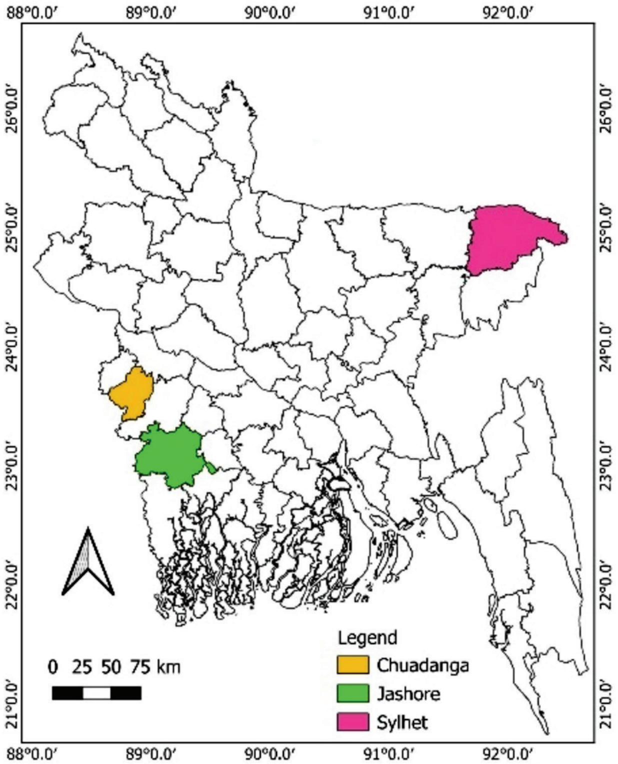

Fig. 1. Map showing the survey areas of bottle gourd insect pest in Bangladesh during 2020-2021

the main subject in the first section of the questionnaire. In the second part of the questionnaire, farmers' knowledge and perceptions on insect infestation in bottle gourd field was highlighted. The third section of the questionnaire aimed to gather information on farmers' insect-pest management strategies for bottle gourd, as well as the training status of the farmers about pest management of bottle gourd (Table 1). For the identification of bottle gourd insects, a laminated photograph was composed containing different key insects and their damage. The images of the insects were selected based on pre-survey and review and literature (Bhowmik and Saha 2017, Chanda *et al.* 2022).

Data collection: A face-to-face interview of 150 farmers was conducted with 50 farmers included from each upazila of each district. Farmers were randomly selected through consultation with the Agriculture Extension Officers (AEO) from

Table 1. Overview of survey questionnaire on insect pest infestation and its damage in bottle gourd across three surveyed districts of Bangladesh

Question group	Description
Farmers' socio-demographic characteristics and bottle gourd farming practices	1. Farmers' age 2. Farmers' gender 3. Farmers' educational level 4. Land type 5. Experience of bottle gourd cultivation 6. Varity of cultivated bottle gourd
Farmers' knowledge of insect infestation in bottle gourd	1. Major insect pest of bottle gourd 2. Insect pests at vegetative stage 3. Insect pests at reproductive stage 4. Yield loss caused by insect infestation 5. Effect of fruit fly infestation on shape and size of bottle gourd
Farmers' management practices of insect-pest and training status	1. Which type of methods do you apply? 2. How many times you apply pesticide? 3. In which stage you start to apply pesticide? 4. Pre-harvest interval of insecticide application 5. Did you get any training about bottle gourd pest management strategies?

the respective upazilas of the surveyed districts. The following equation was used to determine the total number of respondents (n = 150) for selecting farmers from the three districts. using following formulas:

$$N = \frac{N}{1+N\,\varepsilon^2}$$

Where, n is the sample size, N is the total number of farmers in each area and is the desired number of errors (Tuan *et al.* 2014).

Statistical Analysis: All the collected data were summarized and descriptive statistics (frequencies and percentages) were calculated using SPSS (version 27). The percentages of farmers' responses were calculated for each category of related response. The data were visualized through python (version 3.11.5) using pandas, matplotlib, seaborn libraries. Bar charts and pie charts were created to visualize the farmers' responses clearly.

RESULTS

Farmers' socio-demographic characteristics: The socio demographic results showed that among the surveyed bottle gourd farmers, majority of them (88.7%) were male and about 25.7% were in middle aged (31-45), whereas 19.3% were between 46-60 years. About 30.7% farmers got only primary level education. According to the results, about 70% of farmers have their own land for cultivation whereas 52.7% farmers cultivated bottle gourd taking land for lease. In the surveyed areas, 36% farmers have 1-5 years of bottle gourd cultivation experience whereas 28.7% farmers have more than 20 years of experiences (Table 2).

Table 2. Socio-demographic conditions of the bottle gourd farmers in three surveyed districts of Bangladesh (n=150)

Factor	Category	Frequency	% of total farmers
Age (years)	15-30	9	3.0
	31-45	77	25.7
	46-60	58	19.3
	>60	6	2.0
Gender	Male	133	88.7
	Female	17	11.3
Education level	Illiterate	2	1.3
	Only Signature	33	22.0
	Class 1-5	46	30.7
	Class 6-9	31	20.7
	SSC (Secondary School Certificate)	29	19.3
	HSC (Higher Secondary Certificate)	7	4.7
	Graduate	2	1.3
Land type	Own	105	70
	Lease	79	52.7
	Borga (Tenant)	21	14.0
Experience in bottle gourd cultivation (years)	1-5	54	36.0
	6-10	16	10.7
	11-15	20	13.3
	16-20	17	11.3
	>20	43	28.7

Farmers' knowledge and perception of insect pests of bottle gourd in Bangladesh: In Bangladesh, several varieties of bottle gourd are cultivated. Among them, the high-yielding hybrid varieties such as Moina, Daina, Marshal, and White Gold are particularly popular and widely recognized by the farming communities in the Sylhet, Jashore, and Chuadanga districts. (Table 3). All the framers (100%) in surveyed areas reported aphid, fruit fly and red pumpkin beetle as the major pests in their bottle gourd field. On average more than 50% farmers observed tobacco cutworm in bottle gourd plant. A large percentage of farmers (more than 70%) identified squash bug and sap beetle as major threat in bottle gourd (Table 4). The results revealed that all the farmers (100%) reported the presence of aphids and red pumpkin beetles during the vegetative stage of bottle gourd (Table 5).

According to the farmers, fruit fly (99.3%) and sap beetle (86.7%) were the most observed insects in bottle gourd plant at reproductive stage (Table 6). Most of the farmers (66.67%) identified fruit fly as the key insect that causes significant yield loss of bottle gourd. In addition, 22% of farmers reported sap beetle as a responsible pest to the yield loss of bottle gourd. A smaller number of farmers (7.3% -14%) identified aphids, thrips, and squash bugs as the causes of yield loss in bottle gourd (Table 7). Almost all the farmers (99.33%) reported that shape and size of bottle gourd distorted when fruit fly attacks the bottle gourd fruit (Fig. 2).

Table 3. Cultivated varieties of bottle gourd in three surveyed districts of Bangladesh (n=150)

Sylhet	Jashore	Chuadanga
Moina	Marshal	Moina
Diana	BARI Sita lau 1	Diana
Marshal	Diana	White Gold
White Gold	Moina	
Bari lau 2		

Table 4. Farmers' knowledge (%) on major insect pest of bottle gourd in three surveyed districts of Bangladesh (n=150)

Insects Name	Scientific Name	Family	Order	% respondent in different study areas		
				Sylhet	Jashore	Chuadanga
Aphid	*Aphis* spp.	Aphidoidea	Hemiptera	100	100	100
Fruit Fly	*Bactrocera cucurbitae*	Tephritidae	Diptera	100	100	100
Red pumpkin beetle	*Aulacophora faveicollis*	Chrysomelidae	Coleoptera	100	100	100
Thrips	*Magalurothrips* sp.	Thripidae	Thysanoptera	28	37	58
Tobacco Cutworm	*Spodoptera litura*	Noctuidae	Lepidoptera	66	49	76
Squash Bug	*Anasa tristis*	Coreidae	Hemiptera	87	70	92
Sap beetle	*Epuraea* sp.	Nitidulidae	Coleoptera	79	63	86

Table 5. Farmers' knowledge (%) on insect pest observed in vegetative stage of bottle gourd in three surveyed districts of Bangladesh (n=150)

Insects Name	Scientific Name	Family	Order	Frequency	% Respondents
Aphid	*Aphis* spp.	Aphidoidea	Hemiptera	150	100
Tobacco Cutworm	*Spodoptera litura*	Noctuidae	Lepidoptera	23	15.5
Squash Bug	*Anasa tristis*	Coreidae	Hemiptera	8	5.3
Red pumpkin beetle	*Aulacophora faveicollis*	Chrysomelidae	Coleoptera	150	100

Table 6. Farmers' knowledge (%) on insect pest observed in reproductive stage of bottle gourd in three surveyed districts of Bangladesh (n=150)

Insects Name	Scientific Name	Family	Order	Frequency	% respondents
Fruit fly	*Bactrocera cucurbitae*	Tephritidae	Diptera	149	99.3
Sap beetle	*Epuraea* sp.	Nitidulidae	Coleoptera	130	86.7
Thrips	*Magalurothrips* sp.	Thripidae	Thysanoptera	74	49.3

Table 7. Farmers' knowledge (%) on yield loss of bottle gourd due to the insect pest infestation in three surveyed districts of Bangladesh (n=150)

Insects Name	Scientific Name	Family	Order	Frequency	% Respondents
Fruit fly	Bactrocera cucurbitae	Tephritidae	Diptera	100	66.67
Aphid	*Aphis* spp.	Aphidoidea	Hemiptera	11	7.3
Red pumpkin beetle	*Aulacophora faveicollis*	Chrysomelidae	Coleoptera	4	2.7
Thrips	*Magalurothrips* sp.	Thripidae	Thysanoptera	21	14.0
Squash Bug	*Anasa tristis*	Coreidae	Hemiptera	11	7.3
Tobacco Cutworm	*Spodoptera litura*	Noctuidae	Lepidoptera	5	3.3
Sap beetle	*Epuraea* sp.	Nitidulidae	Coleoptera	33	22.0

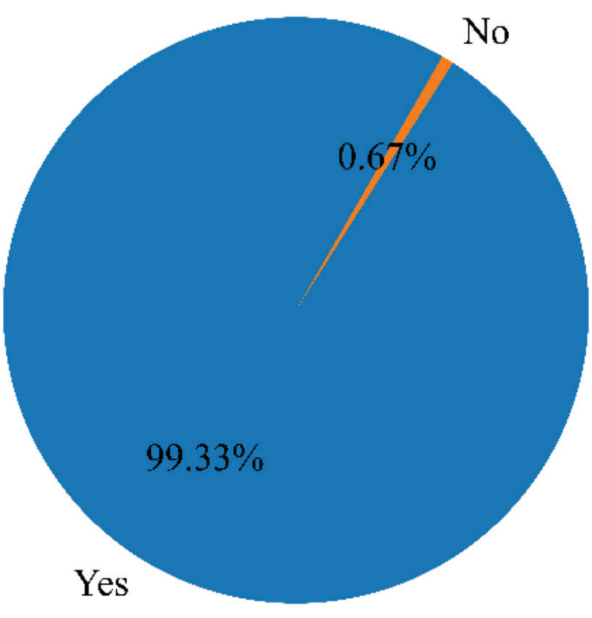

Fig. 2. Farmers' responses (%) of the impact of fruit fly infestation on the shape and size of bottle gourd in three surveyed districts of Bangladesh (N= 150)

Management practices implemented by farmers against insect pest of bottle gourd: The results revealed that, almost 100% of the farmers applied chemical pesticides to control bottle gourd insects and pests. Around 70% of the farmers used pheromone traps for fruit fly control, whereas 37.3%, 44% and 21% farmers applied soapy water, bio pesticides, and ash respectively (Fig. 3). Almost all farmers (99.3%) applied pesticides more than five times in a single bottle gourd cropping season, and majority of them (71.3%) started applying insecticides at seedling stage of bottle gourd (Figs. 4a-b). About 62.7% farmers maintained 15 days interval for insecticide application whereas 37.3% applied insecticide at 7 days interval. Most of the farmers (34%) stop insecticide application 4-5 days before harvesting of bottle gourd, while 30.7% and 18.7% farmers stop 6-7 days and 2-3 days before harvesting, respectively (Figs. 5a-b). Among the total respondents, majority of the farmers (68.67%) did not take any kind of training on pest management of bottle gourd (Fig. 6).

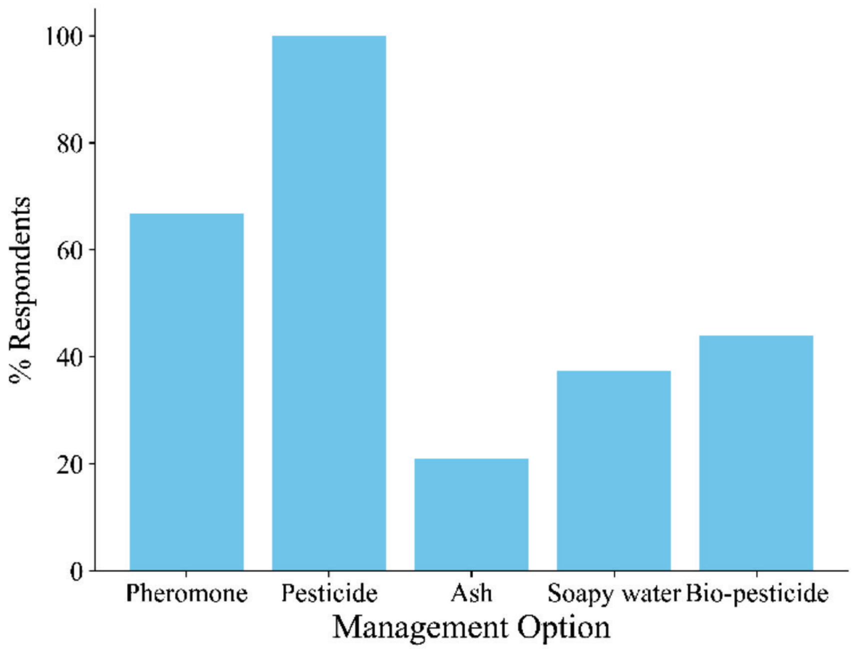

Fig. 3. Farmers' responses (%) on the use of management practices against the infestation of insect pests of bottle gourd in three surveyed districts of Bangladesh (N= 150)

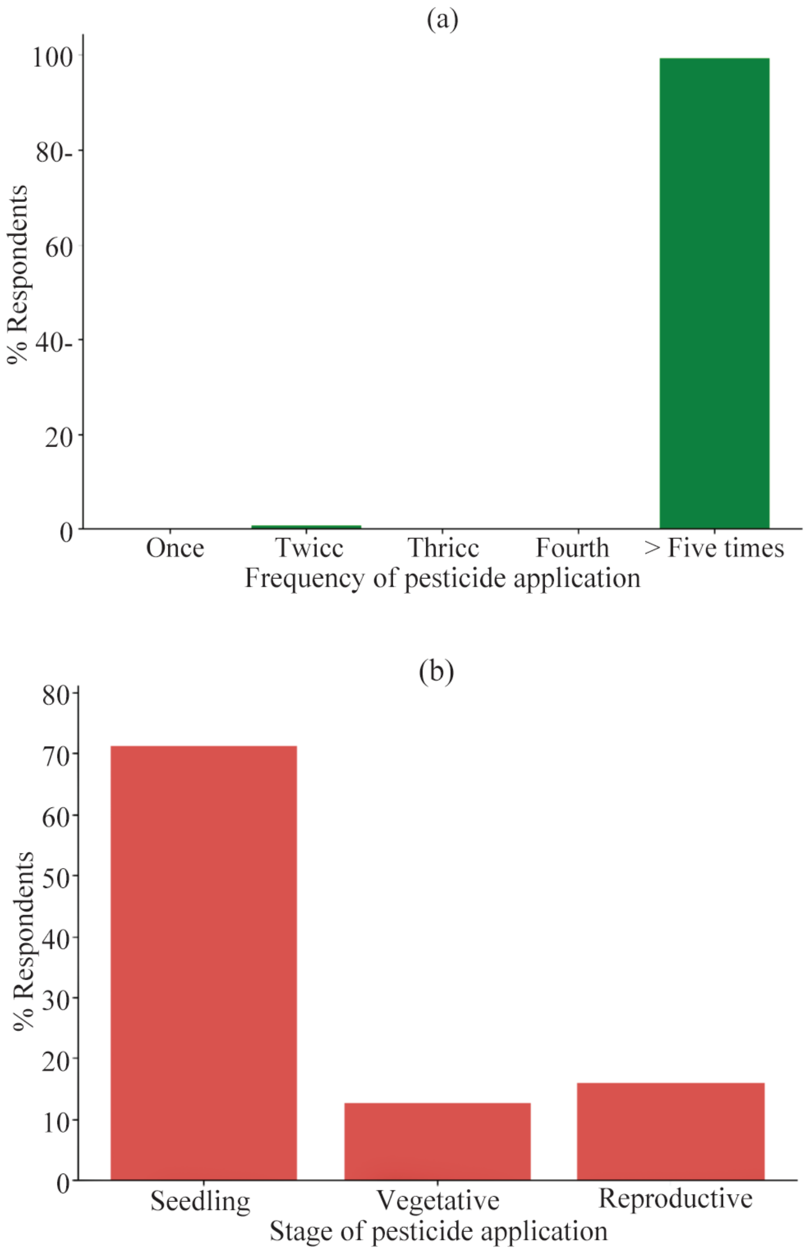

Fig. 4. Farmers' responses (%) on (a) the frequency of pesticides application, (b) the growth stages of pesticide application in a single bottle gourd growing season in three surveyed districts of Bangladesh (N= 150)

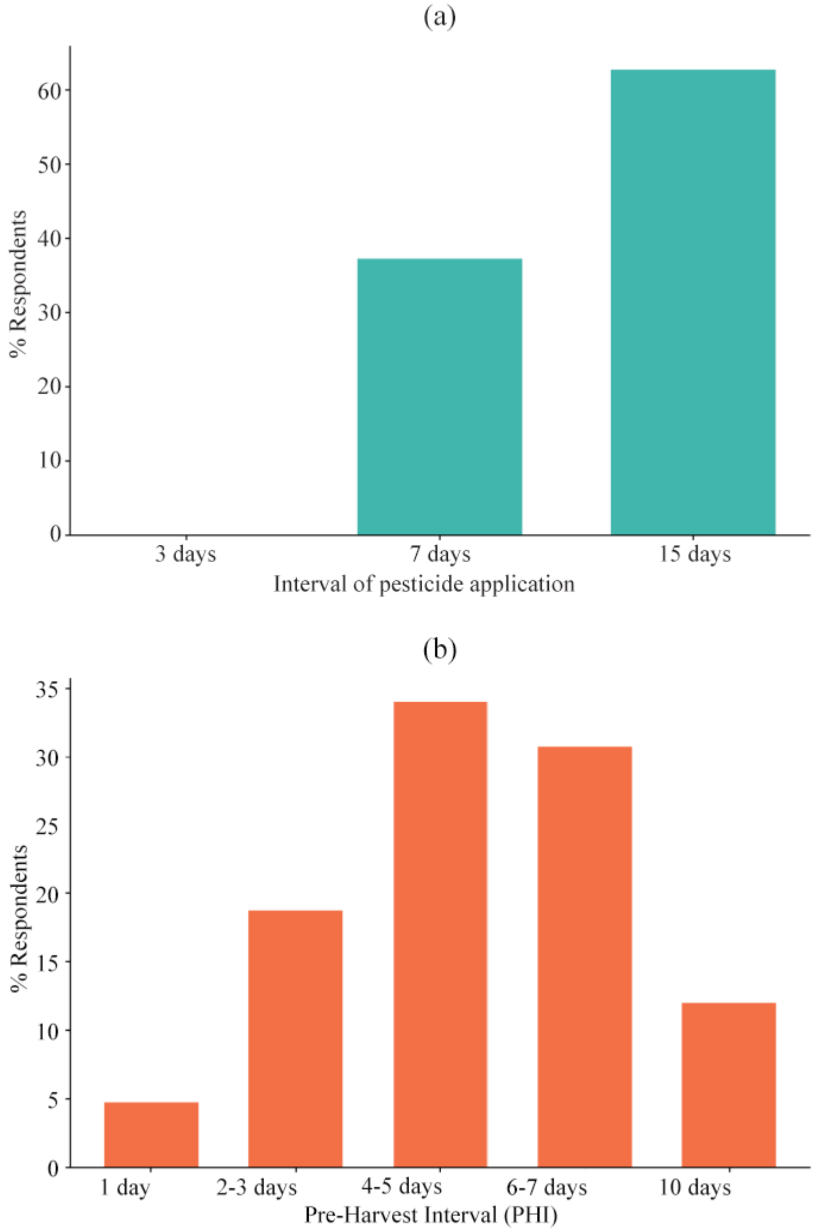

Fig. 5. Farmers' responses (%) on (a) interval of pesticides application; (b) Pre Harvest Interval (PHI) and in the bottle gourd field against the insect pests in three surveyed districts of Bangladesh (N= 150)

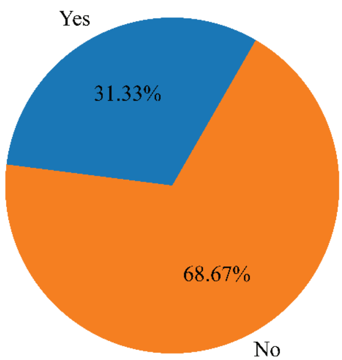

Fig 6: Farmers' responses (%) about training program on bottle gourd insect pest in three surveyed districts of Bangladesh (N= 150)

DISCUSSION

Results showed that most of the bottle gourd farmers were male, middle-aged and primarily educated in the surveyed districts. Several researches reported that most of the farmers are male, mid-aged, and primarily educated in Bangladesh (Islam *et al.* 2020, Rahman *et al.* 2022). The majority of the bottle gourd farmers in the survey areas cultivated hybrid varieties like Moina, Daina, Marshal and White gold. These results may be because of the higher yield of these varieties. Developed varieties provide higher yields, and that's why they are very common and cultivated by the growers in the most growing areas in Bangladesh (Miah *et al.* 2015, Sohrawardy and Sultana 2019).

All the bottle gourd growers identified aphid, fruit fly, red pumpkin beetle, are the main insect pests of bottle gourd. Several researches reported significant damage of fruit fly, red pumpkin beetle, in bottle gourd production (Sarker and Akter 2017, Abrol 2019, Rashid *et al.* 2014, Dhillon *et al.* 2005). Majority farmers reported that aphid attacked in bottle gourd at seedling stage and cause curling and yellowing of tender leaf. Islam (2020) also reported that aphid attack at seedling stage of bottle gourd, hamper the growth of tender leaf and disseminate the viral disease. The current results revealed that all bottle gourd farmers have been faced red pumpkin beetle infestation at vegetative stage in bottle gourd plant. Red pumpkin beetle attacked predominantly on leaves, flower buds and flowers of bottle gourd plant (Rashid *et al.* 2014, Gahlot *et al*. 2024). The percentage of damages due to red pumpkin beetle reached up to 35-75% at seedling stage that might cause 30-100% yield losses in the bottle gourd (Dilon *et al.* 2005, Rahman and Uddin 2016). Results showed that majority of the farmers faces severe fruit fly infestation in their bottle gourd field. In addition, all the farmers agreed that shape and size of bottle gourd was distorted due to fruit fly attack. Several researches reported fruit fly as one of the major pests in cucurbit crops, and it can cause up to 100% yield loss in bottle gourd and other cucurbits at reproductive stage by damaging the fruits (Abrol 2019, Sarker and Akter 2017, Bhoumik *et al.* 2017). Our findings revealed that a significant number of farmers reported sap beetle infestation during the flowering stage of bottle gourd. Additionally, farmers also identified that this insect caused considerable yield loss in bottle gourd. Mondal *et al.* (2022) showed that sap beetle can reduced 29.6% to 52.6% yield by reducing flower setting of bottle gourd plant in North-eastern region of Bangladesh.

All the farmers in the surveyed areas mainly applied pesticide for pest management. Additionally, significant number of farmers used pheromone, bio-pesticide, soapy water and ash as their pest management strategies. Islam *et al.* (2023) confirm that farmers predominantly rely on chemical pesticides for pest control, whereas notable number of farmers adopting mechanical (pheromones, soapy water) and biological (biopesticides) methods for pest management strategies. Farmers applied pesticide more than five times in a single bottle gourd growing season. Most farmers applied pesticides at intervals of 7-15 days, while the majority maintained a pre-harvest interval of 4-7 days. Bentley and Jeffery (2009) reported that the farmers of Norsingdi district applied insecticides at least 6-7 times in a week for controlling cucurbit fruit fly in vegetable crops. In another study, Chanda *et al.* (2022) reported that majority of farmers employed insecticides 30-40 times as chemical control approach in vegetable production to combat pumpkin beetle, epilachna beetle, thrips, jassid, field cricket, leaf eating weevil, and mealy bug insects. Most of the farmers in our surveyed districts got no training on pest management of bottle gourd. Lack of field-based training among farmers is the main reason for farmers' misconceptions about proper pest management strategies. Feder *et al.* (2004) stated that field level training helps the farmers to adopt more sustainable methods of pest management.

CONCLUSION

Bottle gourd is one of the popular vegetables in Bangladesh. A large number of farmers face a great problem for insect pest infestation in bottle gourd production. The aim of this research was to assess the status of insect pest infestation in the field and explore the management practices employed by farmers. The survey results revealed that fruit fly, aphid, red pumpkin beetle, epilachna beetle and sap beetle were the major pest in bottle gourd field. Significant numbers of farmers are facing yield loss of due to fruit fly and sap beetle in bottle gourd. Farmers apply chemical pesticides, pheromone and bio pesticide to control the insect pests. Almost all the farmers applied pesticide severely in a single growing season. Farmers applied pesticides indiscriminately, without following the recommended application intervals. Most of the farmers didn't get any training about pest management of bottle gourd. Our baseline survey will help the policymaker to understand the seriousness of insect pest infestation in bottle gourd, as well as will help to develop sustainable insect management approaches.

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INCIDENCE AND DAMAGE SEVERITY OF PINK *HIBISCUS* MEALYBUG, *MACONELLICOCCUS HIRSUTUS* INFESTING ORNAMENTAL PLANTS

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ABSTRACT

Pink *hibiscus* mealybugs infest all plant parts; feeder roots, root crowns, stems, twigs, leaves, and flowers of ornamental plants. Ornamental plants enhance the beauty of homes, gardens, and commercial landscapes but this tiny pest can silently damage them. The study was conducted at Patuakhali Science and Technology University campus to assess the incidence of pink *hibiscus* mealybugs, *Maconellicoccus hirsutus* and their damage symptoms on different ornamental plant species grown in landscape and pots during period from February to September 2021. Results revealed that the highest incidence of mealybugs per plant in common coleus and china rose was recorded in the month of April and the lowest was in September. Among three hosts, the highest incidence was found on jatropha followed by Ixora and Mussaenda. In jatropha, the highest number of mealybugs per branch was observed in the month of April whereas the lowest number was in the month of September. In Ixora, the maximum number of mealybugs was recorded in the month of April and whereas the lowest number was in the month of September. Among ornamental plants, the highest percent leaf area covered by Mealybugs was found on garden croton (65%) and the lowest percent was on red China rose (10%). The maximum twig area covered by Mealybugs was recorded on yellow China rose (45%) while the minimum twig area covered was observed on croton (21%). The highest percent flower area covered by Mealybugs was found on Mussaenda (40%) and the lowest percent flower area covered was recorded on Ixora (12%). Findings on the incidence and damage severity by mealybugs on ornamental plants illustrated the serious threats to landscape and beautification of different institutions.

Keywords: Pink mealybugs, incidence, damage severity, ornamental plants, homes garden, landscape, pots

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INTRODUCTION

The Pink *Hibiscus* Mealybug, *Maconellicoccus hirsutus*, (Green) is a serious pest of many plants, trees, and shrubs in tropical and subtropical regions. It is native within the area encompassing Southeast Asia, Africa, and northern Australia. It is also known as the grape mealybug, the grapevine mealybug, the pink mealybug, the pink *Hibiscus* mealybug and the *Hibiscus* mealybug. *M. hirsutus* is highly invasive if introduced in the absence of its natural enemies, as demonstrated by its rapid spread through the Caribbean Islands and beyond in spite of plant quarantine throughout the region. Without natural controls it had a devastating impact on the agriculture, natural forests and tourism of Grenada (Peters and Watson 1999), damaging foreign exchange, trade in agricultural products, and the local ecology and water economy. Estimated economic losses due to its damage and control have been predicted to reach $700 million in the United States (Moffitt 1999) and $5 billion globally (Ranjan 2006). Mealybugs are considered pests of economic importance in several crops in the world (Morandi 2015, Garcia *et al.* 2016). They are worldwide pests of ornamental plants grown indoors and outdoors (Frank 2010). Mealybugs are soft, oval, wax-covered insects that feed on many plants in garden, landscape, and indoor settings. Cottony white wax is usually the first sign of their presence. Mealybugs may be found at rest or slowly crawling on the undersides of leaves, on stems in flowers or even on the pot. Usually found in colonies, they are piercing-sucking insects closely related to soft scales but lack the scale covers. Like soft scales, they can produce abundant honeydew and are often associated with black sooty mold. They are most active in warm, dry weather and thrive in areas without cold winters or on indoor plants. In warmer climates, mealybugs are serious pests on many citrus and ornamental plants. Pink *Hibiscus* mealybug is a polyphagous sap-sucking insect that feeds on a wide range of host plants in 76 plant families and over 200 genera (Mani 1989, Garland 1998, Pasiecznik *et al.* 2005). Its host range is very large, exceeding over 200 perennial and annual plant species, many of which are important in agriculture and ornamentals (Roltsch and Meyerdirk 2008). A polyphagous insect pest with a host range of more than 125 species of plants feeding on fruits, vegetables and fibre crops such as coffee, maize, sugarcane, soybean, okra and cotton. It is a primary consumer that also attacks ornamental plants such as the rose and *Hibiscus* (Reddy *et al.* 2009). Both greenhouse and field-grown ornamentals are commonly attacked. Most species of ornamental plants can be infested with mealybugs. *M. hirsutus* destroys crops and ornamental plants (Hoy *et al.* 2003). Mealybugs damage plants by inserting their threadlike mouthparts into any part of the plant and sucking sap (Frank 2011). It is a pest of many plants, and a new problem on ornamental plants in Bangladesh. Recently it causes serious damage to ornamental plants in landscape and plants grown in pots. For proper management of any insect pest, it is important to know the incidence and damage extent of the particular insect pest. The sufficient information regarding incidence and damage extent of mealy bugs on ornamental plants is limited in Bangladesh. Considering above facts, the study was conducted to know the incidence of mealybugs on different ornamental plant species and to determine their damage severity.

MATERIALS AND METHODS

Incidence of mealybug populations and their damage symptoms were observed on different ornamental plant species grown in landscape and pots at Patuakhali Science and Technology University campus during February to September 2021. Five plants of each ornamental plant species were selected for data collection. Data were recorded on the number of mealybugs per leaf, per twig, per branch, per flower of each plant species as required. The number of mealybugs per plant was calculated by summing the number of mealybugs from each plant parts of 5 plants. The percentage of damage was determined from leaf, twig and flower area covered by mealybug which was measured by eye estimation.

Microscopic study of mealybug species identification: The mealybugs of different ornamental plants were collected separately in a plastic bag containing cotton balls soaked in ethyl acetate. Each individual was dipped in 99% ethyl alcohol for 2-3 seconds to wet the specimen and then placed in distilled water for 3-5 minutes. Finally mealybugs were observed in glycerine jelly using a stereoscopic microscope (Zoom Stereo Microscope, BTB-3A). Photographs of the specimen were made using digital camera (Plate 1).

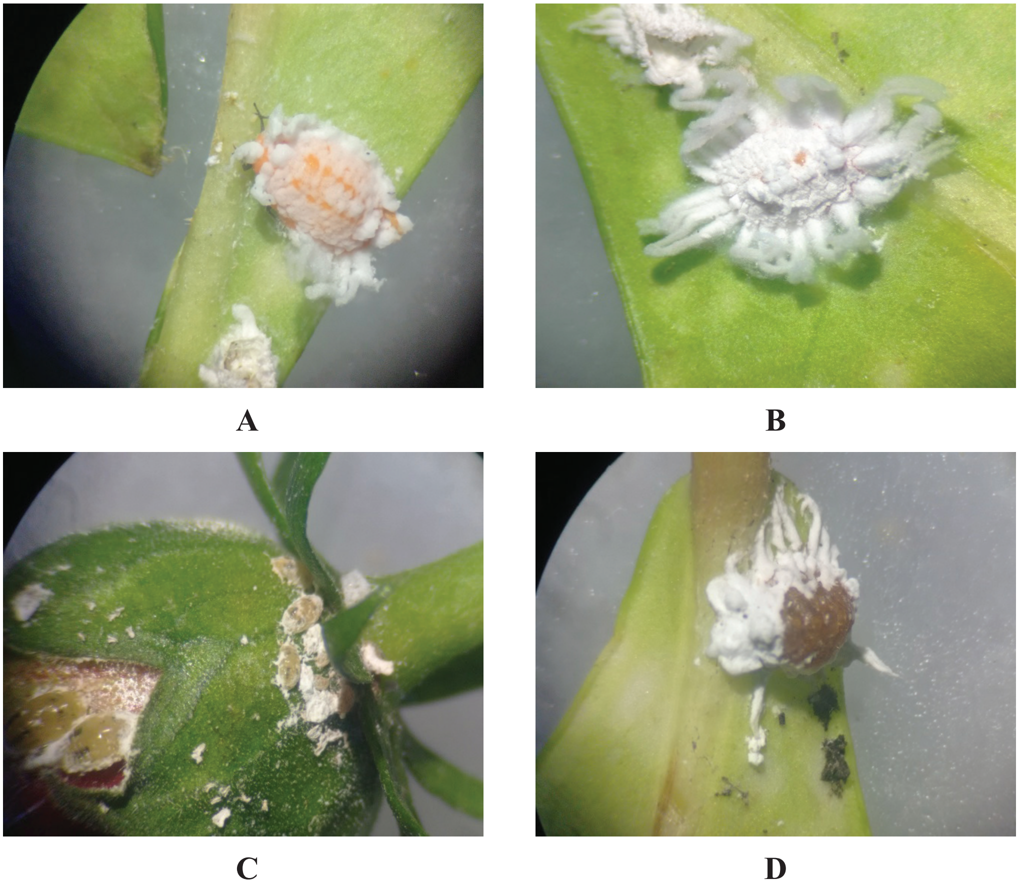

Plate 1. Microscopic views of the pink *Hibiscus* mealybugs (A-D)

Statistical analysis: Collected data were tabulated and graphical presentation was performed by using MS Excell program.

RESULTS AND DISCUSSION

Monthly incidence of Mealybugs per plant on maity and elite coleus: In elite coleus, the highest incidence of Mealybugs per plant was recorded in the month of April followed by May, June and March while the lowest incidence was in the month of September followed by August, July and February. In case of maity coleus, similar trend was also observed indicating the highest incidence in the month of April followed by May and the lowest in the month of September followed by August (Fig. 1).

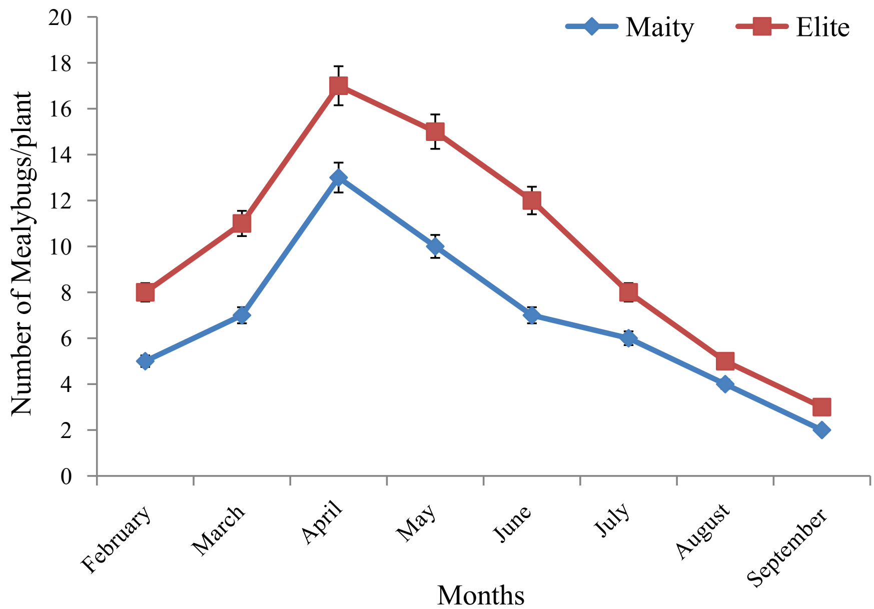

Fig. 1. Monthly incidence of Mealybugs per plant on maity and elite coleus plants at PSTU campus during February to September 2021

Monthly incidence of Mealybugs per plant on red and yellow China rose: Figure 2 revealed that the highest number of Mealybugs per plant was recorded in the month of April followed by May, June and March while the lowest was in the month of September followed by August, July and February on yellow China rose. In case of red China rose, similar trend was also observed indicating the highest number in the month of April followed by May and the lowest in the month of September followed by August.

Monthly Incidence of Mealybugs per branch on Jatropha, Ixora and Mussaenda: Among three hosts, the highest incidence was found on jatropha followed by Ixora and Mussaenda. In jatropha, the highest number of mealybugs per branch was observed in the month of April followed by May and June whereas the

Fig. 2. Monthly incidence of Mealybugs per plant on red and yellow China rose plants at PSTU campus during February to September 2021

lowest number was in the month of September followed by August, February, July and March. In Ixora, the maximum number of mealybugs was recorded in the month of April followed by May and June while the lowest was in the month of September followed by August, February, July and March. Similar trend of monthly incidence was also observed in case of Mussaenda (Fig. 3).

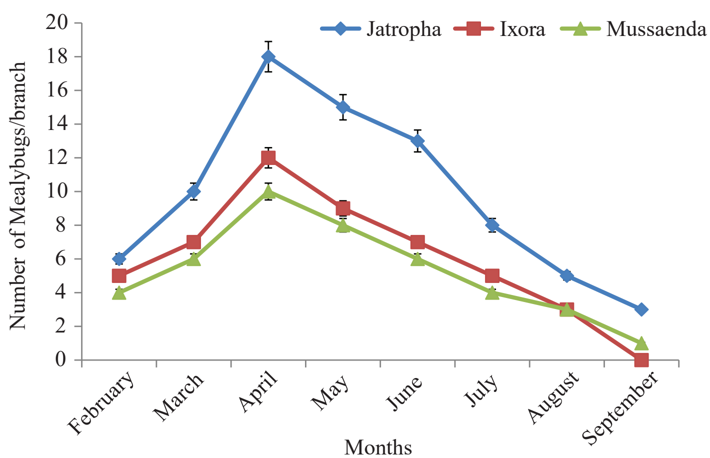

Fig. 3. Monthly Incidence of Mealybugs per branch on Jatropha, Ixora and Mussaenda plants at PSTU campus during February to September 2021

Damage potential of Pink hibiscus mealybugs: Leaf area (%) covered by Mealybugs: Among ornamental plants, the highest percent leaf area covered by Mealybugs was found on maity coleus (65%) followed by *Acalypha hispida* (35%), elite coleus (25%), croton (20%) and yellow China rose (18%). However, the lowest percent was on red China rose (10%) followed by *A. wilkesiana* (15%) and agnishar (16%) (Fig. 4).

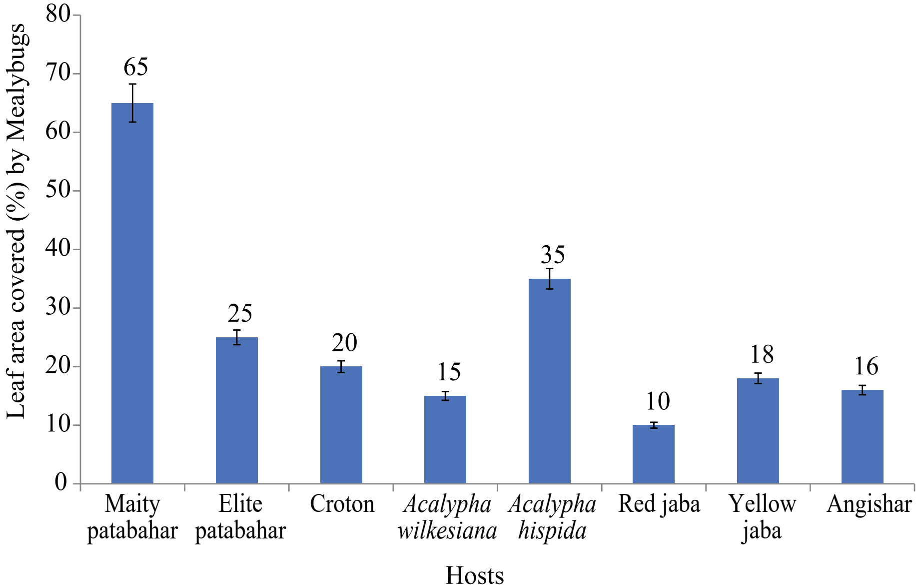

Fig. 4. Percentage of leaf area covered by Mealybugs on different ornamental plants

Percentage of twig area covered by Mealybugs: Figure 5 revealed that the maximum percent twig area covered by Mealybugs was recorded on yellow China rose (45%) which was followed by Mussaenda (40%), elite coleus (35%), jatropha (30%), red China rose (30%) and *A. wilkesiana* (28%) while the minimum twig area covered was observed on croton (21%) followed by rose (22%), maity coleus (23%), Ixora (24%) and *A. hispida* (25%).

Percentage of flower area covered by Mealybugs: Figure 6 illustrated that the highest percent flower area covered by Mealybugs was found on Mussaenda (40%) followed by jatropha (35%) and red China rose (28%) whereas the lowest percent flower area covered was recorded on Ixora (12%) followed by *A. hispida* (18%).

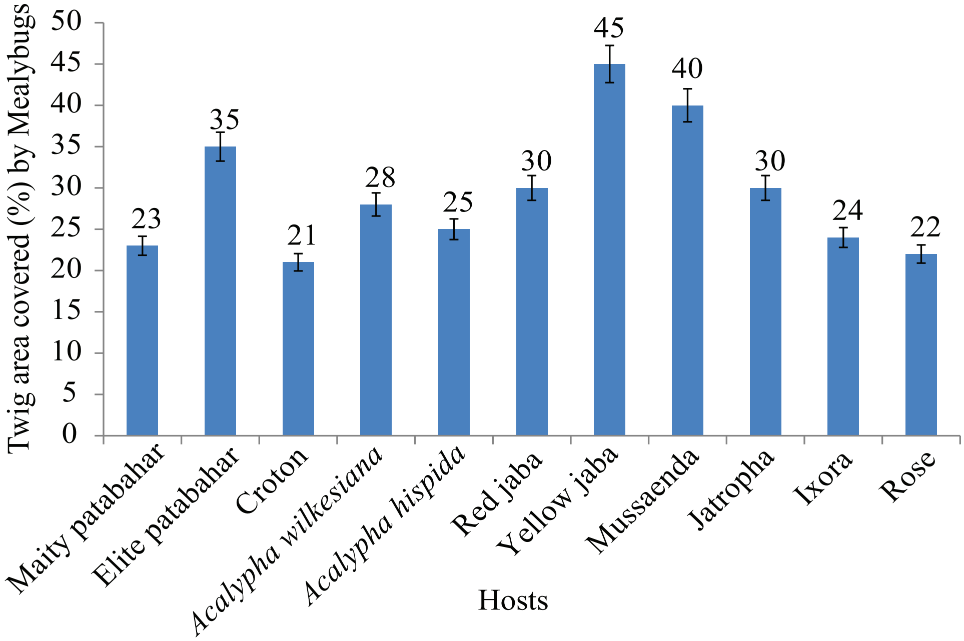

Fig. 5. Percentage of twig area covered by Mealybugs on different ornamental plants

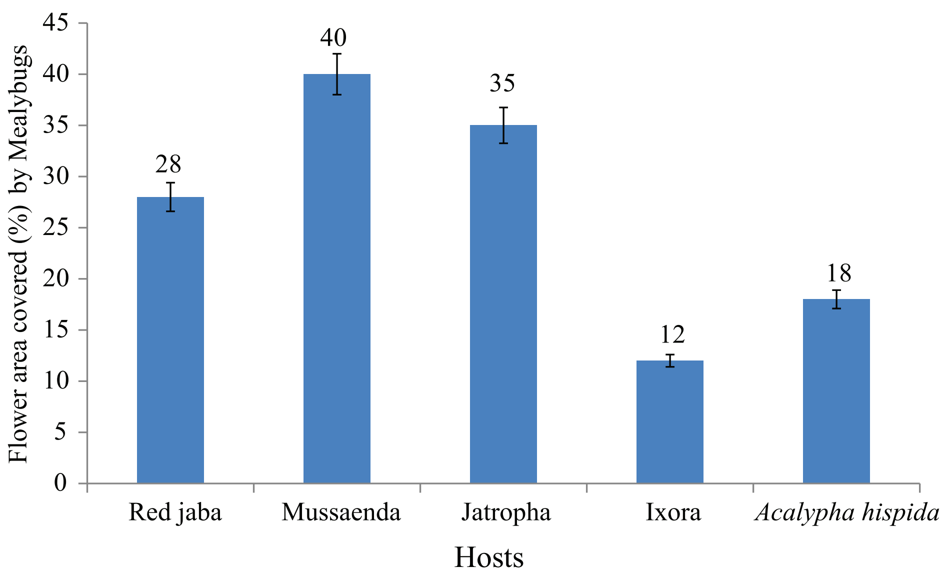

Fig. 6. Percentage of flower area covered by Mealybugs on different ornamental plants

The findings of the present study are supported by Raghuraman Angu *et al.* (2017) who stated that the population of mealybug on grapevine started increasing from third week of January 2015 and peak incidence was recorded from ninth week of February 2015 to thirteenth week of March 2015. Khan (2023) found that the highest incidence of mealybug per leaf was recorded on century plant and the lowest was on Mussaenda. The highest number of mealybugs per twig was found on Elite coleus followed by *Hibiscus* while the lowest number was found on Croton. He also stated that the highest percentage of infested twigs per plant was found on *Hibiscus* followed by Jatropha while the lowest percentage was on Maity coleus. Pink *Hibiscus* mealybug feeds on the soft tissues of many plant species and injects a toxic saliva that causes curling and contortion of leaves. The entire plant may be stunted and the shoot tips develop a bushy appearance. Buds may not flower and stems may twist. Fruit may also be deformed. The mealybug excretes honeydew which encourages the development of black sooty mold. Very high mealybug populations can kill plants (Williams 1996). The pink *Hibiscus* mealybug is expected to attack many Florida crops including citrus, avocado, carambola, fig, guava, mango, soursop, and sugarcane; vegetable crops including asparagus, beans, beets, cabbage, peanuts, pigeon pea, cucumber, lettuce, pepper, pumpkin, and tomato; forest trees, and many species of ornamental plants including *Allamanda, Angelica, Anthurium, Bougainvillea*, croton, ginger lily, *Heliconia, Ixora, Hibiscus*, palm, and oleander (Frank 2010). In the Caribbean, damage has been reported on *Annona* spp., *Spondias* spp., okra (*Abelmoschus esculentus*), mango, sorrel (*Hibiscus sabdariffa*), *Albizia saman* and other ornamentals important to the tourist industry, and forest trees such as blue mahoe (*Hibiscus elatus*) and teak (*Tectona grandis*) (Pollard 1995). *M. hirsutus* destroys crops and ornamental plants (Hoy *et al.* 2003). As it feeds, the *Hibiscus* mealybug injects into the plant a toxic saliva that results in malformed leaf and shoot growth, stunting, and occasional death. Leaves show a characteristic curling, similar to damage caused by viruses. Heavily infested plants have shortened internodes leading to resetting or a “bunchy top” appearance. A heavy, black, sooty mold may develop on an infested plant’s leaves and stems as a result of the mealybug’s heavy honey-dew secretions. When fruits are infested, they can be entirely covered with the white waxy coating of the mealybug.

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RESPONSE OF BENEFICIAL ARTHROPODS TO INSECTICIDES; USED FOR THE IPM MODULE AGAINST COTTON JASSID (*AMRASCA BIGUTTULA BIGUTTULA* ISHIDA)

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ABSTRACT

A field experiment was conducted during the August 2024 to February 2025 cotton seasons at the Cotton Research, Training, and Seed Multiplication Farm, Sreepur, Gazipur, to evaluate five insecticides, viz., Imidacloprid (Tido 20 SL) @ 0.5 ml L^{-1}, Thiamethoxam (Spike 25 WG) @ 0.3 g L^{-1}, Diafenthiuron (Pannel 50 SC) @ 0.5 ml L^{-1}, Acetamiprid (Tundra 20 SP) @ 0.5 g L^{-1}, and Acephate (Asataf 75 SP) @ 1.5 g L^{-1}. Significant differences were observed among treatments in suppressing jassid population, conserving beneficial arthropods, and improving productivity. Diafenthiuron recorded the lowest mean jassid population (0.53 $leaf^{-1}$) with 84.77% reduction over untreated control. Acetamiprid and Acephate showed moderate efficacy, while Imidacloprid provided comparatively lower control. Thiamethoxam performed poorly and sometimes increased jassid incidence. After five sprays, Acetamiprid conserved the highest populations of spiders (0.33 $plant^{-1}$) and ladybird beetles (0.32 $plant^{-1}$), while Diafenthiuron produced the highest seed cotton yield (2713.99 kg ha^{-1}), net return (Tk. 124,979 ha^{-1}), and benefit-cost ratio (1.85).

Keywords: Cotton, jassid, insecticide, beneficial arthropods, IPM module

INTRODUCTION

Cotton is the "King of Fiber" and one of the most important cash crops in Bangladesh. For its importance as a main raw material in the textile and garment industry, major contribution to national GDP and foreign earnings, it's also called

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"White Gold". Bangladesh ranks as the world's second-largest cotton importer and the fourth-largest consumer. During 2024-2025, cotton was cultivated on 46,760 hectares, producing 99,798 metric tons of seed cotton and 219,338 bales of lint (CDB 2025). In spite of high demand, there are many constraints for cultivating cotton in Bangladesh, including erratic rainfall during sowing time, infestation by serious pests and diseases, heavy weed infestations, long crop duration, lower yields, and fluctuation of the seed cotton price. Among these, infestation of major insect pests is one of the main constraints from sowing to harvesting. However, cotton is vulnerable to various insect pests, which cause serious damage to the crop, leading to severe yield losses. In recent years, the incidence of the sucking pest, *Amrasca biguttula biguttula* (jassid or leafhopper), also called *Amrasca devastans* (Dist.), has become serious in Bangladesh, India, Pakistan, Thailand, and other South East Asian countries (Roy *et al*. 2009). Cotton jassid damage alone may reduce yield by 50 %, and damage by jassids and bollworms together may reduce yield as much as by 70 % (Wadud and Moniruzzaman 2001).

To control the insect pests of cotton, sustainable management strategies are preferable for an eco-friendly approach. However, farmers prefer chemical pesticides over other management techniques because of their effectiveness, availability, and cost-effectiveness (Siddique and Azad 2010). Despite of all the positive and negative impacts of insecticides, cases of natural enemies showing resistance to insecticides have also been recorded in some studies (Barbosa *et al*. 2016). It is recommended that selective insecticides be encouraged to control cotton pests, maintaining the natural enemies' population (Machado *et al*. 2019). Besides, chemical control is the most effective tactic for the management of cotton insect pests, but should only be used as last option, judiciously in combination with proper spray technology and only when economic threshold levels approaches to reduce pesticide loads (Asrar *et al.* 2013). The uses of neonicotinoids are supposed to be less toxic to the non-target insects like predators and parasitoid than other conventional insecticides. These chemicals are selective and specific, with no side as well as after effects on non-target insects and environment (Hafeez *et al.* 2020). Integration of chemical and biological control strategies remain a viable option in an IPM programme for the control of cotton pests (Malinga and Laing 2022). So it is imperative to find out an eco-friendly and need based use of chemical pesticides as a component of Integrated

Pest Management (Murugesan *et al*. 2002). From the above circumstances an experiment was conducted in the cotton field to evaluate the efficacy of different synthetic insecticides against jassid infestation and to observe their effect on the abundance of natural enemies.

MATERIALS AND METHODS

Experimental design and crop management: The trial was established using a randomized complete block design (RCBD) with three replications. Each plot consisted of four rows, each 4.5 m long, with 90 cm spacing between rows and 35 cm between individual plants. Standard agronomic practices for cotton were applied uniformly across all plots. Fertilizer application followed recommended rates, while irrigation, weeding, and other crop management operations were performed consistently for all treatments.

Data Collection: Treatments were applied to the experimental plots immediately after pest infestation and repeated at 10-day intervals for a total of five applications. At 3 and 7 days after treatment (DAT), nymphs and adults were sampled from three leaves (top, middle, and bottom) of three randomly selected plants per plot. Beneficial arthropods (spiders and ladybird beetles) were similarly recorded from five randomly selected plants per plot at the same intervals. Yield was assessed from two separate pickings. Jassid density (nymphs + adults) per leaf and the abundance of natural enemies were calculated for each replicate of every treatment at 3 and 10 DAT. The percent reduction of jassid population over farmers practice was calculated by using the following formula:

$$\%\text{ reduction of jassid population over control} = \frac{\text{Jassid number in control - Jassid number in treatment}}{\text{Jassid number in control}} \times 100$$

Seed Cotton Yield and BCR: Seed cotton from each treated and control plot was harvested, sun-dried, weighed, and converted to yield per hectare based on plot size. Total production cost for each treatment was determined by accounting insecticide prices and application expenses. The monetary value of seed cotton yield was then estimated, and the BCR was calculated as the ratio of net profit to total cost.

Statistical Analysis: All experimental data were encoded, organized, and processed using Microsoft Excel 2010. Treatment effects were assessed through analysis of variance (ANOVA) under a Randomized Complete Block Design (RCBD) using R software (version 4.5.1). Mean separation was performed using Duncan's Multiple Range Test (DMRT) following Gomez and Gomez (1984). Graphs were generated in Microsoft Excel 2010.

RESULTS

In the present study, the effectiveness of different chemical insecticides against jassid (*Amrasca biguttula biguttula* Ishida) was evaluated, where five sprays were applied and the number of jassid population per leaf, number of natural enemies (spider and ladybird beetle) per plant, and yield data were collected from pre-treatment and three and seven days after treatment (DAT).

Effect of insecticidal treatments on jassid and associated natural enemies after the application of first spray: Pre-treatment observations showed no significant differences in jassid (3.02-3.66 leaf^{-1}), spider (0.80-0.93 plant^{-1}), or ladybird beetle populations (0.40-0.53 plant^{-1}), indicating uniform initial conditions (Table 1).

Table 1. Effect of different insecticidal treatments on jassid (per leaf) and associated natural enemies (spiders and ladybird beetles per plant) after first spray.

Treatments	Jassid/leaf			Natural enemies/plant					
				Spider			Ladybird beetles		
	Pre-Treatment	3 DAT	7 DAT	Pre-Treatment	3 DAT	7 DAT	Pre-Treatment	3 DAT	7 DAT
Imidacloprid	3.02a	1.01c	1.69d	0.80a	0.47b	0.40b	0.53a	0.20c	0.40b
Thiamethoxam	3.45a	1.66b	2.55b	0.93a	0.20c	0.27b	0.60a	0.20c	0.27c
Diafenthiuron	3.41a	0.63d	0.99f	0.80a	0.20c	0.40b	0.40a	0.20c	0.33b
Acetamiprid	3.56a	0.66d	1.32e	0.80a	0.47b	0.40b	0.47a	0.33b	0.40b
Acephate	3.59a	0.86c	1.99c	0.87a	0.27bc	0.20b	0.53a	0.20c	0.20c
Control	3.66a	3.82a	3.15a	0.80a	0.73a	0.73a	0.53a	0.47a	0.60a
Sig. Level	NS	***	***	NS	**	*	NS	***	***
SEM (±)	0.34	0.11	0.11	0.20	0.13	0.15	0.12	0.06	0.05
CV %	9.85	7.81	5.63	31.28	68.31	77.33	23.35	22.61	12.95
LSD (0.05)	0.61	0.20	0.20	0.59	0.39	0.46	0.21	0.11	0.08

DAT-Days After Treatment; Means within a column followed by the same letter(s) do not differ significantly according to the LSD test at $p \leq 0.05$. *** = Significant at 0.1% level of probability; ** = Significant at 1% level of probability; * = Significant at 5% level of probability; NS = Non-significance, SEM = Standard error of the mean.

After the first spray, all insecticides significantly reduced jassid density at 3 DAT compared to untreated control (3.82 leaf^{-1}), with Diafenthiuron (0.63 leaf^{-1}) and Acetamiprid (0.66 leaf^{-1}) providing the greatest suppression, followed by Acephate, Imidacloprid, and Thiamethoxam ($p < 0.001$). This trend persisted at 7 DAT, where Diafenthiuron (0.99 leaf^{-1}) and Acetamiprid (1.32 leaf^{-1}) remained most effective, while the control recorded the highest population (3.15 leaf^{-1}). Spider abundance was not significantly affected by treatments at either observation, whereas ladybird beetle populations were significantly reduced by all insecticides, with Thiamethoxam and Acephate causing the greatest declines and the control maintaining the highest density ($p < 0.001$).

Effect of insecticidal treatments on jassid and associated natural enemies after the application of second spray: All insecticides significantly reduced jassid populations at 3 and 10 DAT compared with the untreated control ($p < 0.001$) (Table 2). Diafenthiuron provided the highest suppression, recording the lowest jassid density at both 3 DAT (0.09 leaf^{-1}) and 7 DAT (0.38 leaf^{-1}), followed by Acephate and Acetamiprid. Thiamethoxam was the least effective, while the control maintained the highest infestation at both observation periods. Spider and ladybird beetle populations were significantly affected by treatments at both observation times. The untreated control consistently recorded the highest abundance of both natural enemies. Among insecticides, Acetamiprid maintained relatively higher spider (0.40 plant^{-1}) and ladybird beetle populations (0.40-0.47 plant^{-1}), indicating comparatively lower toxicity. Diafenthiuron and Imidacloprid showed moderate adverse effects, whereas Acephate and Thiamethoxam caused the greatest reductions in natural enemy abundance.

Effect of insecticidal treatments on jassid and associated natural enemies after the application of third spray: After the third spray, all insecticides significantly reduced jassid populations at 3 DAT compared with the untreated control (3.34 leaf^{-1}; $p < 0.001$) (Table 3). Diafenthiuron was most effective (0.16 leaf^{-1}), followed by Acetamiprid (0.26 leaf^{-1}) and Acephate (0.27 leaf^{-1}), while Imidacloprid showed moderate control and Thiamethoxam was least effective (2.32 leaf^{-1}). At 7 DAT, Diafenthiuron maintained the lowest jassid density (0.78 leaf^{-1}), followed by Acetamiprid and Acephate, whereas Imidacloprid and Thiamethoxam recorded

Table 2. Effect of selected insecticides on jassid population (per leaf) and associated natural enemies (per plant) after second spray.

Treatments	Jassid/leaf		Natural enemies/plant			
			Spider		Ladybird beetles	
	3DAT	7DAT	3DAT	7DAT	3DAT	7DAT
Imidacloprid	0.51c	1.97b	0.20c	0.27b	0.27bc	0.40a
Thiamethoxam	1.56b	2.11b	0.20c	0.33b	0.20c	0.20b
Diafenthiuron	0.09f	0.38c	0.27c	0.33b	0.27bc	0.40a
Acetamiprid	0.26d	0.57c	0.40b	0.40b	0.40ab	0.47a
Acephate	0.21e	0.57c	0.20c	0.27b	0.20c	0.27b
Control	3.19a	3.37a	0.60a	0.87a	0.47a	0.40a
Sig. Level	***	***	***	**	**	**
SEM (±)	0.02	0.11	0.05	0.16	0.08	0.06
CV %	2.67	7.12	43.91	39.49	25.95	16.98
LSD (0.05)	0.05	0.19	0.14	0.29	0.14	0.11

Means within a column followed by the same letter(s) do not differ significantly according to the LSD test at $p \leq 0.05$. *** = Significant at 0.1% level of probability; ** = Significant at 1% level of probability. SEM = Standard error of the mean.

higher populations; the control remained highest (3.84 leaf^{-1}) ($p < 0.001$). Spider abundance differed at 3 DAT ($p < 0.05$) but not at 7 DAT. The control supported the highest spider population; Diafenthiuron retained comparatively more spiders among treated plots, while Acephate and Thiamethoxam caused complete suppression at 3 DAT. Ladybird beetle populations were significantly affected at both observations. Acetamiprid maintained relatively higher populations, whereas Imidacloprid, Thiamethoxam, Diafenthiuron, and Acephate caused strong suppression; the control consistently recorded the highest abundance.

Effect of insecticidal treatments on jassid and associated natural enemies after the application of fourth spray: Following the fourth spray, all insecticidal treatments significantly reduced jassid populations at 3 DAT relative to the untreated control (3.10 leaf^{-1}; $p < 0.001$) (Table 4). Diafenthiuron provided the highest suppression (0.26 leaf^{-1}), followed by Acetamiprid (0.74 leaf^{-1}) and Acephate (0.92 leaf^{-1}), and while Imidacloprid showed moderate efficacy and Thiamethoxam was least effective (1.95 leaf^{-1}). At 7 DAT, Diafenthiuron maintained the lowest jassid

Table 3. Effect of selected insecticides on jassid population (per leaf) and associated natural enemies (per plant) after third spray.

Treatments	Jassid/leaf		Natural enemies/plant			
			Spider		Ladybird beetles	
	3DAT	7DAT	3DAT	7DAT	3DAT	7DAT
Imidacloprid	0.54c	2.45b	0.07bc	0.27ab	0.00b	0.07c
Thiamethoxam	2.32b	2.45b	0.00c	0.07b	0.00b	0.00c
Diafenthiuron	0.16d	0.78d	0.13ab	0.27ab	0.00b	0.13bc
Acetamiprid	0.26d	1.43c	0.07bc	0.27ab	0.20a	0.27ab
Acephate	0.27d	1.75c	0.00c	0.07b	0.00b	0.00c
Control	3.34a	3.84a	0.20a	0.47a	0.27a	0.33a
Sig. Level	***	***	*	NS	***	**
SEM (±)	0.12	0.20	0.07	0.17	0.05	0.09
CV %	10.77	9.72	86.68	71.56	59.21	69.08
LSD (0.05)	0.22	0.37	0.12	0.30	0.08	0.16

Means within a column followed by the same letter(s) do not differ significantly according to the LSD test at $p \leq 0.05$. *** = Significant at 0.1% level of probability; ** = Significant at 1% level of probability; * = Significant at 5% level of probability; NS = non-significance. SEM = Standard error of the mean.

density (1.01 $leaf^{-1}$), followed by Acetamiprid and Imidacloprid; Acephate and Thiamethoxam recorded higher populations, and the control remained highest (3.70 $leaf^{-1}$) ($p < 0.001$). Spider populations differed significantly at both observations ($p < 0.05$). At 3 DAT, Acetamiprid and the control supported higher spider abundance, Diafenthiuron and Imidacloprid showed moderate reductions, while Thiamethoxam and Acephate caused complete suppression. By 7 DAT, spider numbers partially recovered, with the highest populations in Acetamiprid and control plots and the lowest under Acephate. Ladybird beetle populations were unaffected at 3 DAT but differed at 7 DAT ($p < 0.01$), with Acetamiprid sustaining the highest abundance, Imidacloprid and Diafenthiuron intermediate levels, and Thiamethoxam and Acephate remaining most suppressive.

Table 4. Effect of selected insecticides on jassid population (per leaf) and associated natural enemies (per plant) at 3 and 7 days after treatment (DAT) of fourth spray.

Treatments	Jassid/leaf		Natural enemies/plant			
			Spider		Ladybird beetles	
	3DAT	7DAT	3DAT	7DAT	3DAT	7DAT
Imidacloprid	1.43c	1.74d	0.07bc	0.13b	0.07ab	0.20ab
Thiamethoxam	1.95b	2.61b	0.00a	0.13b	0.00b	0.00c
Diafenthiuron	0.26f	1.01f	0.07a	0.20ab	0.07ab	0.19ab
Acetamiprid	0.74e	1.46e	0.20a	0.33a	0.20ab	0.27a
Acephate	0.92d	2.21c	0.00a	0.07b	0.00b	0.07bc
Control	3.10a	3.70a	0.27a	0.33a	0.27a	0.20ab
Sig. Level	***	***	*	*	NS	**
SEM (±)	0.04	0.08	0.08	0.10	0.11	0.07
CV %	2.89	3.66	85.86	48.61	58.71	45.18
LSD (0.05)	0.07	0.14	0.25	0.29	0.19	0.12

Means within a column followed by the same letter(s) do not differ significantly according to the LSD test at $p \leq 0.05$. *** = Significant at 0.1% level of probability; ** = Significant at 1% level of probability; * = Significant at 5% level of probability; NS = Non-significance. SEM = Standard error of the mean.

Effect of insecticidal treatments on jassid and associated natural enemies after the application of fifth spray: After the fifth spray, all insecticidal treatments significantly suppressed jassid populations at 3 DAT compared with the untreated control (3.51 leaf^{-1}; $p < 0.001$) (Table 5). Diafenthiuron was most effective (0.28 leaf^{-1}), followed by Acetamiprid (0.60 leaf^{-1}) and Acephate (0.94 leaf^{-1}), whereas Imidacloprid showed moderate efficacy and Thiamethoxam was least effective (2.33 leaf^{-1}). At 7 DAT, Diafenthiuron maintained the lowest jassid density (0.67 leaf^{-1}), with Acetamiprid and Acephate performing similarly, while Imidacloprid and Thiamethoxam recorded higher populations; the control remained highest (3.64 leaf^{-1}) ($p < 0.001$).

Table 5. Effect of selected insecticides on jassid population (per leaf) and associated natural enemies (per plant) after fifth spray.

Treatments	Jassid/leaf		Natural enemies/plant			
			Spider		Ladybird beetles	
	3DAT	7DAT	3DAT	7DAT	3DAT	7DAT
Imidacloprid	1.39c	2.02b	0.00b	0.13b	0.00b	0.20b
Thiamethoxam	2.33b	2.45b	0.00b	0.07b	0.00b	0.00c
Diafenthiuron	0.28f	0.67d	0.00b	0.20b	0.00b	0.20b
Acetamiprid	0.60e	1.29c	0.26a	0.53a	0.27a	0.40a
Acephate	0.94d	1.31c	0.00b	0.00b	0.00b	0.00c
Control	3.51a	3.64a	0.33a	0.53a	0.33a	0.53a
Sig. Level	***	***	***	**	***	***
SEM (±)	0.10	0.32	0.07	0.15	0.06	0.09
CV %	6.54	16.70	71.02	62.77	60.30	41.45
LSD (0.05)	0.18	0.57	0.21	0.46	0.11	0.16

Means within a column followed by the same letter(s) do not differ significantly according to the LSD test at $p \leq 0.05$. *** = Significant at 0.1% level of probability; ** = Significant at 1% level of probability. SEM = Standard error of the mean.

Spider abundance differed significantly at both 3 and 7 DAT. At 3 DAT, spiders were present only in the control and Acetamiprid plots, while all other treatments caused complete suppression. By 7 DAT, spider populations partially recovered, with Acetamiprid and the control supporting the highest densities, Diafenthiuron showing moderate abundance, Imidacloprid and Thiamethoxam lower levels, and Acephate remaining fully suppressive. Ladybird beetle populations were also significantly affected at both observations ($p < 0.001$). At 3 DAT, beetles were recorded only in the control and Acetamiprid plots. At 7 DAT, Acetamiprid sustained the highest beetle population among treatments, followed by Imidacloprid and Diafenthiuron, whereas Thiamethoxam and Acephate continued to cause complete suppression.

Overall mean number of jassid per leaf after application of five consecutive sprays: Across five consecutive sprays, all insecticidal treatments significantly reduced mean jassid population per leaf compared with the untreated control, which consistently recorded the highest infestation (Fig. 1). The lowest population was recorded in Diafenthiuron-treated plots (0.53 $leaf^{-1}$), followed by Acetamiprid

(0.86 leaf^{-1}) and Acephate (1.10 leaf^{-1}). Imidacloprid-treated plots showed a mean population of 1.48 leaf^{-1}, whereas Thiamethoxam recorded 2.20 leaf^{-1}. The highest jassid population was observed in the untreated control (3.47 leaf^{-1}).

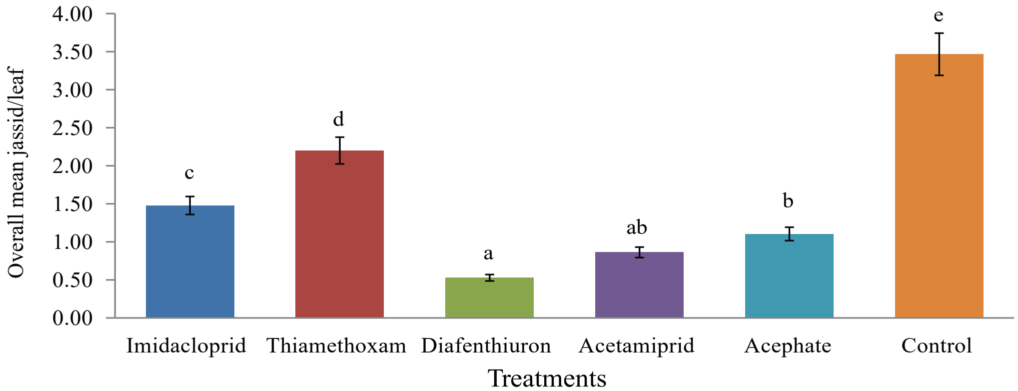

Fig. 1. Overall mean (± SE) jassid (*Amrasca biguttula biguttula*) population per leaf across five consecutive sprays under different insecticide treatments.

Overall mean percent reduction of jassid population over the untreated control: Mean percent reduction of jassid population over the untreated control differed significantly among insecticides (Fig. 2). Diafenthiuron recorded the highest suppression (84.77%), followed by Acetamiprid (75.13%) and Acephate (68.15%). Imidacloprid showed moderate efficacy (57.36%), while Thiamethoxam was the least effective (36.53%).

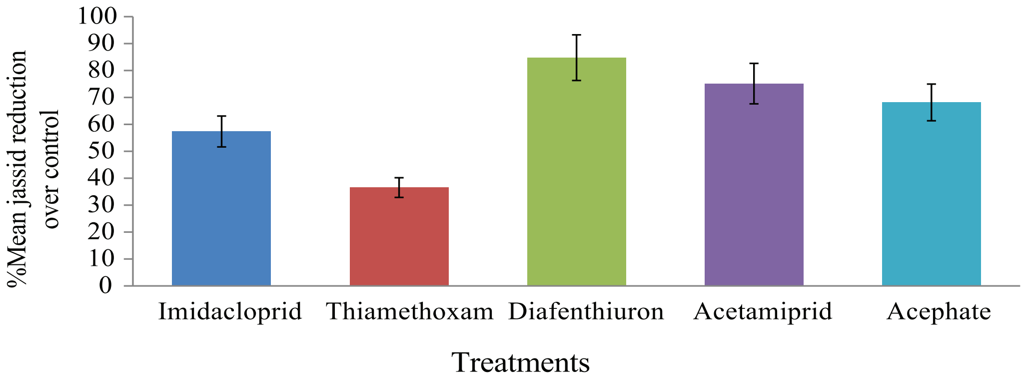

Fig. 2. Mean percent reduction of jassid (*Amrasca biguttula biguttula*) population over untreated control following insecticide applications.

Overall mean number of natural enemies/plant after application of five consecutive sprays: Mean predator abundance differed significantly among treatments (Fig. 3). Spiders and ladybird beetles were most abundant in the untreated control (0.51 and 0.39 plant^{-1}, respectively). Among insecticides, Acetamiprid and Diafenthiuron conserved relatively higher predator populations (spiders: 0.21-0.33; ladybird beetles: 0.18-0.32 plant^{-1}), whereas Thiamethoxam and Acephate were most suppressive; imidacloprid showed intermediate effects. Overall, Acetamiprid and Diafenthiuron were comparatively safer to natural enemies, indicating better compatibility with IPM.

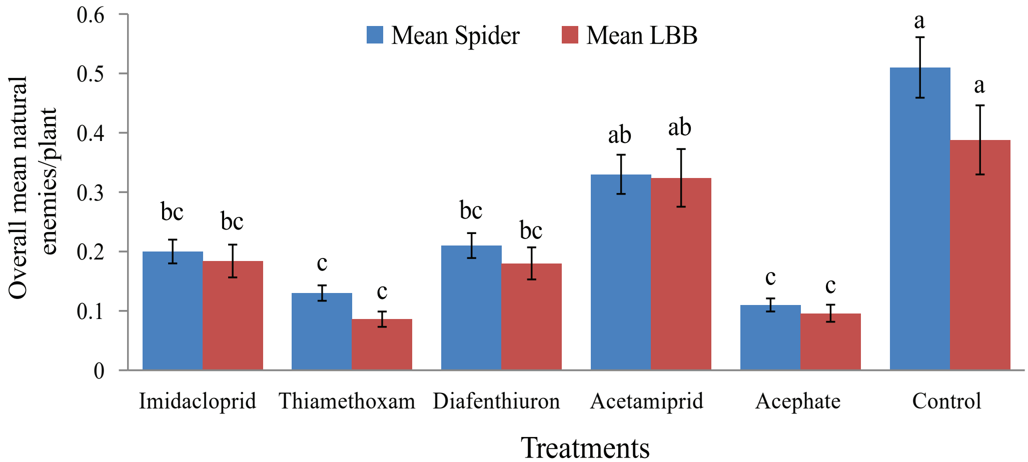

Fig. 3. Effect of different insecticidal treatments on the mean abundance of natural enemies (spiders and ladybird beetles per plant) at 3 and 7 days after treatment.

Seed cotton yield and economics of cotton: Seed cotton yield differed significantly among treatments, with Diafenthiuron producing the highest yield (2713.99 kg/ha), followed by Acetamiprid (1868.31 kg/ha) and Acephate (1802.47 kg/ha) (Table 6). Imidacloprid achieved moderate yield (1668.73 kg/ha), whereas Thiamethoxam and the untreated control had the lowest yields (985.59 and 412.76 kg/ha, respectively). Correspondingly, net returns were highest for Diafenthiuron (124979 Tk/ha) and favorable for Acetamiprid (46584 Tk/ha) and Acephate (52346 Tk/ha), while Thiamethoxam and control plots incurred negative net returns. The benefit-cost ratio (BCR) was greatest for Diafenthiuron (1.85), indicating superior economic efficiency, followed by Acephate (1.41) and Acetamiprid (1.33), and Imidacloprid

(1.09), respectively. The lowest benefit-cost ratio (0.69) was recorded in the untreated control plots followed by Thiamethoxam (0.81) treated plots. These results highlight Diafenthiuron as the most profitable treatment, combining high yield with strong economic returns.

Table 6. Effect of different insecticidal treatments on seed cotton yield, production cost, gross returns, net returns, and benefit-cost ratio (BCR)

Treatments	Seed Cotton Yield (Kg/ha)	Production Cost (Tk/ha)	Gross Returns (Tk/ha)*	Net Returns (Tk/ha)	BCR
Imidacloprid	1668.73c	152593	166873	14280	1.09
Thiamethoxam	985.59d	121728	98559	-23169	0.81
Diafenthiuron	2713.99a	146420	271399	124979	1.85
Acetamiprid	1868.31b	140247	186831	46584	1.33
Acephate	1802.47b	127901	180247	52346	1.41
Control	412.76e	60000	41276	-18724	0.69
Sig. Level	***	-	-	-	-
SEM (±)	52.93	-	-	-	-
CV %	3.36	-	-	-	-
LSD (0.05)	95.11	-	-	-	-

Means within a column followed by the same letter(s) do not differ significantly according to the LSD test at $p \leq 0.05$. *** = Significant at 0.1% level of probability; SEM = Standard error of the mean. *Seed Cotton Rate-100 Tk/Kg.

DISCUSSION

Across all sprays and observation periods, Diafenthiuron consistently maintained the lowest jassid population at both 3 and 7 DAT, indicating rapid knockdown and prolonged residual activity. Acetamiprid and Acephate provided moderate yet consistent suppression across sprays. Imidacloprid showed variable performance, with moderate reduction at 3 DAT but comparatively higher populations at 7 DAT, suggesting shorter persistence. Thiamethoxam consistently recorded the highest jassid populations among treated plots and was therefore the least effective, indicating limited residual effectiveness under the prevailing field conditions. These results are consistent with findings reported by other researchers. Diafenthiuron has been reported as an effective control agent against *A. biguttula* (Babu and Santharam 2000; Aslam *et al*. 2004). Razaq *et al.* (2005) reported that Diafenthiuron and Acetamiprid were the most effective in suppressing jassid populations below the economic threshold level (ETL), with Acetamiprid-treated plots recording the lowest population (0.43 leaf^{-1}). Similarly, Sahito *et al*. (2017) observed that both Diafenthiuron and Acetamiprid caused higher mortality and effectively reduced jassid densities to 1-1.5 leaf^{-1}. Supporting these findings, Dutta *et al*. (2017) and Maqboo *et al*. (2003) identified Diafenthiuron as the most efficient chemical against cotton jassid. Bontha and Mallapur (2017) also recorded the lowest mean leafhopper population (1.26/leaf) in plots treated with a combination of Diafenthiuron 50 WP + Carbendazim 50 WP, followed by Diafenthiuron alone. Kumar *et al.* (1999) reported the efficacy of Acetamiprid 20% SP against cotton leafhopper up to 10 days after treatment, which was further confirmed by Kolhe *et al*. (2009).

Diafenthiuron showed the highest efficacy against jassid, providing maximum population reduction over untreated control of both the cases (84.77%), indicating superior field performance. Acetamiprid and Acephate offered moderate suppression, whereas Imidacloprid was less effective. Thiamethoxam performed poorly, with minimal reduction over the control and a negative response compared with farmers' practice, suggesting inadequate control under field conditions. Halappa and Patil (2014) conducted an experiment against cotton leafhopper, *Amarasca biguttula biguttula* (Ishida), and Diafenthiuron 50 WP was found most effective against leafhopper with 76.23% reduction over the untreated control. Supporting these findings, Razaq *et al*. (2004), and Parvez *et al*. (2011) also observed that both cotton and okra crops experienced notable decreases in jassid populations when compared to untreated control. Additionally, studies by Babu and Santharam (2000), Aslam *et al*. (2004), and Badgujar *et al*. (2014) reported that plots treated with Diafenthiuron 50 SC achieved the highest reduction in infestation over the control, recorded 86.39%, against cotton jassids in okra.

Although all tested insecticides reduced natural enemy populations, Acetamiprid was comparatively less toxic and relatively safer for both spiders and ladybird beetles. Diafenthiuron exhibited moderate suppression of spiders, whereas Imidacloprid, Acephate, and Thiamethoxam resulted in marked reductions or complete suppression at early observation periods. The higher sensitivity of spiders to these insecticides may be related to their broad-spectrum activity and contact toxicity. Ladybird beetles were found to be highly sensitive to most insecticidal treatments across sprays. Acetamiprid consistently recorded higher ladybird beetle populations compared to other insecticides, indicating comparatively safer effects. Diafenthiuron and Imidacloprid showed moderate adverse effects, while Acephate and Thiamethoxam resulted in severe suppression or complete elimination of ladybird beetles at both observation periods. The pronounced reduction of ladybird beetle populations under Acephate and Thiamethoxam treatments may be attributed to their broad-spectrum insecticidal activity and high contact toxicity. The results of the present study are consistent with those of Patil *et al*. (2000), who reported no adverse effects of Acetamiprid on predator populations. Similarly, Acharya *et al.* (2002) observed that Acetamiprid (20 g a.i./ha) was relatively safer for predatory ladybird beetles. In line with this, Bharpoda *et al*. (2014) reported higher spider populations in plots treated with Diafenthiuron 50 WP @ 0.05% and Acetamiprid 20 SP @ 0.01%, suggesting comparatively lower toxicity. Halappa and Patil (2014) further confirmed that Diafenthiuron 50 WP, Acetamiprid 20 SP were relatively safe to natural enemies, including coccinellids, chrysopids, micromus, and spiders. Conversely, Rao (1986) reported that acephate at 0.5 kg a.i./ha exerted a harmful effect on the predator *M. sexmaculatus*.

The significant differences in seed cotton yield among insecticidal treatments closely reflected their relative effectiveness in jassid suppression. Diafenthiuron produced the highest yield (2713.99 kg/ha) and economic return (Tk. 124,979/ha; BCR 1.85), indicating superior biological efficacy and profitability. Acetamiprid, Acephate, and Imidacloprid resulted in moderate yield gains and returns, consistent with their intermediate control levels. Babu and Santharam (2000) and Badgujar *et al*. (2014) also reported that the highest cotton yield (1.25 t/ha) was obtained from plots treated with Diafenthiuron 50 SC. Similarly, Yesmin (2023) found that Diafenthiuron outperformed other insecticides, achieving the highest yield (2.15 t/ha), the best benefit-cost ratio (1.67), and significant reductions in jassid population (89.45%), resulting in a 69.76% increase in cotton yield. Khan (2011) also observed that Acetamiprid 20 SP was more effective than other tested insecticides in managing sucking pests and enhancing seed cotton yield.

CONCLUSION

In conclusion, Diafenthiuron proved highly effective in suppressing jassid populations but exhibited moderate adverse effects on natural enemies, indicating the need for cautious application. Acetamiprid emerged as the most balanced option, providing satisfactory jassid control while conserving higher populations of spiders and ladybird beetles. The concurrence of effective pest suppression with better preservation of beneficial arthropods highlights the suitability of Acetamiprid and Diafenthiuron, when judiciously applied, in sustainable IPM programs.

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EVALUATION OF DIFFERENT BIO-PESTICIDES AGAINST RUGOSE SPIRALING WHITEFLY INFESTING COCONUT CROP UNDER FIELD CONDITION

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ABSTRACT

Coconut is an important cash crop in Bangladesh, particularly for coastal livelihoods, contributing significantly to safeguard economic stability, nutritional security, and environmental protection. But being invasive sap-sucking insect pest, the rugose spiraling whitefly (RSW) (*Aleurodicus rugioperculatus*) has recently been recognized as a serious threat to coconut cultivation all over Bangladesh. Studies were carried out in two locations viz. Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Jashore and RARS, BARI, Barishal to document the comparative efficacy of five biopesticides against rugose spiraling whitefly (RSW) infesting coconut during 2023-24. The results revealed that biopesticide Bioclean 5% SL (d-limonene) provided highest efficacy with 66.51-70.56% reduction of nymph/adult population of RSW over control. Whereas, application of Fizimite (10% sodium lauryl ether sulfate) offered the second highest efficacy with 60.05-61.38% reduction of nymph/adult population of RSW over control. The highest natural parasitism (17.01-18.34%) and parasitoid adult emergence (12.35-13.59%) was recorded from Fytoclean (potassium salt of fatty acid) followed by Biotrin (5% matrine). The best performing biopestcides viz. Bioclean 5% SL and Fizimite could be utilized in a well designed IPM program against rugose spiraling whitefly in coconut.

***Keywords*:** Biotrin, Fizimite, Fytoclean, *Aleurodicus rugioperculatus,* IPM

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INTRODUCTION

Bangladesh being a tropical country with a warm and humid climate and free of trade and movement of agricultural commodities has always been vulnerable to threats of invasive pests. The rugose spiraling whitefly (RSW), *Aleurodicus rugioperculatus* Martin (Aleyrodidae: Hemiptera), a new invasive insect pest in Bangladesh, was first identified in May 2019 on coconut plants in Jashore (Dutta *et al.* 2019). RSW attack and cause damage about 250 other plants but coconut is the most preferred host (TNAU 2025). Recent survey study showed that the whole Bangladesh has been invaded by this invasive insect pest infesting 61 host plants with highest damage severity in coconut plants (Das *et al.* 2023).

Coconut is an important fruit crop in Bangladesh, which generates income for the growers continuously and contributes a lot to increase the total homestead income. It provides livelihood to coconut farmers through its versatile uses. At present, coconut cultivation in Bangladesh is being seriously impeded by RSW. This pest feeds on leaf sap , causing a severe stress to the host plant. The sticky honeydew excreted by the whiteflies drops on the lower fronds provides a substrate for sooty mould to grow producing black, dusty patches on leaves and other surfaces. The honeydew can be a nuisance, attracting ants and wasps, and the sooty mould can disrupt photosynthesis.

In severe cases, the whitefly infestation can lead to drying of leaves and leaflets (Moyem *et al.* 2023; Puvvala *et al*. 2024). The RSW have the great potential to spread and reproduce throughout the year with multiple and overlapping generations. It has now become one of the most important pests of coconut and many other economically important crop plants, warranting control measures to avoid crop losses. Until 2020, the pest infestation was limited to only the south-western districts of Bangladesh, but by this time the pest has been reported from all other districts causing havoc to coconut cultivation in the country (Dutta *et al*. 2025). Chemical control is the only weapon of our farmers to control this pest. Spraying of chemical insecticides would highly suppress the population buildup of all the natural enemies in coconut ecosystem. Biopesticides are the most feasible, efficient, eco-friendly alternatives to chemical insecticides. Bio-pesticides offer an ecologically sound and effective solution to pest problems (Gupta and Dikshit, 2010). Although chemical pesticides may be sometimes more effective on crop pests than biopesticides, their long-term usage affects the natural enemy population, resistance development in pests, environmental pollution and human health hazards. Moreover, the biopesticides could play a vital role as component of sustainable IPM approaches against RSW. With the above perspectives, attempts were made to find out the comparative effectiveness of certain biopesticides against RSW in coconut under field conditions in Bangladesh.

MATERIALS AND METHODS

Field experiments were carried out in two locations viz. Regional Agricultural Research Station (RARS), Jashore and RARS, Barishal to select the best biopesticide(s) against rugose spiraling whitefly infesting coconut. The same methodology was followed in both the locations. Experiment was conducted in a randomized block design with three replicates consisting of single palm each. There were six treatments including the control. Treatments were assigned as follows: T_1: Spraying Bio-chamak 1% EW (*Celastrus angulatas*) @ 2.5 ml/litre of water; T_2: Spraying Biotrin (Matrine) @ 1.5 ml/ litre of water; T_3: Spraying Fizimite 10% (Sodium lauryl ether sulfate) @1 ml/ litre of water; T_4: Spraying Bioclean (d-limonene) @ 1 ml/ litre of water; T_5: Spraying Fytoclean (Potassium salt of fatty acid) @ 6 ml/ litre of water; T_6: Untreated control (Water spray only).

Three sprays of each insecticide were done using high volume foot pump sprayer/ power sprayer at one month interval. Details of insecticides evaluated in the study are given in Table 1. Nymph and adult whitefly population on coconut leaflets were counted at 1 day before spraying and 7 days after each spraying (Fig. 1a, 1b). From each plant 20 leaflets were collected randomly, kept in polythene bags, brought to lab, and observed under stereo zoom microscope/10x hand lens for counting nymph and adult whitefly population.

Parasitism (%) and adult emergence (%) of nymphal parasitoids were also recorded.

Natural parasitization by parasitoids was calculated using the following formula.

$$\text{Per cent parasitization} = \frac{\text{Number of parasitized whitefly nymphs}}{\text{Total number of whitefly nymphs}} \times 100$$

The number of parasitoids that emerged from the whitefly nymph was recorded based on the emergence hole in the nymph and the per cent emergence was worked out using the following formula:

$$\text{Per cent adult emergence} = \frac{\text{Number of nymphs having emergence hole}}{\text{Total number of parasitized nymphs}} \times 100$$

All recorded data were subjected to analysis of variance (ANOVA) using Statistix 10 analytical software to determine the statistical significance of experimental results (Analytical software, 2013) and means were separated by LSD.

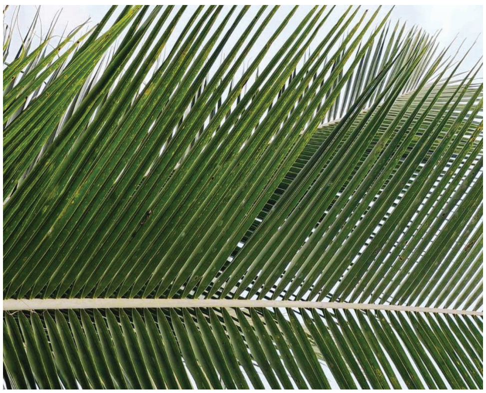

Fig. 1 A. Healthy coconut leaf

Fig. 1 B. RSW infested coconut leaf

Table 1. Details of the biopesticides used in the experiment

Trade name	Common name	Group/Class
Bio-chamak	*Celastrus angulatus*	Natural bio-pesticide derived from *Celastrus angulatus* - a type of perennial herb. Destroys the function of the insect's stomach, causing the insect to die quickly due to starvation.
Biotrin	Matrine	Broad-spectrum botanical biopesticide extracted from plants like *Sophora flavescens*. Control a variety of pests viz. aphids, caterpillars, and thrips etc. It acts as a contact and stomach poison, paralyzing insects' nervous systems. It has also repellent action.

Trade name	Common name	Group/Class
Fizimite	Sodium lauryl ether sulfate	Fizimite is a versatile, toxin-free bio-insecticide / fungicide. Control relies on direct contact with the target pests. It was washes plant for a clear and shiny appearance.
Bioclean	d- limonene	d-Limonene (Found mostly in citrus and also other plants and is a major constituent of essential oil. It is generally used as a component of flavorings and fragrances, as a chemical intermediate and as an insect repellant)
Fytoclean	Potassium salt of fatty acid	Horticultural soap (causes cellular dehydration due to ingestion by larva. The formulation also disrupts the cuticle of soft-bodied insects resulting death).

RESULTS AND DISCUSSION

***Effectiveness of biopesticides in reducing RSW nymphs and adults*:** Results of the field study conducted at RARS, Rahmatpur, Barishal, for evaluating are presented in Table 2. As shown in Table 2, at 7 days after spray (DAS), the lowest mean number of nymphs/leaflet (5.50) was noticed in Bioclean 5% SL treated plants followed by Fizimite 10% treated plants (6.85). The control treatment recorded the highest number of nymphs/leaflet (17.69). Among the bio-pesticides evaluated, significantly the highest per cent reduction of whitefly nymphs over the control was recorded in Bioclean 5% SL (68.91%), followed by Fizimite 10% (61.28%) and Biotrin 0.5% (47.54%).

At 7 days after spray (DAS), the lowest mean number of adults/leaflet (5.77) was noticed in Bioclean 5% SL treated plants followed by Fizimite 10% treated plants (7.83). The control treatment recorded the highest number of whitefly /leaflet (19.60). Among the evaluated bio-pesticides, significantly the highest per cent reduction of whitefly adult population over the control was recorded in Bioclean 5% SL (70.56%) followed by Fizimite 10% (60.05%) and Biotrin 0.5% (48.72%).

Results of the study conducted at RARS, Jashore, are presented in Table 3. As shown in Table 3, at 7 days after spray (DAS), the lowest mean number of nymphs / leaflet (6.59) was noticed in Bioclean 5% SL treated plants followed by Fizimite 10% treated plants (7.60). The control treatment recorded the highest number of nymphs /leaflet (19.68). Among the bio-pesticides evaluated, significantly the highest per cent reduction of whitefly nymphs over the control was recorded in Bioclean 5% SL (66.51%), followed by Fizimite 10% (61.38%) and Biotrin 0.5% (49.24%).

Table 2. Effect of different biopesticides on the reduction of RSW nymphs and adults during 2023-24 at RARS, Rahmatpur, Barishal (Pooled data of three sprays)

Treatments	Mean RSW nymph population/ leaflet		Reduction (%) of RSW nymph population over control	Mean RSW adult population/ leaflet		Reduction (%) of RSW adult population over control
	1 DBS	7 DAS		1 DBS	7 DAS	
Bio-chamak 1% EW	18.03	11.04 b	37.59	20.03	11.77b	39.95
Biotrin 0.5%	18.36	9.28 b	47.54	20.36	10.05bc	48.72
Fizimite 10%	18.07	6.85 c	61.28	19.82	7.83cd	60.05
Bioclean 5% SL	17.91	5.50 c	68.91	19.98	5.77d	70.56
Fytoclean	18.34	9.38 b	46.98	20.47	10.27b	47.60
Untreated control (water spray only)	18.56	17.69 a	-	20.41	19.60a	-
CV (%)	5.71	12.95	-	6.50	12.04	-

Means having the same letter(s) in a column did not differ significantly by LSD ($P < 0.05$).

At 7 days after spray (DAS), the lowest mean number of adults/leaflet (7.0) was noticed in Bioclean 5% SL treated plants followed by Fizimite 10% treated plants (8.07). The control treatment recorded the highest number of whitefly / leaflet (20.61). Among the bio-pesticides evaluated, significantly the highest per cent reduction of whitefly adults over the control was recorded in Bioclean 5% SL (66.04%) followed by Fizimite 10% (60.84%) and Biotrin 0.5% (50.85%).

***Impact of biopesticides on natural parasitism of RSW and parasitoid adult emergence*:** During the study, two species of parasitoids were found associated with *A. rugioperculatus* and parasitizing RSW nymph and identified as *Encarsia guadeloupae* Viggiani and *Encarsia dispersa* Polasze. Parasitization (%) of nymph and adult emergence (%) varied significantly among the treatments in different locations (Table 4). It was observed that , in both the locations lowest parasitization (%) was obtained from Bio-chamak 1% EW (13.02% and 14.21% in Barishal and Jashore, respectively) which was followed by Bioclean 5% SL (14.58% and15.68%, in Barishal and Jashore, respectively). In contrast, significantly the highest parasitization (%) was obtained from the untreated control (22.02% and 23.35%, in Barishal and Jashore, respectively).

Table 3. Effect of different biopesticides on the reduction of RSW nymphs and adults during 2023-24 at RARS, Jashore (Pooled data of three sprays)

Treatments	Mean RSW nymph population/ leaflet		Reduction (%) of RSW nymphs over control	Mean RSW adult population/ leaflet		Reduction (%) of RSW adults over control
	1 DBS	7 DAS		1 DBS	7 DAS	
Bio-chamak 1% EW	20.23	12.12 b	38.41	21.38	12.48b	39.45
Biotrin 0.5%	20.38	9.99 bc	49.24	21.45	10.13bc	50.85
Fizimite 10%	20.12	7.60 de	61.38	21.19	8.07cd	60.84
Bioclean 5% SL	20.27	6.59 e	66.51	21.34	7.0d	66.04
Fytoclean	20.14	9.08 cd	53.86	20.89	9.85c	52.21
Untreated control (water spray only)	20.21	19.68 a	-	21.51	20.61a	-
CV (%)	9.27	10.89	-	7.77	12.61	-

Means having the same letter(s) in a column did not differ significantly by LSD ($P < 0.05$).

Similar results were also observed in case of adult emergence. Percent Parasitoid adult emergence was the lowest in Bio-chamak 1% EW (9.32% and 9.42% in Barishal and Jashore, respestively) which was followed by Bioclean 5% SL (10.28% and11.32%, in Barishal and Jashore, respectively). In both the locations, significantly the highest adult emergence was noticed (17.23 and 18.67% Barishal and Jashore, respectively) from the untreated plants followed by biopesticide treated plants (Table 4).

The invasive rugose spiraling whitefly at present is hindering coconut production in coconut growing regions of the world. Recent invasion of this pest in Bangladesh has led to substantial economic losses, highlighting the urgent need for bio-intensive management. Since the first occurrence of this pest in the country, attempts have been made by several researchers to develop effective management options, but those previous studies mostly concentrated on the efficacy of chemical pesticides, less focusing on biopesticides. Results of the two locations study revealed that biopesticide Bioclean 5% SL (66-70% efficacy) was promising against RSW. Whereas, application of Fizimite offered the second highest efficacy with 60-62% reduction of nymph/adult populations of RSW over the control. These biopesticide could be utilized in a well designed IPM program for RSW. In Bangladesh, Dutta *et al*. (2022) advocated sanitation plus alternate spraying on biopesticide d-limonene 5% SL and acetamiprid 20 SP as sustainable management options against RSW,

Table 4. Parasitization (%) and adult emergence (%) of nymphal parasitoids of rugose spiraling whitefly in biopesticide treatments during 2023-24 at RARS, Jashore and RARS, Barishal

Treatments	RARS, Rahmatpur, Barishal		RARS, Jashore	
	*Percent parasitization (Mean ±SE)	*Percent Parasitoid adult emergence (Mean ±SE)	*Percent parasitization (Mean ±SE)	*Percent Parasitoid adult emergence (Mean ±SE)
Bio-chamak 1% EW	13.02d	9.32d	14.21d	9.42c
Biotrin 0.5%	16.23bc	12.28b	16.85bc	12.42bc
Fizimite 10%	15.38bc	11.22bc	16.20b-d	12.85bc
Bioclean 5% SL	14.58cd	10.28cd	15.68cd	11.32bc
Fytoclean	17.01b	12.35b	18.34b	13.59b
Untreated control (water spray only)	22.02a	17.23a	23.35a	18.67a
CV (%)	7.35	6.00	7.80	15.05

Means having the same letter(s) in a column did not differ significantly by LSD ($P < 0.05$).

which are aligned with the results of Rahman *et al.* (2025) who also observed that alternating applications of acetamiprid and d-limonene were highly effective in managing RSW infestations and may also reduce the risk of pest invasions. Dutta *et al*. (2025) put emphasis on developing capacity among farmers, extension agents, and researchers to implement bio-intensive strategies effectively and reduce reliance on chemical pesticides.

The present study also revealed that natural parasitism in biopesticide treated plots ranged 13-18%. Dutta *et al*. (2026) similarly observed 15-17% natural parasitism with different biopesticides (Bioclean and Fytoclean) spraying against RSW in coconut. However, Dutta *et al*. (2025) observed about 8-12% natural parasitism from different reduced-risk insecticides treatments against RSW in coconut. So, parasitism efficiency of different parasitoids was found to be enhanced with biopesticides.

Outside Bangladesh, Chin *et al.* (2023) in their studies on the efficacy of biopesticides against RSW reported that Fizimite or Bioclean @ 1ml/L at 15 days interval, Neemtach @ 30ml + oil 2 ml/L water and Natrasoap @ 20ml + Oil @

2ml /L water at three days interval can be used to effectively control the rugose spiraling whitefly infestation. It has been reported by Alagar *et al.* (2022) that spraying three rounds of 0.5% neem oil at 15 days interval on the under surface of leaves, three rounds of jet water spray at 10 days interval about 15 days after spraying of neem oil can reduce the rugose spiraling whitefly infestation to a great extent. Mohitha Reddy *et al.* (2022) studied the efficacy of several biopesticides in Andhra Pradesh, India, and observed entomopathogen '*Iceria fumosorosea* NBAIR-Pfu-5' to be more promising in reducing the population of nymphs and adults of RSW. Working with different biopesticides against RSW, Raghuteza *et al.* (2022) also reported that *I. fumosorosea* was more effective in managing the invasive *A. rugioperculatus* adults than that of *Beauveria bassiana*, *Metarhizium anisopliae*, *Lecanicillium lecanii*, azadirachtin and soapnut powder. However, they observed that, azadiracthin 10,000 ppm significantly reduced the nymphal population of RSW and found superior among the different treatments tested. Studies on eco-friendly approaches for the management of coconut rugose spiraling whitefly by Wankhede *et al*. (2023) revealed that, IPM package consisting of neem oil application followed by water spray coupled with yellow sticky traps was found effective in reducing RSW incidence.

CONCLUSION

Considering the damage potential of RSW and present trend of its countrywide spread in Bangladesh, there is an urgent need for sustainable, biorational based pest management options tailored to the tropical climates, needs of coconut growers and diverse agricultural systems of Bangladesh. The biopesticides selected from this study would play a vital role as component of sustainable IPM approaches against this invasive pest.

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CHECKLIST AND TAXONOMIC KEYS TO THE LEAFHOPPER AND PLANTHOPPER OF RICE BASED AGROECOSYSTEM IN BANGLADESH

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ABSTRACT

Leafhopper and Planthopper (Family Cicadellidae and Delphacidae) are very important sucking insect pests of Bangladesh. Many authors indiscriminately have listed these species under different names and hosts without conducting scientific studies. The authors aware that there is no national checklist of insect fauna in Bangladesh. This study was conducted in Department of Entomology, Gazipur Agricultural University during November 2023 to October 2024 to list and describe the available leafhoppers and planthoppers species in Bangladesh. The objective of the study was to conduct an extensive survey in the major rice growing regions of Bangladesh for collecting leafhoppers and planthoppers for their identification, description and preparation checklist. In this survey, the author records a total of 10 species of leafhoppers and 5 species of planthoppers in Bangladesh. The leafhopper species are *Cofana spectra* (Distant 1908), *Exitianus indicus* (Distant 1908); *Hecalus porectus* (Walker 1908), *Maiestas dorsalis* (Motschulsky 1859), *Nephotettix cincticeps* (Uhler 1896), *Nephotettix malayanus* Ishihara & Kawase 1968, *Nephotettix nigropictus* (Stål 1870), *Nephotettix virescens* (Distant 1908), *Orosius orientalis* (Matsumura 1914) and *Thaia oryzivora* Ghauri 1962 as well as planthopper species are *Laodelphax striatellus* (Fallen 1826), *Nilaparvata lugens* (Stål 1854), *Nisia nervosa* (Motschulsky 1863) *Sardia rostrate* Wilson & Claridge 1991 and *Sogatella furcifera* (Horváth 1899). Checklist and taxonomic key for the identification of available leafhopper and planthopper species in Bangladesh are provided here. Additionally, first time the authors have described *Laodelphax striatellus*, (Fallen 1826) from Bangladesh.

Keywords: Taxonomy, Identification, Leafhoppers, Planthoppers, Cicadellidae, Delphacidae, Sucking pests

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INTRODUCTION

The species of leafhopper and planthopper are of a great concern to agriculture and considered the most destructive rice pestand can result in a 44% yield reduction in rice (Ali *et al*. 2021). Hafizal and Idris (2014) reported that Delphacidae (planthopper) and Cicadellidae (leafhopper) population are main insect pests of rice plants as they suck sap from rice plant. They have piercing-sucking mouthparts that cause direct damage to plants by feeding in mesophyll cells or on xylem and/or phloem sap, and indirect damage by transmitting pathogens viz. vectors of bacteria, phytoplasma, or viral pathogens.

Leafhoppers belong to the order Hemiptera and sub order Auchenorrhyncha. Auchenorrhyncha includes three super families: Cicadoidea, Cercopoidea and Membracoidea (Dietrich 2005). Leafhoppers are under the family Cicadellidae of superfamily Membracoidea and is the largest family of Hemiptera. They are called as leafhoppers, because of their habit of hopping on leaves of vegetation, when disturbed. Recent estimates of the leafhopper species from the world range between 35,000- 45,000 species though little over 22,600 species are now described (Dietrich 2004). These differ from other members of the Auchenorrhyncha by the presence of two or more rows of spines on hind tibiae and pronotum not extending back over abdomen (Viraktamath 2007).

The planthoppers are a cosmopolitan group of insects placed in the infraorder Fulgoromorpha (superfamily Fulgoroides), which includes approximately 12,400 described species under 2,200 genera in 21 families, widely distributed all over the zoogeographical regions of the world (Bourgoin 2012). But they are treating many species wrongly with many more misidentifications due to lack of proper taxonomic knowledge and keys to family, genus and species of such insects. Dupo and Barrion (2009) found that sixty-five species of planthoppers representing three subfamilies Astracinae (4 species), Stenocracinae (4 species), and Delphacinae (57 species)- all associated with rice agroecosystems in tropical Asia are taxonomically treated. Of the total, three genera of Delphacinae, *Nilaparvata* Distant 1906, *Laodelphax* Fennah 1963, and *Sogatella* Fennah 1964 are economically important.

Correct identification of pest species is very important for their documentation and proper management (Amin *et al*. 2013). Their presence on crops should be properly monitored to avoid economic loss in future. Regular monitoring and proper identification of leafhopper and planthopper are essential in agro-ecosystems in order to forecast their attack and develop strategies for proper management. Construction of a taxonomic key will be useful for correct identification of the species, which is a prerequisite for easy monitoring and manipulation of this group of insects.

MATERIALS AND METHODS

The present taxonomic study was conducted at Department of Entomology, Gazipur Agricultural University (GAU) during November 2023 to October 2024, based on specimens of leafhopper and planthopper species collected from various regions of Bangladesh are deposited at the Insect Museum, Department of Entomology, GAU, Gazipur. The leafhopper and planthopper specimens were collected from rice fields by extensive field survey in major rice growing areas of Bangladesh like Brahmanbaria, Naogaon, Natore, Kishoreganj, Gazipur, Netrokona and from rice fields of Gazipur Agricultural University (Fig. 1).

The leafhopper and planthopper were collected with a sweep net bearing a very deep net bag which was slowly opened and collected with an aspirator as they crawl toward the opening. Then the specimen was stored in a falcon tube containing cotton balls soaked in ethyl acetate. Morphological terminology that used in the study follows Dietrich (2005). Curating, preparation of specimens and dissections of male genitalia was followed after Kwon's method (Kwon 1988). Taxonomic characters were examined under either stereo or optical microscopes, attached with a digital camera for photography. Images were produced using the software Helicon Focus 5.1 and were imported from Adobe Photoshop CS6 for labeling and plate composition. Measurements of the overall body length (expressed in millimeters) were made with the aid of an ocular micrometer. Dichotomous key was constructed using the characters for easy identification of the species studied.

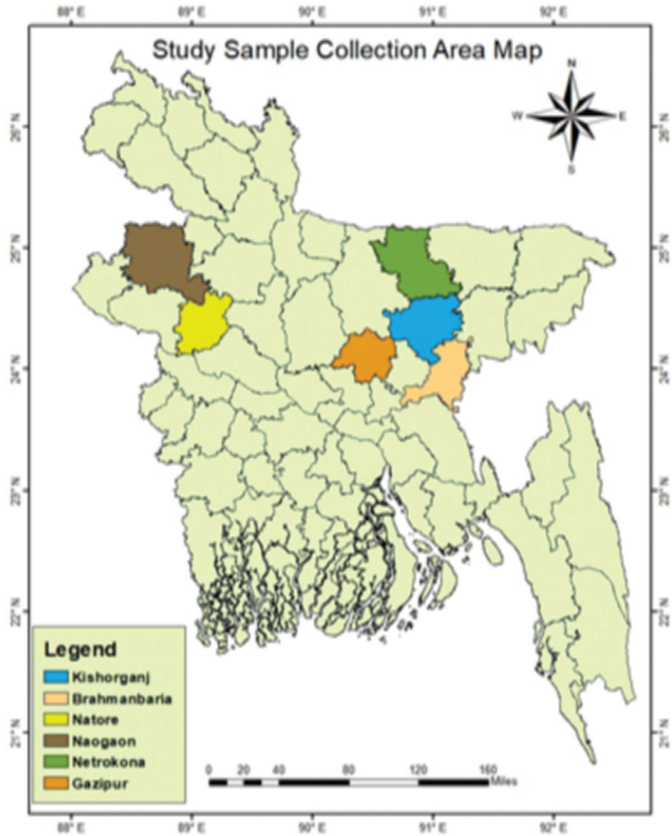

Fig. 1. Map of Bangladesh showing the collecting areas of leafhoppers and planthoppers.

RESULTS AND DISCUSSION

Taxonomic accounts of leafhopper species in Bangladesh

Genus *Cofana* Distant, 1908

Type species: *Tettigoniella spectra* Distant 1908

Type locality: India

***Cofana spectra* (Distant 1908)**

Tettigoniella spectra Distant 1908: 1-501 (Original description).

Cofana spectra, Islam *et al*. 2003, **13**(2): 1-25 (Bangladesh).

Cofana spectra, Islam & Cattling 2012, 422p (Bangladesh).

Cofana spectra, Faruq *et al*. 2017, **2**(1): 25-32 (Bangladesh).

Cofana spectra, Hasan *et al*. 2023, **8**(2): 26-27 (Bangladesh).

Materials examined of *Cofana spectra* (Distant 1908) in current study: Examined 6 males & 4 females at Gazipur Agricultural University, Bangladesh, in rice on 15-16.06.2024, M.S. Hossain examined 13 males from Bangladesh Rice Research Institute, Bangladesh, in rice on 20.07.2024, M.S. Hossain examined 6 males & 5 females at Brahmanbaria, Bangladesh, in rice on 22.10.2023, M.S. Hossain again examined 7 males & 3 females at Kishoreganj, Bangladesh, in rice on 04.02.2024, M.S. Hossain examined 7 males & 5 females at Netrokona, Bangladesh, in rice, 05.02.2024, M.S. Hossain examined 12 males & 9 females, at Naogaon, Bangladesh, in rice on 1-2.12.2023, M.S. Hossain examined 15 males & 12 females at Natore, Bangladesh, in riceon 22-23.08.2024, M.S. Hossain examined 14 males & 12 females at Gazipur, Bangladesh, in rice, 20.08.2024.

Genus *Exitianus* Ball 1929

Type species: *Jassus* (*Thamnotettix*) *obscurinervis* Stål 1859

Type locality: USA.

***Exitianus indicus* (Distant 1908)**

Athysanus indicus Distant 1908: 344 (Original description).

Exitianus indicus, Catling & Islam 2013, **17**(1&2): 79-108 (Bangladesh).

Materials examined of *Exitianus indicus* (Distant 1908) in current study: 12 males & 9 females, Naogaon, Bangladesh, in rice on 3-4.01.2024 by M.S. Hossain, 15 males & 12 females at Natore, Bangladesh, in rice on 22-23.08.2024 by M.S. Hossain, 14 males & 12 females at Gazipur, Bangladesh, in rice on 20.08.2024 again by M.S. Hossain.

Genus *Hecalus* Stål 1864

Type species: *Hecalus paykulli* Stål 1864.

Type locality: Senegal.

***Hecalus porrectus* (Walker 1908)**

Thomosoniella porecta (Walker), Distant 1908, 172 (Bangladesh).

Hecalus porrectus (Walker), Catling & Islam 2013, **17**(1&2): 79-108 (Bangladesh).

Materials examined of *Hecalus porrectus* (Walker 1908) in current study: 7 males & 3 females at Kishoreganj, Bangladesh, in rice on 04.02.2024 by M.S. Hossain also 12 males & 9 females at Naogaon, Bangladesh, in rice on 3-4.01.2024 by M.S. Hossain.

Genus *Maiestas* Distant 1917

Type species: *Maiestas illustris* Distant 1917.

Type locality: Seychelles Islands, Silhouette Island, Mahe Island.

***Maiestas dorsalis* (Motschulsky 1859)**

Deltocephalus dorsalis Motschulsky 1859, Etud. Entomol. **8**: 25-118: 114 (Original description).

Recilia dorsalis, Alam 1977, 79-90 (Bangladesh).

Maiestas dorsalis, Hasan *et al*. 2023, **8**(2): 26–27 (Bangladesh).

Materials examined of *Maiestas dorsalis* (Motschulsky 1859) in current study: 10 males & 2 females at Gazipur Agricultural University, Bangladesh, in rice on 15-16.06.2024 by M.S. Hossain. 5 males & 2 females at Bangladesh Rice Research Institute, Bangladesh, in rice on 20.07.2024 by M.S. Hossain. 6 males & 5 females at Brahmanbaria, Bangladesh, in rice on 22.10.2023 by M.S. Hossain. 7 males & 3 females at Kishoreganj, Bangladesh, in rice on 04.02.2024 also by M.S. Hossain. 7 males & 8 females, 9 males & 12 females at Natore, Bangladesh, in rice on 22-23.08.2024 by M.S. Hossain.

Genus *Nephotettix* Matsumura 1902

Type species. *Selenocephalus cincticeps* Uhler 1896.

Type locality. Japan.

***Nephotettix cincticeps* (Uhler 1896)**

Selenocephalus cincticeps Uhler 1896, Proc. U.S. Nat. Mus. **19**: 292 (Original description).

Nephotettix cincticeps, Ahmed & Amin 2007 (Bangladesh).

Nephotettix cincticeps, BRRI 1977: 131p (Bangladesh).

Nephotettix cincticeps, Islam & Cattling 2012: 422p (Bangladesh).

Nephotettix cincticeps, Islam *et. al.* 2003, **13**(2): 1-25 (Bangladesh).

Nephotettix cincticeps, Islam *et. al.* 2009, **20**(1): 37-43 (Bangladesh).

Nephotettix cincticeps, Faruq *et al*. 2017, **2**(1): 25–32 (Bangladesh).

Nephotettix cincticeps, Hasan *et al*. 2023, **8**(2): 26–27 (Bangladesh).

Materials examined of *Nephotettix cincticeps* (Uhler 1896) in current study: 10 males & 4 females at Gazipur Agricultural University, Bangladesh, in rice on 15-16.06.2024 by M.S. Hossai.13 males, Bangladesh Rice Research Institute, Bangladesh, in rice on 20.07.2024 by M.S. Hossain. 6 males & 5 females at Brahmanbaria, Bangladesh, in rice on 22.10.2023 by M.S. Hossain. 7 males & 3 females at Kishoreganj, Bangladesh, in rice on 04.02.2024 by M.S. Hossain. 7 males & 5 females at Netrokona, Bangladesh, in rice on 05.02.2024 by M.S. Hossain. 12 males & 9 females at Naogaon, Bangladesh, in rice on 1-2.12.2023 by M.S. Hossain. 15 males & 12 females at Natore, Bangladesh, in rice on 22-23.08.2024 by M.S. Hossai.14 males & 12 females at Gazipur, Bangladesh, in rice on 20.08.2024 also by M.S. Hossain.

***Nephotettix malayanus* Ishihara & Kawase 1968**

Nephotettix malayanus Ishihara & Kawase 1968: 119-123 (Original description).

Nephotettix malayanus, Islam *et. al.* 2003, **20**(1): 37-43 (Bangladesh).

Nephotettix malayanus, Faruq *et. al.* 2017, **2**(1): 25-32 (Bangladesh).

Materials examined of *Nephotettix malayanus* Ishihara & Kawase 1968 in current study: 10 males & 4 females at Gazipur Agricultural University, Bangladesh, in rice on 15-16.06.2024 by M.S. Hossain. 13 males at Bangladesh Rice Research Institute, Bangladesh, in rice on 20.07.2024 by M.S. Hossain. 6 males & 5 females aat Bhramonbaria, Bangladesh, in rice on 22.10.2023 by M.S. Hossain. 7 males & 3 females at Kishoreganj, Bangladesh, in rice on 04.02.2024by M.S. Hossain. 7 males & 5 females at Netrokona, Bangladesh, in rice on 05.02.2024 by M.S. Hossain; 12 males & 9 females at Naogaon, Bangladesh, inn rice on 1-2.12.2023 by M.S. Hossain. 15 males & 12 females at Natore, Bangladesh, in rice on 22-23.08.2024 by M.S. Hossain. 14 males & 12 females at Gazipur, Bangladesh, in rice on 20.08.2024 also by M.S. Hossain.

***Nephotettix nigropictus* (Stål 1870)**

Thamnotettix nigropictus Stål 1870, 740: (Original description).

Nephotettix nigropictus, Alam *et al.* 1964: 272p (Bangladesh).

Nephotettix nigropictus, BRRI 1977: 131p (Bangladesh).

Nephotettix nigropictus, Islam *et. al.* 2003, **13**(2): 1-25 (Bangladesh).

Nephotettix nigropictus, Ahmed & Amin 2007 (Bangladesh).

Nephotettix nigropictus, Islam *et. al.* 2009, **20**(1): 37-43 (Bangladesh).

Nephotettix nigropictus, Islam & Cattling 2012: 422p (Bangladesh).

Nephotettix nigropictus, Faruq *et. al.* 2017, **2**(1): 25-32 (Bangladesh).

Nephotettix nigropictus, Hasan *et al.* 2023, **8**(2): 26-27 (Bangladesh).

Materials examined of *Nephotettix nigropictus* (Stål 1870) in current study: 12 males & 6 females at Gazipur Agricultural University, Bangladesh, in rice on 15-16.06.2024 by M.S. Hossain. 9 males at Bangladesh Rice Research Institute, Bangladesh, in rice on 20.07.2024 by M.S. Hossain. 6 males at Brahmanbaria, Bangladesh, in rice on 22.10.2023 by M.S. Hossain. 7 males & 3 females at Kishoreganj, Bangladesh, in rice on 04.02.2024 by M.S. Hossain. 12 males & 5 females at Naogaon, Bangladesh, in rice on 3-4.01.2024 by M.S. Hossain. 15 males & 12 females at Natore, Bangladesh, in rice on 22-23.08.2024 also by M.S. Hossain.

***Nephotettix virescens* (Distant 1908)**

Selenocephalus virescens Distant 1908, 290-291: 359-360 (Original description).

Nephotettix virescens, Alam *et al.* 1964: 272p (Bangladesh).

Nephotettix virescens, BRRI 1977: 131p (Bangladesh).

Nephotettix virescens, Islam *et. al.* 2003, **13**(2): 1-25 (Bangladesh).

Nephotettix virescens, Ahmed & Amin 2007 (Bangladesh).

Nephotettix virescens, Islam *et. al.* 2009, **20**(1): 37-43 (Bangladesh).

Nephotettix virescens, Islam & Cattling 2012: 422p (Bangladesh).

Nephotettix virescens, Faruq *et. al.* 2017, **2**(1): 25-32 (Bangladesh).

Nephotettix virescens, Hasan *et al*. 2023, **8**(2): 26-27 (Bangladesh).

Materials examined of *Nephotettix virescens* (Distant 1908) in current study: 10 males & 4 females at Gazipur Agricultural University, Bangladesh, in rice on 15-16.06.2024 by M.S. Hossain. 13 males at Bangladesh Rice Research Institute, Bangladesh, in rice on 20.07.2024 by M.S. Hossain. 6 males & 5 females at Brahmanbaria, Bangladesh, in rice on 22.10.2023 by M.S. Hossain. 7 males & 3 females at Kishoreganj, Bangladesh, in rice on 04.02.2024 by M.S. Hossain. 7 males & 5 females at Netrokona, Bangladesh, in rice on 05.02.2024 by M.S. Hossain. 12 males & 9 females at Naogaon, Bangladesh, in rice on 19-20.10.2023 by M.S. Hossain. 15 males & 12 females at Natore, Bangladesh, in rice on 22-23.08.2024 again by M.S. Hossain. 14 males & 12 females at Gazipur, Bangladesh, in rice on 20.08.2024 also by M.S. Hossain.

Genus *Orosius* Distant 1918

Type species: *Orosius albicinctus* Distant 1918.

Type locality: South India.

Nesaloha Oman 1943, Panp. Ent. **19**: 33.

Type species: *Nesaloha cantonis* Oman 1943.

Type locality: Canton Island.

***Orosius orientalis* (Matsumura 1914)**

Eutettix orientalis Matsumura 1914, Journ. Coll. Agr. Tohoku Imp. Univ. **5**: 192 (Original description).

Orosius orientalis, Faruq *et al.* 2017, **2**(1): 25-32 (Bangladesh).

Materials examined of *Orosius orientalis* (Matsumura 1914) in current study: 10 males & 7 females at Gazipur Agricultural University, Bangladesh, in rice on 15-16.06.2024 by M.S. Hossain. 6 males & 3 females at Brahmanbaria, Bangladesh, in rice on 22.10.2023 by M.S. Hossain. 7 males & 10 females at Kishoreganj, Bangladesh, in rice on 04.02.2024 by M.S. Hossain. 12 males & 13 females at Netrokona, Bangladesh, in rice on 05.02.2024 also by M.S. Hossain.

Genus *Thaia* Ghauri 1962
Type species: *Thaia oryzivora* Ghauri 1962.
Type locality: Pakistan.

***Thaia oryzivora* Ghauri 1962**

Thaia oryzivora Ghauri 1962, An. Mag. Nat. His. (Ser. 13), 5, 253–256 (Original description).

Thaia oryzivora, Islam *et al.* 2003, **13**(2): 1-25 (Bangladesh).

Thaia oryzivora, Islam & Catling 2012 (Bangladesh).

Materials examined of *Thaia oryzivora* Ghauri 1962 in current study: 6 males & 2 females, at Brahmanbaria, Bangladesh, in rice on 22.10.2023 by M.S. Hossain. 7 males & 10 females at Kishoreganj, Bangladesh, in rice on 04.02.2024 by M.S. Hossain. 2 males & 1 female at Netrokona, Bangladesh, in rice on 05.02.2024 by M.S. Hossain. 5 males & 1 female at Naogaon, Bangladesh, in rice on 19-20.11.2023 by M.S. Hossain. 14 males & 12 females at Natore, Bangladesh, in rice on 22-23.08.2024 also by M.S. Hossain.

Taxonomic accounts of planthopper species in Bangladesh (Fig. 2)
Genus *Laodelphax* Fennah 1963
Type species: *Delphax striatellus* Fallen 1826
Type locality: Europe (original locality of *Delphax striatellus*)

***Laodelphax striatellus* (Fallen 1826)**

Delphax striatella Fallén 1826 (Original description).

Laodelphax spp., Faruq *et.al* 2018, **28**(1): 31-42 (Bangladesh).

First description from Bangladesh

Length: Male 3.4-3.6 mm, female 3.6-3.8 mm.

Coloration: The shiny black mesonotum of the male, the pterostigma of the forewing and the male genitalia are diagnostic for the species.

Head and thorax: The overall body coloration of the male ranges from stramineous (pale yellow) to white and black, with contrasting markings. The vertex stramineous, while the face (frons) fuscous, marked by white carinae. The compound eyes, mesonotum, and abdominal tergites are distinctly darker than the rest of the body, giving a two-toned appearance. The prothorax creamy white with dark brown fasciae located just below the posterior margins of the compound eyes. The mesothorax predominantly dark brown, except for the hind margin of the scutellum, which remains lighter. The tegulae diagnostic creamy white. The forewing hyaline (transparent) and feature a prominent dark claval pterostigma. Beyond the clavus, present light brown suffusion, enhancing wing pattern visibility. Morphometric details show that the head including eyes approximately 0.8× the width of the pronotum in dorsal view. The anterior portion of the head obliquely rounded, and the crown (vertex) 0.2× the width across the eyes. The frontoclypeus broad, and the frontal suture extends up onto the vertex. The median carina of the vertex forked just before reaching the frons. The frons uniform in width throughout, bearing a conspicuous median carina with a white suffusion that splits at the level just below the compound eyes. The pronotum 0.2× longer than wide and 0.3× the length of the scutellum, which gives compact thoracic appearance.

Male genitalia: Male terminalia taxonomically diagnostic and well developed. Pygofer 1.2× longer than wide, slightly elongate and narrowed posteriorly. Tenth abdominal segment short and bears distinct processes, contributing to species-level recognition. Aedeagus broadly attached to the connective at its base, indicating firm structural integration. It measures approximately 4× longer than wide. Structurally, the aedeagus broad at the base, ventrally bent, and features a tube-like process that extends from the mid-length region to the gonopore. Distally, has an elongate process with an acute tip, giving the genitalia a distinctive shape. The style divergent apically and 2.2× longer than wide. Each style duck-head shaped at the apex and shows fine serration on the lateral margins near the apex — a key trait for differentiating from other *Delphacidae*.

Materials examined: 1 male & 2 females at Gazipur, Bangladesh, in rice on 20.08.2024 by M.S. Hossain; 2 males & 2 females at Brahmanbaria, Bangladesh, in rice on 22.10.2023 by M.S. Hossain.

Host plants: Rice (*Oryza sativa*), wheat (*Triticum aestivum, T. durum*), maize (*Zea mays*), Oats (*Avena sativa*), barley (*Hordeum vulgare*), millet species (*Setaria* spp.), a wide array of wild grasses and other plants, including orchard grass, bent grass, Bermuda grass, beet, garlic.

Distribution: Widely distributed in the Palaearctic, from the UK where it is rare, to Japan (and Soviet Maritime Territory). Appears also to be found at higher altitudes in tropical Asia (e.g., Northern Philippines, North Sumatra) where it may be found on upland rice.

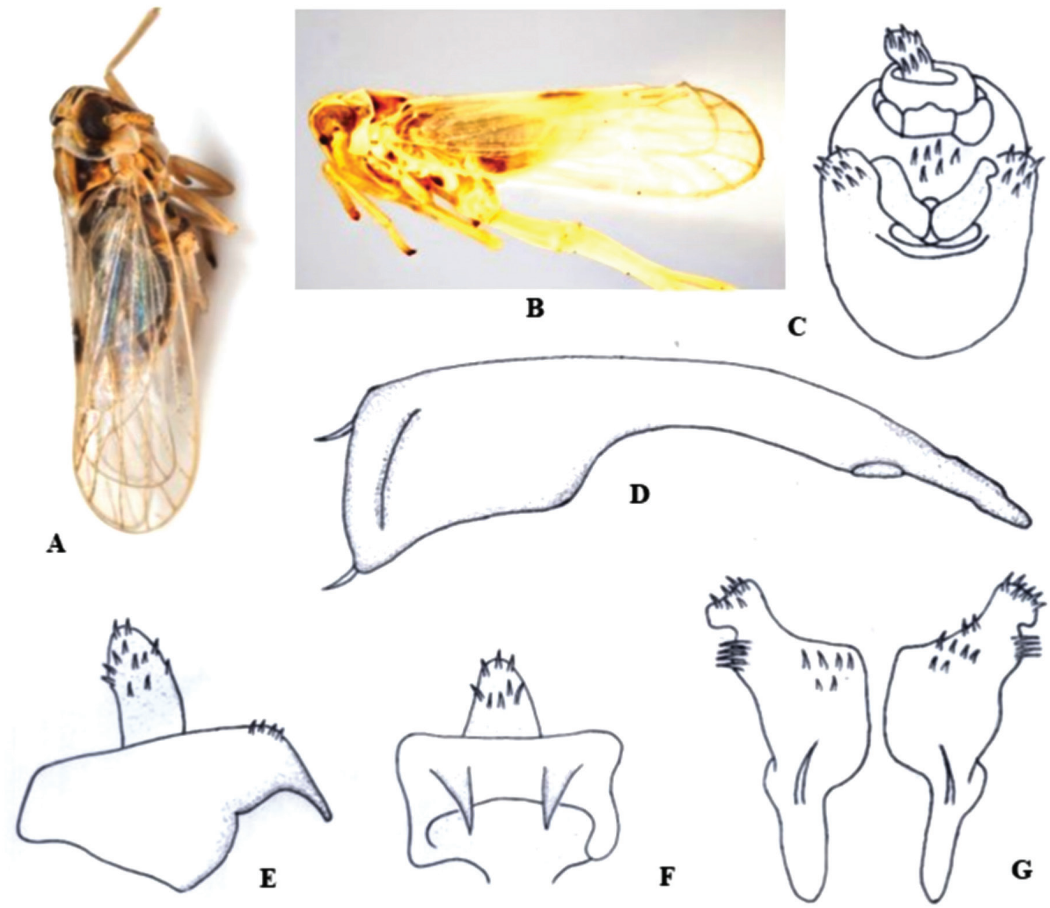

Fig. 2. A-G. ***Laodelphax striatellus*** **(Fallen 1826):** A. Dorsal habitus; B. Lateral habitus; C. Male genitalia; D. Aedeagus (lateral view); E. Anal segment (lateral view); F. Anal segment (ventral view); G. Style.

Genus *Nilaparvata* Distant 1906
Type species: *Delphax lugens* Stål 1854
Type locality: Sri Lanka.

***Nilaparvata lugens* (Stål 1854)**
Delphax lugens Stål 1854: 246 (Original description).
Nilaparvata lugens, Alam *et. al.* 1977, 79-90 (Bangladesh).
Nilaparvata lugens, Ahmed & Amin 2007 (Bangladesh).
Nilaparvata lugens, BRRI 1977: 131p (Bangladesh).
Nilaparvata lugens, Islam & Cattling 2012: 422p (Bangladesh).
Nilaparvata lugens, Islam *et. al.* 2003, **13**(2): 1-25 (Bangladesh).
Nilaparvata lugens, Islam *et. al.* 2009, **20**(1): 37-43 (Bangladesh).
Nilaparvata lugens, Hasan *et al.* 2023, **8**(2): 26-27 (Bangladesh).

Materials examined of *Nilaparvata lugens* (Stål 1854) in current study: 10 males & 7 females at Gazipur Agricultural University, Bangladesh, in rice on 15-16.06.2024 by M.S. Hossain. 13 males & 11 females,at Bangladesh Rice Research Institute, Bangladesh, in rice on 20.07.2024 by M.S. Hossain. 6 males & 11 females at Brahmanbaria, Bangladesh, in rice on 22.10.2023 by M.S. Hossain. 7 males & 10 females, at Kishoreganj, Bangladesh, in rice, on 04.02.2024 by M.S. Hossain; 12 males & 13 females at Netrokona, Bangladesh, in rice on 05.02.2024 also by M.S. Hossain. 12 males & 9 females at Naogaon, Bangladesh, in rice on 19-20.11.2023 again by M.S. Hossain; 14 males & 12 females at Natore, Bangladesh, in rice on 22-23.08.2024 again by M.S. Hossain.

Genus *Nisia* Melichar 1903
Type species: *Livilla nervosa* Motschulsky (=*Meenoplus atrovenosa* Lethierry 1888) 1863.
Type locality: Sri Lanka (Ceylon)

***Nisia nervosa* (Motschulsky 1863)**
Livilla nervosa Motschulsky 1863: 1-153 (Original description).
Nisia atrovenosa, Catling & Islam 2013, **17**(1&2): 79-108 (Bangladesh).
Nisia nervosa, Faruq *et. al*. 2018: **28**(1), 31−42 (Bangladesh).

Materials examined of *Nisia nervosa* (Motschulsky 1863) in current study: 2 males & 2 females at Natore, Bangladesh, in rice on 23.08.2024 by M.S. Hossain; 5 males at Noagaon, Bangladesh, in rice on 01-02.12.2023 by M.S. Hossain.

Genus *Sardia* Melichar 1903
Type Species: *Sardia rostrata* Wilson & Claridge1991
Type Locality: Karachi, Pakistan.

***Sardia rostrata* Wilson & Claridge 1991**
Sardia rosatrata Melichar 1903: 96 (Original description).
Sardia rostrata, Faruq *et.al.* 2018, **28**(1): 31-42 (Bangladesh).

Materials examined of *Sardia rostrata* Wilson & Claridge 1991 in current study: 3 males & 2 females at Netrokona, Bangladesh, in rice on 05.02.2024 by M.S. Hossain. 1 male and 1 female at Gazipur, Bangladesh, in rice on 20.08.2024 by M.S. Hossain.

Genus *Sogatella* Fennah 1956
Type species: *Delphax furcifera* Horvath 1899
Type locality: Taiwan.

***Sogatella furcifera* (Horváth 1899)**
Delphax furcifera Horváth 1899 (Original description).
Sogatella furcifera, Alam *et. al*. 1964: 272p (Bangladesh).
Sogatella furcifera, Ahmed & Amin 2007 (Bangladesh).
Sogatella furcifera, Islam & Cattling 2012: 422p (Bangladesh).
Sogatella furcifera, Islam *et. al.* 2003, **13**(2): 1-25 (Bangladesh).
Sogatella furcifera, Islam *et. al.* 2009, **20**(1): 37-43 (Bangladesh).
Sogatella furcifera, Faruq *et.al*. 2018, **28**(1): 31-42 (Bangladesh).
Sogatella furcifera, Hasan *et al*. 2023, **8**(2): 26-27 (Bangladesh).

Materials examined of *Sogatella furcifera* (Horváth 1899) in current study: 6 males at Bangladesh Rice Research Institute, Bangladesh, in rice on 19.08.2024 by

M.S. Hossain. 2 males & 2 females at Noagoan, Bangladesh, in rice on 3-4.01.2024 by M.S. Hossain. 3 males & 4 females at Kishorgonj, Bangladesh, in rice on 04.02.2024 by M.S. Hossain. 3 males at Natore, Bangladesh, in rice on 22.08.2024 also by M.S. Hossain.

Checklist of the recorded leafhopper and planthopper species in Bangladesh

Leafhopper species

Genus *Cofana* Distant 1908

1. *Cofana spectra* (Distant 1908)

Genus *Exitianus* Ball 1929

2. *Exitianus indicus* (Distant 1908)

Genus *Hecalus* Stål 1864

3. *Hecalus porrectus* (Walker 1908)

Genus *Maiestas* Distant 1917

4. *Maiestas dorsalis* (Motschulsky 1859)

Genus *Nephotettix* Matsumura 1902

5. *Nephotettix cincticeps* (Uhler 1896)
6. *Nephotettix malayanus* Ishihara & Kawase 1968
7. *Nephotettix nigropictus* (Stål 1870)
8. *Nephotettix virescens* (Distant 1908)

Genus *Orosius* Distant 1918

9. *Orosius orientalis* (Matsumura 1914)

Genus *Thaia* Ghauri 1962

10. *Thaia oryzivora* Ghauri 1962

Planthopper species

Genus *Laodelphax* Fennah 1963

1. *Laodelphax striatellus* (Fallen 1826)

Genus *Nilaparvata,* Distant 1906

2. *Nilaparvata lugens* (Stål 1854)

Genus *Nisia* Melichar 1903

3. *Nisia nervosa* (Motschulsky 1863)

Genus *Sardia* Melichar 1903

4. *Sardia rostrata* Wilson & Claridge 1991

Genus *Sogatella,* Fennah 1956

5. *Sogatella furcifera* (Horváth 1899)

Key to the leafhopper species in Bangladesh

1. Forewings without oblique vittae or with oblique vittae usually forming continuous zigzag pattern ……………………………………………………… *Maiestas dorsalis*

-. Forewings not forming continuous zigzag pattern ………….……………..…… 2

2. Typhlocybine leafhopper, lack of ocelli………………………… *Thaia oryzivora*

-. *Deltocephaline* leafhopper, ocelli present …………………………….………..…… 3

3. General body color creamy white color with brown spots …… *Orosius orientalis*

-. General body color green color with or without brown spots ……….…………… 4

4. Aedeagus lacking paraphyses and basal aedeagal processes……… *Cofana spectra*

-. Aedeagus with paraphyses and with or without basal aedeagal processes……..… 5

6. Aedeagus symmetrical, tubular, with processes at apex ……… *Hecalus porrectus*

-. Aedeagus not truely symmetrical with or without processes at apex …………… 7

7. Dorsal side of aedeagus shaft without spines ………………… *Exitianus indicus*

-. Dorsal side of aedeagus shaft with spines ……………………...………………… 8

8. Aedeagus bearing 8 pairs of spines on the shaft ………….. *Nephotettix nigropictus*

-. Aedeagus bearing less than 8 pairs of spines on the shaft ………….…………….. 9

9. with 4 pairs of separated spines located in middle ……..………… *N. malayanus*

- with 5 pairs of spines located in middle of aedeagal shaft ………..……….. 10

10. Lateral parts of tegmina with dark brown spot ……………..…… *N. virescens*

- Lateral parts of tegmina without dark brown spot …….………..…… *N. cincticeps*

Key to the planthopper species in Bangladesh

1. Each style duck-head shaped at the apex and shows fine serration on the lateral margins near the apex ……………………………………... *Laodelphax striatellus*

- Style not duck-head shaped at the apex ……………………...……………… 2

2. Style large, inner margin roundly emarginate at middle, inner angle strongly projected, apex pointed, viewed caudolaterally………………… *Nilaparvata lugens*

- Style inner margin not roundly emarginate at middle ………………….………… 3

3. Style angulately curved at middle, dorsad, with two lobes near base, inner lobe trifurcate apically, outer lobe with numerous teeth-like process at apex and hairy ………. *Nisia nervosa*

- Style inner lobe not trifurcate apically …………………….……………………… 4

4. Style subparallel, rounded upper area, inner margin slightly concave, basal angle obtuse laterocaudally …………..............………………………… *Sardia rostrata*

- Style divergent, each with outer angle widely formed, inner angle formed as long as outer one, apically acute …………….………………………… *Sogatella furcifera*

CONCLUSION

The present study recorded a total 15 species of hoppers comprising 10 species of leafhoppers (Cicadellidae) under 7 genera and 5 species of planthoppers (Delphacidae) under 5 genera, from different agro-ecological zones of Bangladesh. As an outcome of this research, a checklist of available leafhopper and planthopper species in Bangladesh has been developed along with the taxonomic key for their correct identification. This provides a valuable baseline for further taxonomic, ecological, and pest management studies. Further extensive surveys, including in the hilly regions of Bangladesh, should be conducted, and molecular identification tools should be incorporated for more detailed research.

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ASSESSMENT OF ADULTERATION IN DIFFERENT MARKETED BRANDS OF COMMONLY USED PESTICIDES IN BANGLADESH

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ABSTRACT

Pesticide adulteration is extremely harmful for agricultural production and also detrimental to the environment. This study was carried out to investigate the adulteration of the available marketed brands of five selected pesticide groups collected from different dealers in Kishoreganj, Gazipur, and Dhaka. High Performance Liquid Chromatography with an ultra violet detector was used to analyze the pesticides at the Pesticide Analytical Laboratory of Entomology Division, Bangladesh Agricultural Research Institute. Results revealed that 45% of tested pesticides contained lower levels of active ingredients than those specified on the product containers/labels. Of the 68 pesticide brands tested, 37 (approximately 54%) revealed 100% presence of active ingredient (AI), 15 brands had between 80% and 98% of active ingredient (AI), while the remaining 16 brands contain less than 80% active ingredient (AI) as per product labels. Among these, one brand contained no active ingredient of concerned.

Keywords: Assessment, Pesticides, Adulteration, HPLC, Active ingredient

INTRODUCTION

Since the strategies of agriculture and pest management are continuously changing, the use of pesticides has become necessary to maintain sustainable crop yields and protect food supplies worldwide (Singh 2024). Several factors, like changes in cropping patterns and the global population growth, are responsible for the subtle trends in pesticide usage, trade, and indicators around the world (Wisnujati *et al.* 2023). In 2023, the usage of agricultural pesticides reached 3.73 million tons of

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active ingredients, indicating a 14 percent increase over the past decade and nearly a twofold rise since 1990 (FAO 2025). The widespread use of pesticides has become a pivotal part of agriculture in developing countries like Bangladesh to reduce pest infestations and maximize crop yields (Bhuiya *et al*. 2024). Hence, farmers are spraying chemical pesticides extensively and injudiciously. In Bangladesh, the adulteration of pesticides is considered a major factor contributing to the excessive use of these chemicals. According to a report by the FAO, the average pesticide usage in Bangladesh is approximately 1.80 kg per hectare of land. The total consumption of pesticides in the country in 2022 was around 15,500 tons of active ingredients (FAO 2024).

Pesticide adulteration is not only responsible for reducing crop yields but also leads to the development of resistance in pests to the pesticides used. Impure or adulterated pesticides leave unacceptable residues on crops and the environment at a higher level that exceeds permissible limits, posing threats to human health and ecosystems (Hasan *et al*. 2024). Adulteration of pesticides may occur during various stages of active ingredient (AI) manufacture, particularly when substandard raw materials and low-quality solvents are used, often due to avoidance of necessary purification processes (Bayoumi 2021). Adulteration of pesticides is a serious issue in Bangladesh, as studies indicating numerous pesticide brands contain fewer active substances than specified.

Afroze *et al*. (2021) conducted a study to determine the purity of eleven pesticides using GC and HPLC and reported that 40% of the tested brands contain lower active ingredients than stated on the package/container label. The selected brands of acephate, carbofuran, diazinon, dimethoate, chlorpyrifos, quinalphos, malathion, carbosulfan, cypermethrin, fenvalerate and fenitrothion were collected from Rajshahi, Rangpur, Jamalpur, Bogura, Cumilla, Jashore and Gazipour. In another study, Begum *et al*. (2016) tested the adulteration of several brands of marketed pesticide groups viz., chlorpyriphos, diazinon, carbofuran, pyrazosulfuron ethyl, dimethoate, cypermethrin, carbendazim, mancozeb and quinalphos which were purchased from local dealers of Dinajpur, Rangpur, Rajshahi, Bogura, Jashore, Cumilla, Mymensingh and Narsingdi districts. This study revealed that more than 66% of the tested pesticides had a purity of over 90% as per active ingredients mentioned, 12% had a purity of between 80% and 90%, and the remaining 22%

had a purity of less than 80%. Notably, three brands contained no active ingredients (AI) of the specified pesticides. Another study by Kabir *et al*. (2008) found that most of the marketed pesticides had lower active ingredients (AI), specifically ≤60%, than those mentioned on the labels of the containers. They tested several brands of Carbofuran, Carbaryl, Carbosulfan, Malathion, Diazinon, Cypermethrin, Quinalphos, Dimethoate and Chlorpyrifos.

The FAO Corporate Document Repository indicates that the regulatory framework for pesticide registration is systematic. But in practice, there exist gaps between policies and their implementation. In Bangladesh, pesticide regulation is primarily governed by the Pesticide Act (2018), and Pesticide Rules (2020), which provide strict guidelines for the import, formulation, packaging, labeling, and sale of pesticides. However, the lack of adequate facilities and trained analysts hinders effective monitoring. The pesticide markets in Bangladesh are growing more rapidly than the capacity of regulatory monitoring. Unfortunately, the increase in generic brands, combined with inadequate regulatory enforcement in markets, has led to a significant rise in substandard pesticides. Hence, the quality control of pesticides is essential for ensuring their efficacy, overall quality, and safe application. From this perspective, this study aims to conduct a comprehensive purity analysis of different brands of marketed pesticides in Bangladesh and to ensure their effective, safer, and non-hazardous use.

MATERIALS AND METHODS

Pesticides from five groups were investigated to determine the percentage of active ingredient namely, carbofuran, carbendazim, imidacloprid, emamectin benzoate and thiamethoxam. Various brands of those tested groups were obtained from several dealers of Kishoreganj, Gazipur and Dhaka in the year of 2024 and 2025. The brands were chosen based on their availability in the selected regions and preferences to the farmers. Each container/packet was labeled with an alphanumeric code to identify the location of purchase, active ingredient and the specific brands of pesticides. All formulated products whether granular, powder or liquid were dissolved in the corresponding solvents. Those solvents were selected according to the criteria described by Lehotay and Mastovska (2004).

The pesticide solutions from various brands were prepared following the procedure aligned with the particular instruments in the pesticide analytical laboratory of Entomology Division, Bangladesh Agricultural Research Institute. The solid inert materials were removed through filtration process in case of powder or granular formulations. For liquid pesticides, the solutions were prepared directly at the known concentrations. High-performance liquid chromatography (HPLC) is a commonly used method for assessing the active ingredients of plant protection products. Here, the protocols for testing various brands using HPLC-UV were developed by optimizing the instrument parameters to analyze concerned pesticide groups, which were selected based on the peak sharpness of the chromatogram and retention time of each compound. The instrument parameters of HPLC-20A prominence set for analysis of each group of pesticide are listed below (Table 1):

Table 1. The instrument parameters of HPLC-20A prominence set for analysis of the selected pesticide groups

Pesticide group	Solvent	Detector	Pump mode	Mobile phase	Flow rate	Injec-tor	Inj. vol.
Carbofuran	Methanol	UV detector	Binary gradient	Methanol/water =80/20 (v/v)	1ml/min	Auto	20 µL
Carbendazim	Methanol	UV detector	Binary gradient	Methanol/water =80/20 (v/v)	1ml/min	Auto	20 µL
Imidacloprid	Acetonitrile	UV detector	Binary gradient	Acetonitrile / water=70/30 (v/v)	1ml/min	Auto	20 µL
Emamectin benzoate	Acetonitrile	UV detector	Binary gradient	Acetonitrile / water=70/30 (v/v)	1ml/min	Auto	20 µL
Thiamethoxam	Acetonitrile	UV detector	Binary gradient	Acetonitrile / water=70/30 (v/v)	1ml/min	Auto	20 µL

Quantitative analysis of some common pesticides: Following the injection, data were obtained and analyzed using the concerned instrument i.e., HPLC. The quantity of the active substance present in each brand was determined by comparing with standard solution of corresponding pesticide group through the built-in software of HPLC (LC solution). The purity percentage was calculated by comparing the actual amount of active ingredients (AI) found in various brands to the amount of AI specified for the respective pesticides, using the following formula:

$$\text{Percent of purity} = \frac{\text{Actual amount of AI present in the pesticide}}{\text{Amount of AI recommended /required}} \times 100$$

RESULTS AND DISCUSSION

Carbofuran: Carbofuran is a highly toxic, broad-spectrum carbamate insecticide. Bangladesh has banned the carbofuran pesticide group since 2023, but some brands are still available in markets. While collecting samples, eight brands of carbofuran were found in the selected areas. Those brands of carbofuran 5G and 3G were tested with HPLC-20A Prominance using UV detector. Table 2 shows the amount of active ingredients and their purity percentages in the formulated pesticides.

Table 2. Percentage of Active Ingredient presents in some marketed brands of Carbofuran 5G and 3G

SL No.	Code	Formulation	Amount of AI found (G)	Purity (%)
1.	CfDhKd	3 G	2.22	74
2.	CfDhSr	5 G	2.65	53
3.	CfKiFr	3 G	3	100
4.	CfGaBf	5 G	5	100
5.	CfGaSf	5 G	3.3	66
6.	CfDhCf	5 G	1.4	28
7.	CfDhSf	5 G	5	00
8.	CfGaGf	5 G	3.35	67

The purity levels of the tested carbofuran brands range from 28% to 100%. Notably, one brand did not contain any active ingredients for carbofuran. Out of the eight brands tested, only two had an active ingredient concentration of 100%, four brands had concentrations above 50%, and one brand had AI of 28%.

Carbendazim: Carbendazim is a broad-spectrum, systemic fungicide popularly used in agriculture, forestry, and veterinary medicine to control fungal diseases. The purity of the tested brands of carbendazim was 50% to 100% in terms of AI. Among the fourteen brands, eight contained 100% AI, and the other brands had AI ranging from 50 to 94% purity. The amount of active ingredients found in the formulated pesticides, along with their purity percentages are shown in Table 3.

Table 3. Percentage of Active Ingredient present in the selected marketed brands of Carbendazim 50 WDG, 50 WP and 75 WP

SL No.	Code	Formulation	Amount of AI found (WDG, WP)	Purity %
1.	CdDhAt	50 WDG	50	100
2.	CdDhKn	50 WP	50	100
3.	CdKiSz	50 WP	43.5	87
4.	CdKiKb	50 WP	38.5	77
5.	CdKiDz	50 WP	50	100
6.	CdGaAc	50 WP	50	100
7.	CdGaTb	50 WP	47	94
8.	CdDhAn	50 WDG	50	100
9.	CdDhMn	75 WP (Carbendazim-12%)	10.8	90
10.	CdDhSz	50 WP	50	100
11.	CdGaRd	50 WP	46	92
12.	CdGaAt	50 WDG	50	100
13.	CdGaKn	50 WP	25	50
14.	CdKiBd	50 WP	50	100

The result revealed that out of fourteen tested brands about 58% i.e., eight brands were 100% pure in terms of AI presence. Three brands CdDhMn, CdGaRd and CdGaTb contained above 90% AI while the other three brands CdKiSz, CdKiKb and CdGaKn are 87%, 77% and 50% pure in terms of AI presence.

Imidacloprid: Imidacloprid is a systemic neonicotinoid insecticide which is a class of neuro-active insecticides modeled after nicotine. The purity of the tested brands of imidacloprid was 70% to 100% excluding two brands which contain <50% of AI. Among the twenty brands, twelve contained 100% and the other brands contained AI between <50% to 98%. Table 4 represents the amount of active ingredients as well as their respective purity percentages in the formulated pesticides.

Emamectin benzoate: Emamectin benzoate is a selective insecticide derived from the avermectin compounds. Eighteen popular brands of emamectin benzoate were tested using HPLC-UV. The purity percentages of different marketed brands of emamectin benzoate are shown in Table 5.

Table 4. Percentage of Active Ingredient present in the selected marketed brands of Imidacloprid 20SL, 70WG, 80 WDG and 57.5 WDG

SL No.	Code	Formulation	Amount of AI found (SL, WG, WDG)	Purity %
1.	ImDhEt	20 SL	20	100
2.	ImDhEp	20 SL	17.2	86
3.	ImDhPr	20 SL	14	70
4.	ImGaAd	20 SL	20	100
5.	ImGaTd	20 SL	20	100
6.	ImKiEt	20 SL	20	100
7.	ImKiMk	70WG	31.5	45
8.	ImKiCf	70WG	70	100
9.	ImDhAp	20 SL	20	100
10.	ImDhImx	20 SL	18.2	91
11.	ImDhIt	20 SL	20	100
12.	ImDhTd	20 SL	20	100
13.	ImGaSc	20 SL	19.6	98
14.	ImGaIt	20 SL	20	100
15.	ImGaRp	20 SL	14.4	72
16.	ImKiIt	20 SL	20	100
17.	ImKiTc	80 WDG (Imidacloprid-40%)	40	100
18.	ImKiTg	57.5 WDG (Imidacloprid-52.5%)	52.5	100
19.	ImKiTr	20 SL	6.2	31
20.	ImKiAd	20 SL	16.8	84

In case of 20 tested brands of imidacloprid, apart from twelve brands that contained 100% AI, two brands i.e., ImDhImx and ImGaSc, showed purity over 90%. Four brands namely ImDhPr, ImGaRp, ImKiAd and ImDhEp contained 70% to 86% of active ingredients while the remaining two brands ImKiMk and ImKiTr contained 45% and 31% AI respectively.

Table 5. Percentage of Active Ingredient present in some marketed brands of Emamectin benzoate 5 SG, 10 SG, 10 WDG, 75 WDG and 5 WDG

SL No.	Code	Formulation	Amount of AI found (SG, WDG)	Purity %
1.	EBDhPc	5 SG	5	100
2.	EBDhLv	10 SG	10	100
3.	EBDhSp	5 SG	4.1	82
4.	EBKiJm	5 SG	5	100
5.	EBKiWd	5 WG	3.9	78
6.	EBKiHu	10 WDG	7.5	75
7.	EBKiWb	5 SG	3.4	67
8.	EBGaMD	5 WDG	5	100
9.	EBGaEc	5 WDG	4.3	86
10.	EBGaPt	5 SG	5	100
11.	EBDhAr	5 SG	3	60
12.	EBDhJm	5 SG	5	100
13.	EBDhSd	5 SG	4.6	92
14.	EBGaPr	5 SG	5	100
15.	EBGaBz	75 WDG (EB-5%)	4.15	83
16.	EBKiTg	5 WDG	5	100
17.	EBKiSp	5 WDG	5	100
18.	EBKiGm	5 SG	4.8	96

Analysis results of emamectin benzoate revealed that nine of the tested brands were 100% pure in terms of AI presence. Two brands EBDhSd and EBKiGm contained above 90% AI, while five brands contained AI between 75% to 86%. The remaining two brands EBKiWb and EBDhAr were 67% and 60% pure, respectively in terms of AI presence.

Thiamethoxam: Thiamethoxam is a widely used neonicotinoid insecticide having systemic, contact, and stomach action against a broad spectrum of pests. Eight brands of thiamethoxam were collected and analyzed for adulteration using HPLC-UV. The purity percentages and active ingredient concentrations of different marketed thiamethoxam brands are presented in Table 6.

Table 6. Percentage of Active Ingredient presents in some marketed brands of Thiamethoxam 25 WG, 70 WS and 40 WDG

SL No.	Code	Formulation	Amount of AI found (WG, WS, WDG)	Purity %
1.	TmDhAt	25 WG	25	100
2.	TmKiCr	70 WS	70	100
3.	TmKiMm	25 WG	24.3	97
4.	TmGaCr	70 WS	70	100
5.	ThDhAc	25 WG	25	100
6.	ThGaAc	25 WG	25	100
7.	ThDhCr	70 WS	70	100
8.	ThKiAb	40 WDG (Thiamethoxam-20%)	19.2	96

In case of thiamethoxam, among the eight tested brands, six brands TmDhAt, TmKiCr, TmGaC, ThDhAc, ThGaAc and ThDhCr showed 100% presence of AI, whereas the other two brands TmKiMm and ThKiAb were 97% and 96% pure, respectively in terms of AI presence.

The farmers in Bangladesh are traditionally using synthetic pesticides to protect crops from insect pests' infestation and to maximize yield on the limited arable land. Due to adulteration, pesticides do not perform effectively in the field and numerous pests are becoming resistance to pesticides (Begum *et al*. 2016). Tahir *et al*. (2024) reported that of pesticide resistance across numerous pest species often increases up to 25,000 times and resistance to one pesticide can leads to cross resistance to other unrelated pesticides. This growing resistance compels farmers to either increase pesticide doses and frequency, or move to more powerful, sometimes more environmentally persistent alternatives. Moreover, the destruction of natural predators through pesticide application can lead to pest resurgence and secondary pest outbreaks. These phenomena often result in a vicious cycle of increased pesticide application, which leads to the presence of pesticide residues in various agricultural commodities, as reported by researchers in Bangladesh (Paul *et al*. 2025, Ahmed *et al*. 2024, Alam *et al*. 2023, Alam *et al*. 2022, Hasan *et al*. 2021, Islam *et al*. 2021, Nisha *et al*. 2021, Parven *et al*. 2021, Parvin *et al*. 2021, Prodhan *et al*. 2021, Nahar *et al*. 2020, Islam *et al*. 2019, Islam *et al*. 2019a, Islam *et al*. 2019b, Rahman *et al*. 2019, Prodhan *et al*. 2018, Prodhan *et al*. 2018a, Prodhan *et al*. 2018b).

The extensive use of adulterated pesticides unintentionally destroys beneficial organisms, like pollinators and predators, thereby disrupting biodiversity and ecological balance (Lengai and Muthomi 2018). Besides, a significant amount of capital is also spent for purchasing pesticides (Afroze *et al*. 2021). In addition, the lower active material concentrations in marketed pesticides and their residues have raised concerns regarding their potential adverse effects on human health and the environment (Beyuo *et al*. 2024). These residues can lead to acute and chronic toxicities, including immediate neurotoxic effects such as headaches and respiratory disorders, as well as long-term health problems (Ahmad *et al*. 2024, Carreiró *et al*. 2025). Chronic exposure has been associated with higher risks of cancer like non-Hodgkin lymphoma, Parkinson's disease, and endocrine disruption (Beyuo *et al*. 2024, Zhou *et al*. 2025). Infants and pregnant women are more vulnerable to these threats. On the other hand, residues of these adulterated pesticides also resulted in significant environmental degradation along with soil contamination and aquatic ecosystem disruption. These residues additionally facilitate the bioaccumulation and biomagnification of persistent organic pollutants within food chains (Munir *et al*. 2024, Osaili *et al*. 2022).

CONCLUSION

Pesticides play an essential role in the present food production systems, serving as indispensable means to protect crops from pests, diseases, and weeds. So, quality control of marketed pesticides is crucial to ensure safe and effective pesticide usage in agriculture. The study result indicates that, around 45% of tested pesticides contained lower active ingredients than specified on the product labels. From the present study, it is recommended that, before pesticides are authorized for use in the market, they should undergo a quality assessment to identify whether there is actual amount of AI present or not. In addition, this study highlights the importance of rigorous monitoring and adulteration testing of marketed pesticides.

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DOCUMENTATION OF INSECT PEST ATTACK AND PESTICIDE USAGE ON NEW PLANTATIONS OF COFFEE (*COFFEA* SPP.) IN SYLHET

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ABSTRACT

Coffee cultivation is emerging as a promising high-value agricultural crop in some areas of Bangladesh, particularly in Sylhet region. But information on insect pest occurrence and pesticide use in newly established coffee plantations remains limited. This study was conducted to document the major insect pests associated with coffee cultivation and assess pesticide usage patterns in Sylhet district. A field survey was carried out across five upazilas of Sylhet district using structured questionnaires, face-to-face interviews, and focus group discussions involving 60 respondents. Data were normalized first and then analyzed using descriptive statistics in R-studio and origin to characterize pest incidence, farmer profiles, and pesticide use practices. The findings revealed that *Coffea arabica* was the predominant coffee species cultivated by 96.67% of farmers. A total of 16 insect pest species were documented from coffee plantations. Coffee berry borer (*Hypothenemus hampei*) and coffee leaf miner (*Leucoptera coffeella*) were identified as the most important pests, reported by 55.00% and 46.67% of respondents, respectively. Other frequently occurring pests included white stem borer (43.33%), mealybug (40.00%), and shot hole borer (38.33%). Functional group analysis showed that sap-sucking insects constituted the dominant pest category (43.75%), followed by stem borers and leaf feeders (18.75% each). The study further revealed extensive dependence on chemical pesticides, with 83.34% of respondents using WHO Class II (moderately hazardous) pesticides, primarily organophosphates, neonicotinoids, and pyrethroids. Notably, 76.67% of farmers had not received any formal training on coffee pest management. The high prevalence of key insect pests, combined with heavy reliance on moderately hazardous pesticides and limited technical knowledge, highlights the urgent need for farmer training, strengthened extension services, and the adoption of integrated pest management strategies to ensure sustainable coffee production in Sylhet.

Keywords: Bangladesh**,** Documentation of Pest diversity; Pesticide hazard; WHO Class.

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INTRODUCTION

Coffee is the most important beverage worldwide, after crude oil (Esquivel and Jimenez 2012). Coffee is widely produced in about 60 tropical and subtropical countries, and coffee is the main export product of some countries (Lashermes *et al*. 2008). According to plant taxonomy, coffee belongs to the Rubiaceae family, which includes about 90 species (Davis 2001). Millions of farmers in Asia, Africa, and Latin America have made it as their main agricultural product (Arunyanark *et al*. 2022). From these coffee species, two species are globally popular: *Coffea arabica* and *Coffea canephora*, accounting for 99% of the world's coffee production (Arunyanark *et al*. 2022). However, Robusta coffee is more widely cultivated in Asian countries due to its tolerance to environmental conditions and high productivity (Harvey *et al*. 2021). Coffee is so popular globally because of its bioactive compounds and various health benefits (Makiso *et al*. 2024). Coffee beans contain several beneficial compounds, such as phenolic compounds and chlorogenic acids, which increase antioxidant activity and cardiovascular health benefits (Farah 2012). Another important component of coffee is Trigonelline, which can provide neuroprotective and metabolic benefits (Konstantinidis *et al*. 2023). Coffee by-products, such as coffee pulp and spent coffee grounds contain dietary fiber and phenolic compounds that can be utilized in food products and functional ingredients (Cañas *et al*. 2020, Papageorgiou *et al*. 2024, Meerasri and Sothornvit 2022). Coffee also contains essential minerals like potassium and magnesium that support physiological functions (Gyedu-Akoto *et al*. 2019). Coffee cultivation has recently gained attention in Bangladesh as a potential high-value crop. The Department of Agricultural Extension (DAE) has initiated coffee plantation activities in several hilly regions of the country, particularly in the north-eastern parts (DAE 2024). Climatic conditions of Bangladesh are considered favorable for coffee cultivation. Currently, coffee is grown in some hilly areas of Sylhet and Moulvibazar districts under the Sylhet division. Among these areas, Sylhet district has emerged as one of the important regions for coffee cultivation in Bangladesh.

Despite the recent rapid expansion of coffee cultivation in Sylhet, scientific information regarding the production areas, insect pest infestations, and pesticide use remains very limited. Insect pests are known to cause serious damage to coffee plants at different growth stages and may significantly affect yield and quality.

Moreover, farmers often indiscriminately apply chemical pesticides for pest management, which may cause human health hazards and environmental pollution. Based on acute oral and dermal toxicity (hazard), the World Health Organization (WHO) classification with color bands is shown in Table 1.

Table 1. Pesticide classes with their hazards, colour bands and toxicity levels (WHO 2020)

Class	Hazards	Colour bands	LD50 for the rat (mg kg^{-1} body weight)	
			Oral	Dermal
Ia	Extremely hazardous	PMS red 199 C	< 5	< 50
Ib	Highly hazardous	PMS red 199 C	5–50	50–200
II	Moderately hazardous	PMS Yellow C	50–2000	200–2000
III	Slightly hazardous	PMS Blue 293 C	Over 2000	Over 2000
U	Unlikely to present acute hazard	PMS Green 347 C	5000 or higher	

Class Ia and Class Ib are combinedly regarded as Highly Hazardous Pesticides (HHPs) which can cause serious harm to human health, the environment, and agricultural sustainability. Class 1b have high acute toxicity and can cause severe poisoning or death even at relatively low exposure. Class II have moderate acute toxicity that can cause poisoning if improperly handled. Class III have relatively low acute toxicity under normal use. Class U have very low acute toxicity which are unlikely to cause acute health hazards.

Based upon the facts and findings described above, we documented the spatial distribution of newly established coffee plantations in Sylhet district. Present study also documented insect pests attack and insecticides usage pattern on coffee plantations in Sylhet district.

MATERIALS AND METHODS

Survey site: The survey was conducted in the Northeastern Bangladesh with an area of 3490.40 km^2. The research covers five sub-districts, namely Sylhet Sadar, Beanibazar, Fenchuganj, Golapganj, and Gowainghat in Sylhet district (Fig. 1). The district lies between DMS 24°54' N and 91°52' E. The AEZ for Sylhet is 20 and 21. The Köppen climatic classification places Sylhet in the tropical monsoon bordering on a humid sub-tropical climate category at higher elevation (BAMIS 2020).

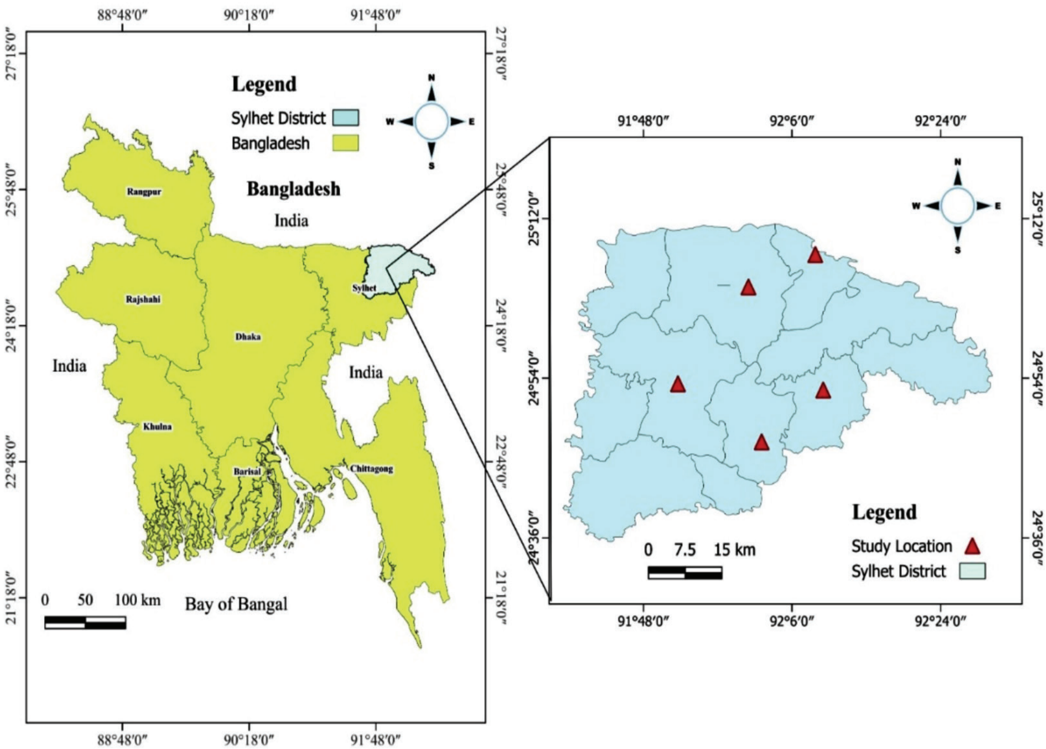

Fig. 1. Map of the study area and the selected Sub-districts under the Sylhet region

Data collection: We randomly selected 60 farmers (N=60) as the respondents via face-to-face interviews using a structured questionnaire and focus group discussion (FGD). The questionnaire was developed in English and translated into Bengali using standard translation methods by an expert translator proficient in both languages and familiar with coffee and local practices. For the selection of the respondents from the five upazilas, the following equation was used to select the total number of respondents.

$$n = \frac{N}{(1 + N\varepsilon^2)}$$

Where, n = sample size, N = the total number of respondents in each area and ε = the desired number of errors (Tuan *et al*. 2014). With a designed number of total 60 respondents i.e., 12 respondents from each upazila were interviewed. Sub-Assistant Agricultural Officer (SAAO), Department of Agricultural Extension (DAE) project personnel, coffee-related workers of the respective surveyed areas were the respondents of the survey works. Printed and laminated coloured photographs of the coffee insect pests were placed to the respondents for their identification. The photographs were also used to confirm whether or not they were able to correctly identify the insect pest species. The printed and laminated coloured photographs of the insect species were given a code against each insect shown. This was done because of the quick recording of the listed insect pests to the questionnaire.

Data analysis: The collected data were first normalized to ensure consistency and suitability for statistical analysis. Subsequently, descriptive statistics, including frequency counts, percentages, means, and standard deviations, were used to summarize the outcomes effectively. Data analysis was performed using R-Studio (Version 2026.04.0), while QGIS (Version 3.44.4-Solothurn) and OriginPro (Version 10.1.0.178) were used to create the study area map and various visually informative graphs and charts.

RESULTS

Demographic characteristics of the respondents: From the field survey, socio-economic characteristics (age, gender, education level and coffee cultivation experience) of the 60 respondents from five upazilas of Sylhet district were recorded to understand their personal and professional background (Table 2). The mean age of the respondents was 43.51±6.43 years. It was observed that the majority (76.67%) of the respondents belonged to the 36–50-year age group, whereas 15.00% were above 50 years and only 8.33% were within the 20-35 years age group. Most respondents were male (98.33%), while only 1.67% were female. The mean education level of the respondents was 0.90±1.21 (based on ordinal scoring of education categories). The study revealed that most of the respondents were illiterate (55.01%), followed by those with primary education (18.33%). A smaller proportion of respondents had completed secondary (13.33%) and higher secondary education (8.33%), while only 5.00% had a graduate degree. Moreover, the mean experience of the respondents in coffee cultivation was 5.75±3.00 years. About 41.67% of the respondents had less than 5 years of experience in coffee cultivation, whereas 51.66% and 6.67% had 5-10 years and more than 10 years of cultivation experience, respectively. The distribution of coffee varieties shows that the vast majority of respondents cultivated *Coffea arabica* (96.67%), while only a small proportion grew *Coffea canephora* (3.33%).

Table 2. Demographic characteristics of the respondents from the five selected upazilas of Sylhet district (N=60)

Factor(s)	Category	Frequency (n)	Percentage (%)	Mean	SD
Gender	Male	59	98.33	–	–
	Female	1	1.67		
Age (years)	20–35	5	8.33	43.51	6.43
	36–50	46	76.67		
	>50	9	15.00		
Education level	Illiterate	33	55.01	0.90	1.21
	Primary	11	18.33		
	Secondary	8	13.33		
	Higher secondary	5	8.33		
	Graduate	3	5.00		
Experience in coffee plantation (years)	<5	25	41.67	5.75	3.00
	5–10	31	51.66		
	>10	4	6.67		
Variety of Cultivated Coffee	*Coffea arabica*	58	96.67	0.97	0.18
	Coffea canephora	2	3.33		
Training	Yes	14	23.33	0.23	0.42
	No	46	76.67		

Major pests of coffee plantations: Respondents from the study areas in Sylhet district reported a total of 16 insect pests infesting coffee plantations (Table 3), including coffee berry borer (*Hypothenemus hampei*), coffee leaf miner (*Leucoptera coffeella*), shot hole borer (*Xylosandrus compactus*), white stem borer (*Xylotrechus quadripes*), green scale (*Coccus viridis*), red borer (*Zeuzera coffeae*), brown scale (*Saissetia coffeae*), mealybug (*Planococcus lilacinus / P. citri*), coffee grasshopper (*Zonocerus variegatus*), coffee caterpillar (*Epicampoptera* spp.), termite (*Isoptera* spp.), antestia bug (*Antestiopsis lineaticollis*), coffee bean weevil (*Araecerus fasciculatus*), leafhopper (*Empoasca* spp.), coffee plant bug (*Helopeltis antonii*), and glassy wing sharpshooter (*Homalodisca vitripennis*). Among these, coffee berry borer and coffee leaf miner were identified as the most destructive pests, reported by 55.00% and 46.67% of respondents, respectively, mainly attacking fruits and leaves. White stem borer (43.33%), mealybug (40.00%), and shot hole borer (38.33%) were also frequently observed, affecting stems, roots, leaves, and bark. Termite infestation was reported by 8.33% of respondents, while green scale and leafhopper were each noted by 5.00%. Minor pests such as red borer, brown scale, coffee grasshopper, and coffee plant bug were reported by 3.33% of respondents. The least-observed pests (1.67%) included the coffee caterpillar, antestia bug, coffee bean weevil, and glassy-winged sharpshooter. Overall, these pests were found to infest different plant parts including leaves, flowers, fruits, seeds, stems, and roots. Finally, only 23.33% of respondents received training on coffee pest management, while the rest (76.67%) reported negative responses (not receiving any training).

Table 3. Major insect pests associated with coffee plantations in Sylhet district (N=60)

Sl.	Common name	Scientific name / Order / Family	Infested plant parts	Respondents (%)
1	Coffee leaf miner	*Leucoptera coffeella* (Lyonetiidae, Lepidoptera)	Tender leaf, Older leaf	46.67
2	Coffee berry borer	*Hypothenemus hampei* (Curculionidae, Coleoptera)	Fruit	55.00
3	Shot hole borer	*Xylosandrus compactus* (Curculionidae, Coleoptera)	Stem	38.33
4	White stem borer	*Xylotrechus quadripes* (Cerambycidae, Coleoptera)	Stem, Bark	43.33
5	Green scale	*Coccus viridis* (Coccidae, Hemiptera)	Older leaf, Tender leaf, Stem	5.00
6	Red borer	*Zeuzera coffeae* (Cossidae, Lepidoptera)	Stem, Bark	3.33
7	Brown scale	*Saissetia coffeae* (Coccidae, Hemiptera)	Older leaf, Tender leaf, Stem	3.33
8	Mealy bug	*Planococcus lilacinus / P. citri* (Pseudococcidae, Hemiptera)	Root, Tender leaf, Stem	40.00
9	Coffee grasshopper	*Zonocerus variegatus* (Pyrgomorphidae, Orthoptera)	Older leaf, Tender leaf	3.33
10	Coffee caterpillar	*Epicampoptera* spp. (Notodontidae, Lepidoptera)	Older leaf	1.67
11	Termite	*Isoptera* spp. (Termitoidae, Blattodea)	Root, Stem, Bark	8.33

Sl.	Common name	Scientific name / Order / Family	Infested plant parts	Respondents (%)
12	Antestia bug	*Antestiopsis lineaticollis* (Pentatomidae, Hemiptera)	Flower, Fruit, Tender leaf	1.67
13	Coffee bean weevil	*Araecerus fasciculatus* (Anthribidae, Coleoptera)	Seed	1.67
14	Leafhopper	*Empoasca* spp. (Cicadellidae, Hemiptera)	Older leaf, Tender leaf	5.00
15	Coffee plant bug	*Helopeltis antonii* (Miridae, Hemiptera)	Tender leaf, Fruit	3.33
16	Glassy wing sharpshooter	*Homalodisca vitripennis* (Cicadellidae, Hemiptera)	Older leaf	1.67

Relative abundance of coffee pest functional groups: Figure 2 presents the distribution of coffee insect pests by functional groups based on 16 recorded species in Sylhet district. Sap-sucking insects were the most dominant group, accounting for 43.75% of the total pests. Stem borers and leaf feeders (chewers) each contributed 18.75%, while fruit borers and root feeders represented 12.50% and 6.25%, respectively. This pattern indicates that sap-sucking insects exert the highest pest pressure on coffee plants in the surveyed areas.

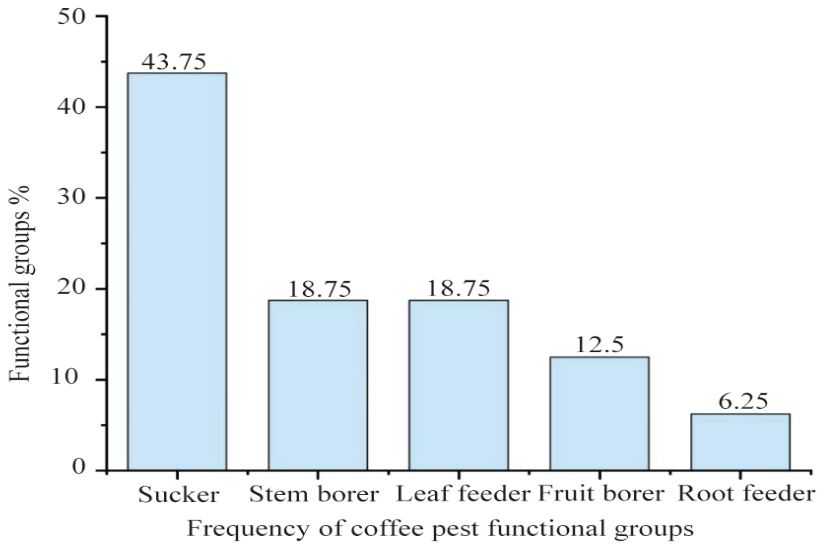

Fig. 2. Percentage distribution of coffee insect pest functional groups in Sylhet district, showing dominance of sap-sucking insects followed by stem borers, leaf feeders, fruit borers, and root feeders

Distribution of pesticide groups and hazard classes: Table 4 shows that a wide range of pesticides are used on coffee plantations of Sylhet district. Insecticides are the most commonly used group. Most pesticides belong to WHO Class II (moderately hazardous), with a few from Class Ib, Class III, and Class U. The major chemical groups include organophosphates, neonicotinoids, pyrethroids, and their mixtures. Fungicides and herbicides such as propiconazole, mancozeb, and glyphosate are also used. Overall, the results indicate a strong dependence on moderately hazardous chemical pesticides for pest management.

Table 4. Common pesticide groups used for coffee pest management in Sylhet district (N = 60)

Types	WHO Class	Chemical Group(s)	Common Name(s)	Trade Name(s)
Insecticide	Class Ib	Carbamate	Carbofuran	Carbofuran 3G
Insecticide	Class II	Organophosphate	Chlorpyrifos	Chlorpyriphos 20EC
Insecticide	Class II	Organophosphate	Chlorpyrifos	Dursban 20EC
Insecticide	Class II	Organophosphate	Quinalphos	Kinalux 25EC
Insecticide	Class II	Neonicotinoid	Imidacloprid	Admire 20SL
Insecticide	Class II	Neonicotinoid	Thiacloprid	Helocide 24SC
Insecticide	Class II	Neonicotinoid	Imidacloprid	Imitaf 20SL
Insecticide	Class II	Neonicotinoid	Acetamiprid	Platinum 20SP
Insecticide	Class II	Neonicotinoid + Pyrethroid	Acetamiprid + Cypermethrin	Juti 30SL
Insecticide	Class II	Neonicotinoid + Pyrethroid	Thiamethoxam + Lambda-cyhalothrin	Lamix 24.7SC
Insecticide	Class II	Neonicotinoid + Pyrethroid	Imidacloprid + Lambda-cyhalothrin	Roland 20SC
Insecticide	Class II	Neonicotinoid + Pyrethroid	Imidacloprid + Cypermethrin	Stroke 50EC
Insecticide	Class II	Neonicotinoid + Pyrethroid	Imidacloprid + Lambda-cyhalothrin	Wicket 30SC
Insecticide	Class II	Neonicotinoid + Phenylpyrazole + Pyrethroid	Imidacloprid + Fipronil + Deltamethrin	Proloy 32SC
Insecticide	Class II	Pyrethroid	Lambda-cyhalothrin	Karate 2.5EC
Insecticide	Class II	Pyrethroid	Cypermethrin	Ripcord 10EC
Insecticide	Class II	Pyrethroid + Organophosphate	Cypermethrin + Dimethoate	Merger 45EC

Types	WHO Class	Chemical Group(s)	Common Name(s)	Trade Name(s)
Insecticide	Class II	Pyrethroid + Phenylpyrazole	Fipronil + Lambda-cyhalothrin	Otova 10EC
Insecticide	Class III	Organophosphate	Malathion	Fyfanon 57EC
Fungicide	Class II	Triazole	Propiconazole (25%)	Tilt 250 EC
Fungicide	Class U	Dithiocarbamate	Mancozeb 80%	Zebco 80 WP
Fungicide	Class U	Dithiocarbamate / Morpholine / Cyanoacetamide-oxime	Mancozeb 64% + Dimethomorph 10% + Cymoxanil 8%	Spiner 82 WP
Herbicide	Class III	Phosphonomethyl	Glyphosate	Sun Up

Percentage distribution of pesticide use based on WHO hazard classes*:* Figure 3 shows the percentage of pesticide use based on WHO hazard classes. The majority of respondents (83.34%) used Class II pesticides. A smaller proportion (8.33%) used Class III pesticides. Only 5.00% of respondents used Class Ib pesticides. The least used group was Class U, with 3.33%. This indicates a strong reliance on moderately hazardous pesticides in the study area.

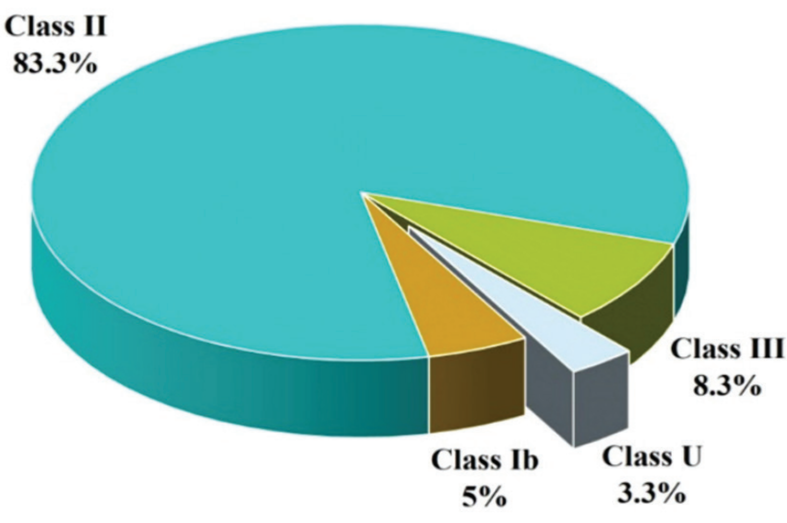

Fig. 3. Percentage distribution of pesticide usage based on WHO hazard classes in coffee plantations of Sylhet district, showing dominance of Class II pesticides followed by Class III, Class Ib, and Class U

DISCUSSION

The socio-demographic profile of coffee producers in Sylhet, characterized by a mean age of 43.51 years, suggests a workforce in its peak productive years (Torrez *et al*. 2023). This age distribution is consistent with middle-aged farmer profiles documented in the Philippines, where the average age of coffee smallholders is recorded at 43 years (Rodolfo *et al*. 2016). Similar trends are observed in developing countries, including Brazil and Honduras, where fewer young individuals are entering agriculture (Buys *et al*. 2023). The high rate of illiteracy (55.01%) identified in the current study presents a formidable obstacle to the adoption of modern agricultural technologies. Illiterate farmers struggle to comprehend technical information, reducing their likelihood of adopting new practices (Idisi *et al*. 2025). This educational deficit is notably more severe than that of coffee farmers in Vietnam, who average over nine years of formal education, enabling them to better engage with digital monitoring and certification protocols (Noreen 2026). Furthermore, the near-total male dominance (98.33%) in Sylhet coffee farming contrasts with more gender-inclusive systems in parts of Ethiopia and Indonesia, where women frequently manage post-harvest activities (Pascucci 2024). Even, Training programs have led to an 80% increase in farmers' knowledge and skills, directly correlating with improved coffee quality and income (Matoneng *et al*. 2025).

The documentation of 16 insect pests in Sylhet highlights a complex agro-ecological challenge for local producers (Parija *et al*. 2025). The coffee berry borer, identified by 55.00% of respondents as the most destructive pest, stand as the primary biological threat to coffee globally, causing annual economic losses exceeding $500 million (Johnson *et al*. 2020, Moreno-Ramirez *et al*. 2024). The high prevalence of Coffee bean borer in Sylhet is a characteristic shared with Ethiopian coffee systems, where infestation levels often vary by altitude and management intensity (Azeez 2025). Similarly, the prominence of the coffee leaf miner in the study area (46.67%) aligns with its status as a major pest in neotropical countries like Brazil and Colombia, where it accounts for yield losses of up to 70% (Dantas *et al*. 2021). The identified dominance of sap-sucking insects (43.75%) suggests high pest pressure that mirrors the biological dynamics of shaded coffee agroforestry systems in Indonesia (Sunanto *et al*. 2024).

Pest management in Sylhet is defined by an overwhelming reliance on WHO Class II (moderately hazardous) chemical pesticides (Global Coffee Platform 2021). The frequent use of organophosphate and neonicotinoid insecticides reflects intensive agricultural production systems similar to those reported in Vietnam and Brazil, where high crop yields have historically been supported by substantial pesticide inputs (Jardim *et al*. 2018). Despite their effectiveness, these substances pose significant occupational health risks, as evidenced by reports of acute pesticide poisoning among plantation workers in India (Ssekkadde *et al.* 2026). The lack of Integrated Pest Management (IPM) training in Sylhet (76.67% untrained) is far more acute than in Honduras, where government-led programs have reached 87% of smallholders (USDA 2023). This training gap is a critical vulnerability that has been linked to the misuse of banned pesticides in other developing regions (Henry and Feola 2013).

Finally, the livelihood vulnerability of Sylhet farmers, driven by low education and limited technical support, parallels the socio-economic pressures faced by Ethiopian smallholders who lack diversified income streams (Teferra 2022). Furthermore, climate change is expected to aggravate these pressures, as seen in Tanzania where rising temperatures have caused pests like the CBB to migrate to higher elevations (Jaramillo *et al*. 2011). To improve the sustainability of the Sylhet coffee industry, policymakers must implement participatory training models, which have successfully promoted non-chemical pest management in Central America (Aristizábal *et al*. 2023).

CONCLUSION

Coffee cultivation in Sylhet district is expanding rapidly, with Coffea arabica being the predominant species grown by farmers. The study documented 16 insect pest species, among which coffee berry borer and coffee leaf miner were identified as the most important pests affecting coffee production. Sap-sucking insects constituted the dominant pest functional group, indicating substantial pest pressure in the surveyed plantations. Pest management was heavily dependent on WHO Class II pesticides, while the majority of farmers lacked formal training in coffee pest management. The combination of high pest incidence, extensive pesticide use, and limited technical knowledge highlights the need for strengthened extension services and integrated pest management programs. Adoption of sustainable pest management practices will be essential for improving the productivity, environmental safety, and long-term sustainability for the emerging coffee sector in Sylhet.

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EXPLORING SELECTED MICROBIAL PESTICIEDES AGAINST SUCKING PESTS OF BRINJAL

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ABSTRACT

Brinjal (*Solanum melongena* L.) is one of the most pesticide-intensive vegetable crops in Bangladesh, where excessive insecticides are used to control the brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenée) and sap-sucking pests which poses severe environmental and health risks. To develop an eco-compatible alternative, field experiments were conducted during two consecutive Rabi seasons (2020-2021 and 2021-2022) at the Entomology Research Field, BARI, Gazipur, to evaluate the efficacy of new generation microbial pesticides and some selected insecticides. Significantly the lowest mean population of jassid, thrips and whitefly were received in afidopyropen (Sefina 5 DC) and it was followed by spraying with thiamethoxam (Actara 25 WG). The mean population of jassid, thrips and whitefly were lower in *Metarhizium anisopliae* (Bio Magic 1.15%WP); *Bacillus thuringiensis* var. *kurstaki* (Bio Fighter 2.0%WP), *Bacillus thuringiensis* var. *kurstaki* (Biocure 2.0%WP) and *Metarhizium anisopliae* (Lycomax-M 2.0%WP). These treatments have been showed better performance among the microbial pesticides. The mean aphid, jassid and whitefly population was (2.11, 4.52 & 3.02/five leaves, respectively) in Sefina 5 DC and it was followed by Actara 25 WG (2.72, 5.86 & 6.81/five leaves, respectively). In the treatment *Bacillus thuringiensis* var. *kurstaki* (Biocure 2.0%WP) the mean aphid, jassid and whitefly population was (3.02, 7.15 & 8.49/five leaves, respectively). However, among them afidopyropen (Sefina 5 DC) resulted the greatest pest suppression, appeared as the best approach providing highest average yield (16.08 t ha^{-1}) whereas *Bacillus thuringiensis* var. *kurstaki* (Biocure 2.0%WP) treated plot produced 14.25 t ha^{-1}. The biorational tool offers a robust, residue-free alternative to pesticide-intensive management. Adoption of such bio-intensive strategies can substantially reduce chemical dependency, conserve natural enemies, and promote safer, more sustainable brinjal production systems in Bangladesh and similar agro-ecological regions.

Keywords: Assessment, *Solanum melongena*, jassids, whiteflies, aphids, microbial pesticides

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INTRODUCTION

Brinjal (*Solanum melongena* L.), one of the most widely cultivated and consumed vegetable crops in South and Southeast Asia, holds immense nutritional and economic importance in Bangladesh. It is a vitamin, mineral, phenol, and antioxidant-rich vegetable (Gurbuz *et al.* 2018). This vegetable is cultivated throughout the world because of heat insensitivity, and genetic or morphological diversity (Chapman 2020) with a production of 7,26,000 tons from 54,655 ha area (BBS 2024). Insect pests are the major impediment to the successful cultivation and production of brinjal (Mollah *et al.* 2022a). However, its productivity and quality are severely constrained by a complex of insect pests that infest the crop from the nursery stage to harvest. About 140 species of insect and arachnid pests are reported to infest brinjal throughout the world (Sharma and Tayde 2017). Among these, the brinjal shoot and fruit borer (BSFB) (*Leucinodes orbonalis* Guenée) is considered the most destructive pest, capable of inflicting yield losses exceeding 70-85% in the absence of effective control (Alam *et al*. 2004). In addition, several sap-sucking pests such as the aphid (*Aphis gossypii* Glover), jassid (*Amrasca biguttula biguttula* Ishida), whitefly (*Bemisia tabaci* Gennadius), thrips, and mites have gained considerable importance in recent years due to their increasing infestation and damaging potential (Alam *et al*. 2004, Munde *et al*. 2011). In Bangladesh, green leafhopper (*Amrasca biguttula biguttula*), aphid (*Aphis gossypii*), whitefly (*Bemisia tabaci*), thrips (*Thrips tabaci*), shoot and fruit borer (*Leucinodes orbonalis* G.), and from arachnid, red spider mite (*Tetranychus macfurlanei*) are most prevalent (Dutta *et al.* 2017). Among these, brinjal shoot and fruit borer (BSFB), leafhopper, whitefly, and mealy bugs are most common, prevalent, and destructive in the summer season (Kapil *et al.* 2022, Mollah *et al.* 2023). These pests not only directly reduce plant vigor by sucking cell sap but also act as vectors of viral diseases, further aggravating yield losses that may exceed 85% under severe infestation in Bangladesh. Both adults and nymphs of leafhoppers and other leaf suckers cause serious damage to leave by sucking cell sap from the lower surface of the leaves causing chlorosis and necrotic spots. Finally, the entire plant turns brown and shows burn symptoms and ultimately the leaves droop off. The indirect effect of leafhoppers includes honey-dew secretion that facilitates fungal growth and interrupts photosynthesis (Bosquee *et al.* 2018).
Meanwhile, prolonged outbreaks of sucking pests can stunt plant growth, especially

during dry periods. Despite these challenges, farmers in Bangladesh predominantly depend on repeated applications of synthetic insecticides, often exceeding 80-100 sprays per growing season to achieve blemish-free fruits for the local market. Such indiscriminate pesticide use has led to alarming environmental and health concerns, including pesticide residue accumulation, resurgence of secondary pests, development of insecticide resistance, and disruption of beneficial arthropod populations (Korsak and Sato 1977, Rashid *et al*. 2003, Ulrichs *et al*. 2001). Moreover, the excessive use of insecticides in brinjal (approximately 47% of all vegetable insecticide use in Bangladesh) makes it one of the most pesticide-intensive crops, with an estimated application rate of 1.41 kg or L ha^{-1} (Alam *et al*. 2004). Such practices elevate production costs and pose serious threats to human health and export potential due to pesticide residues (Islam *et al*. 1999). Therefore, the introduction of non-hazardous, plant-based, or microbial-origin bio-insecticides is very essential. Additionally, these are mostly effective, safe for non-target organisms and natural enemies, and target pest-specific, and ecologically sound solutions to pest problems (Mollah *et al.* 2022b). Some commercially formulated microbial or pathogenic bio-insecticides were found effective against the major insect pests of brinjal, brinjal shoot, and fruit borer (Mollah *et al.* 2023) and the sucking insect pests (Gayathri and Geetha 2019). The efficacy of pathogenic or microbial insecticides might come from the combined effect of toxicity (Tobias *et al.* 2018, Mollah *et al.* 2020a), insect host immunity suppression (Mollah *et al.* 2020b, Mollah and Kim 2020), inhibition of immune mediator secretion (Hasan *et al.* 2019, Mollah 2023) and bind with immune proteins (Mollah 2024, Mollah *et al.* 2021). Some botanical insecticides were found effective against the bean pod borer (Mollah *et al.* 2012) and sucking insect pests including aphids of country bean (Mollah *et al.* 2013) and green leafhoppers of brinjal (Kunbhar *et al.* 2018).

For the management of sucking pests use of insecticides is the permanent solution. Recent trend of organic farming and deleterious effect of chemical insecticides on natural enemies has necessitated the alternative approach for economical and eco-friendly management of insect pests. In this context microbial biopesticides attract considerable attention and significant findings have been documented on efficacy of microbial biopesticides in Bt cotton and other various crops (Luo *et al.* 2014, Rajashekhar *et al.* 2017, Chattopadhyay *et al.* 2017). In this context, the paradigm of bio-rational pest management offers a sustainable alternative to sole chemical dependence by integrating multiple eco-compatible components. Among recent advancements, new-generation biorational insecticides including microbial-based products like *Bacillus thuringiensis*, *Beauveria bassiana* and *Metarhizium anisopliae* formulations have shown strong insecticidal potential while preserving ecological safety (Rahman *et al*. 2023, 2025, Rashid *et al*. 2022). These bioactive agents act through unique physiological and behavioral mechanisms, such as feeding inhibition, digestive system disruption, and neuro-modulation, with minimal likelihood of resistance development (Wang *et al*. 2001, Wei *et al*. 2009). However, their field-level integration with conventional management with pesticide remains poorly documented under Bangladesh agro-ecological conditions. A little or no information is available about the efficacy of commercially available microbial insecticides against different sucking pests in the brinjal field.

Therefore, the present study was designed to evaluate and compare the efficacy of new generation commercially formulated microbial pesticides with some selected pesticides, against the sucking insect pests infesting brinjal plants under field conditions during the winter season. The specific objectives were to (i) determine the comparative effectiveness of selected microbial pesticides and insecticides in suppressing sucking pests, (ii) assess their influence on marketable yield and infestation, and (iii) to identify the most economically viable and environmentally safe management strategy. The findings of this research are expected to contribute significantly toward developing a bio-intensive IPM framework for sustainable brinjal production and reducing dependency on hazardous chemical pesticides in Bangladesh.

MATERIALS AND METHODS

Experimental site and duration: Field experiments were conducted for two consecutive winter (*Rabi*) seasons during 2020-2021 and 2021-2022 at the Entomology Research Field of the Bangladesh Agricultural Research Institute (BARI), Gazipur (24°00′N, 90°25′E; elevation 8.4 m above the sea level). The area is characterized by a subtropical climate with distinct dry and cool winters, moderate rainfall, and an average temperature range of 15-30°C. The soil of the experimental site was silty clay loam with pH 6.8 and moderate organic matter content. The experiments were performed under irrigated conditions following standard agronomic practices recommended for brinjal cultivation in central Bangladesh.

Experimental design and crop establishment: The experiment was laid out in a randomized complete block design (RCBD) with nine treatments and an untreated control with three replications. Each plot measured 8.0 m × 2.5 m with 1.0 m spacing between plots and 1.5 m between blocks to prevent cross-interference of treatments. Brinjal variety *BARI Begun-8* was used as the test crop. Thirty-day-old healthy seedlings were transplanted at a spacing of 75 cm × 60 cm during the last week of October in both years. The recommended fertilizer doses were applied at 20 t ha^{-1} cow dung, 120 kg N, 100 kg P_2O_5, 100 kg K_2O, and 15 kg S per hectare. Standard irrigation, weeding, and mulching operations were performed as required to maintain uniform crop growth across all treatments and untreated control.

Treatments applied in the experiment: Seven microbial insecticides and two chemical insecticides were tested in this study (Table 1).

Table 1. Details of microbial pesticides and chemical insecticides applied in the experiment

Treatments	Active ingredient	Dose
T_1= Bio Catch	*Verticillum lecani* (1.15% WP- 2 x 10^8 cfu g^{-1})	6.0 g L^{-1} of water
T_2= Bio Magic	*Metarhizium anisopliae* (1.15% WP- 2 x 10^8 cfu g^{-1})	6.0 g L^{-1} of water
T_3= Bio Power	*Beauveria bassiana* (1.15% WP- 2 x 10^8 cfu g^{-1})	6.0 g L^{-1} of water
T_4= Bio Fighter	*Bacillus thuringiensis* var. *kurstaki* (1.15% WP- 2 x 10^8 cfu g^{-1})	2.5 g L^{-1} of water
T_5= Biocure	*Bacillus thuringiensis* var. *kurstaki* (2.0% WP- 2 x 10^8 cfu g^{-1})	1.0 g L^{-1} of water
T_6= Lycomax-M	*Metarhizium anisopliae* (2.0% WP- 2 x 10^8 cfu g^{-1})	1.0 g L^{-1} of water
T_7= Lycomax-B	*Beauveria bassiana* (2.0% WP- 2 x 10^8 cfu g^{-1})	1.0 g L^{-1} of water
T_8= Sefina 5 DC	Afidopyropen	2.0 ml L^{-1} of water
T_9= Actara 25 WG	Thiamethoxam	0.2 g L^{-1} of water
T_{10}= Untreated control (Water spray)	N/A	N/A

A total of five foliar sprays were applied for each treatment, starting at the initial detection of pest infestation and continued at 7-day intervals. Applications were made using a hand-operated knapsack sprayer calibrated for uniform droplet size.

Data collection

Sucking pest population: Observations on aphids, jassids, thrips, and whiteflies were recorded from five randomly selected plants per plot. From each plant, five leaves were examined (one from the lower canopy, two from the middle, and two from the upper canopy). The number of live insects per leaf was counted from the abaxial surface using a 10× hand lens. Data were expressed as mean insect population per five leaves.

The reduction in pest population over the untreated control was calculated using the following formula:

$$\text{Percent reduction over control} = \frac{\text{Mean population in untreated control - Mean population in treatment}}{\text{Mean population in untreated control}} \times 100$$

Yield: Healthy fruits were harvested periodically from each plot, and total marketable yield (t ha^{-1}) was calculated.

Statistical analysis: All data were subjected to analysis of variance (ANOVA) using R statistical software (version 4.3.1). Treatment means were separated by the least significant difference (LSD) test at a 5% probability level ($p \leq 0.05$). Data expressed in percentages were arcsine-transformed before analysis to ensure homogeneity of variance.

RESULTS AND DISCUSSION

Seasonal incidence and pest pressure: During both cropping seasons (2020-2021 and 2021-2022), brinjal fields were infested by several insect pests, including the shoot and fruit borer (*Leucinodes orbonalis* Guenée), aphids (*Aphis gossypii* Glover), jassids (*Amrasca biguttula biguttula* Ishida), and whiteflies (*Bemisia tabaci* Gennadius). The populations of thrips and epilachna beetles remained negligible throughout the experiment, while predatory ladybird beetles (Coccinellidae) were frequently observed, indicating the conservation of natural enemies under bio-insecticides regimes. Pest populations began to increase from 30-40 days after transplanting (DAT), peaked between 65-90 DAT under warm and dry weather conditions, and gradually declined thereafter. This population trend closely followed fluctuations in temperature and relative humidity, corroborating previous findings by Khan *et al*. (2023) and Saikia *et al*. (2020), who highlighted that climatic factor play a critical role in pest proliferation in brinjal ecosystems.

Effect of different treatments on sucking pest suppression: Application of different treatments significantly reduced the population densities of major sucking pests such as aphids, jassids, and whiteflies compared to the untreated control ($p \leq 0.05$) during both cropping seasons (2020-2021 and 2021-2022). In Rabi 2020-21 season; the mean aphid, jassid, and whitefly populations were the lowest in Sefina® 5 DC treated plot and it was followed by Actara® 25 WG recording 2.06, 4.29 & 3.08 individuals per five leaves, respectively. The Actara® 25 WG treated plot had received aphid, jassid, and whitefly populations 2.67, 5.70 & 7.69 per five leaves, respectively. The mean population of jassid, thrips and whitefly showed lower in *Bacillus thuringiensis* var. *kurstaki* (Biocure 2.0% WP) @ 1.0 g L^{-1} of water and *Metarhizium anisopliae* (Lycomax-M 2.0%WP) @ 1.0 g L^{-1} of water than that of the other microbial pesticides. These two treatments have been showed better performance among the microbial pesticides. In T_5 treatment i.e., *Bacillus thuringiensis* var. *kurstaki* (Biocure 2.0%WP); the mean aphid, jassid and whitefly population was (3.79, 8.47 & 9.67 per five leaves, respectively) and it was performed better than that of the other microbial pesticide. These values were statistically comparable to other microbial pesticides treatment. In contrast, the chemical pesticide treatments (Sefina® 5 DC and Actara® 25 WG); the microbial pesticide treatments showed moderate suppression, while the untreated control recorded the highest pest densities 12.51, 25.93 & 27.42 per five leaves, respectively (Table 2). From Table 3 it was revealed that the highest reduction in aphid, jassid, and whitefly populations over untreated control showed by Sefina® 5 DC (83.53%, 83.46%, and 88.77%, respectively), followed by Actara® 25 WG (78.66%, 78.02%, and 72.02%).

Similar trend of results was also found in Rabi 2021-22 seasons. The mean aphid, jassid, and whitefly populations were the lowest in Sefina® 5 DC and it was followed by Actara® 25 WG recording 2.11, 4.52 & 3.02 individuals per five leaves, respectively. The Actara® 25 WG treated plot showed aphid, jassid, and whitefly populations of 2.72, 5.86 & 6.81per five leaves, respectively. The control treatment had significantly highest population in respect of all the pest viz. aphid, jassid & whitefly (11.95, 27.83, and 29.68/five leaves, respectively). Thus, the maximum reduction of aphid, jassid & whitefly over untreated control was achieved from Sefina® 5 DC (82.34%, 83.76%, and 89.82%, respectively), followed by Actara® 25 WG (81.00%, 78.94%, and 77.06%). Similarly, applications of microbial pesticides have also reduced the mean aphid, jassid & whitefly pest population but not likely to chemical pesticide application. Among the microbial pesticides, *Bacillus thuringiensis* var. *kurstaki* (Biocure 2.0% WP) @ 1.0 g L^{-1} of water and *Metarhizium anisopliae* (Lycomax-M 2.0% WP) @ 1.0 g L^{-1} of water have been showed better than that of the other microbial pesticides. The minimum percent pest population over control was also obtained from these microbial pesticides (Tables 2-3).

The result was found in this study could not be compared with any other findings since these combinations were newly introduced first time in this study. Although chemical control is the common practice to manage the sucking pests, nowadays different microbial native insecticides, microbes or plant-based bioinsecticides are being applied. Raghunandan *et al.* (2018) reported that the population of sucking pests viz. aphid, jassid, whitefly and thrips reduced significantly in the in Bt cotton plots treated with microbial biopesticide. *Lecanicillium lecanii* was the most effective followed by *Beauveria bassiana* and *Metarhizium anisopliae*. Ajith *et al.* (2023) also observed that entomopathogenic fungi, *Lecanicillium lecanii* and *Beauveria bassiana* was most effective for sucking insect pest *viz*., aphid, whitefly and thrips population of chilli. Previous studies reported, where integration of biorationals and physical controls effectively suppressed sucking pests in brinjal (Dutta *et al*. 2012, Aparna and Dethe 2011). The superior efficacy of Afidopyropen and Matrine can be attributed to their novel biochemical modes of action on chordotonal organs and feeding inhibition (Kandasamy *et al*. 2017), while Spinosad provided additional ingestion toxicity with minimal harm to beneficial insects. These results confirm that new-generation microbial pesticides can serve as sustainable alternatives to synthetic pesticides in vegetable IPM systems as well as other crops.

Table 2. Effect of different treatments on the mean population of sucking pests in brinjal over two cropping seasons

Cropping season	Treatments	Number of Aphid /5 leaves	Number of Jassid /5 leaves	Number of Thrips /5 leaves	Number of Epilachna /5 leaves	Number of Whitefly /5 leaves
2020-21	Bio Catch 1.15% WP	4.24 b	10.51 c	-	-	9.00 c
	Bio Magic 1.15% WP	4.18 b	10.50 c	-	-	11.09 bc
	Bio Power 1.15% WP	4.85 b	12.90 b	-	-	12.08 b
	Bio Fighter 1.15% WP	4.57 b	10.98 c			12.75 b
	Biocure 2.0% WP	3.79 b	8.47 d	-	-	9.67 c
	Lycomax-M 2.0%WP	4.05 b	8.50 d	-	-	9.75 c
	Lycomax-B 2.0%WP	4.74 b	9.32 c	-	-	10.41 bc
	Sefina 5 DC	2.06 c	4.29 e	-	-	3.08 d
	Actara 25 WG	2.67 c	5.70 e	-	-	7.69 c
	Untreated control	12.51a	25.93 a	-	-	27.42 a
2021-22	Bio Catch 1.15% WP	4.59 b	11.39 b	-	-	10.05 c
	Bio Magic 1.15%WP	3.07 c	9.43 c	-	-	10.02 b
	Bio Power 1.15% WP	4.91 b	12.27 b	-	-	12.29 b
	Bio Fighter 1.15% WP	3.12 c	9.24 c			10.33 b
	Biocure 2.0% WP	3.02 c	7.08 d	-	-	8.49 c
	Lycomax-M 2.0%WP	3.18 c	7.15 d	-	-	8.62 c
	Lycomax-B 2.0%WP	4.81 b	9.86 c	-	-	11.27 b
	Sefina 5 DC	2.11 d	4.52 e	-	-	3.02 e
	Actara 25 WG	2.72 d	5.86 e	-	-	6.81 d
	Untreated control	11.95a	27.83 a	-	-	29.68 a

Means within the same column for a crop growing season that share the same letter are not significantly different at P > 0.05 according to the LSD test.

Table 3. Percent reduction of major sucking pest populations over untreated control in brinjal under different treatments across two cropping seasons

Treatments	Percent pest population reduction over untreated control					
	2020-21			2021-22		
	Aphid	Jassid	Whitefly	Aphid	Jassid	Whitefly
Bio Catch 1.15% WP	66.11	59.46	67.18	61.59	59.07	66.14
Bio Magic 1.15%WP	66.59	59.51	59.56	74.30	66.12	66.24
Bio Power 1.15% WP	61.23	50.26	55.94	58.92	55.91	58.60
Bio Fighter 1.15% WP	63.47	57.66	54.00	73.89	66.80	65.20
Biocure 2.0% WP	69.70	67.34	64.73	74.73	74.70	71.39
Lycomax-M 2.0%WP	67.63	67.21	64.44	73.39	74.31	70.96
Lycomax-B 2.0% WP	62.11	64.06	62.04	59.75	64.57	62.03
Sefina 5 DC	83.53	83.46	88.77	82.34	83.76	89.82
Actara 25 WG	78.66	78.02	72.02	81.00	78.94	77.06
Untreated control	-	-	-	-	-	-

Effect of microbial pesticides and insecticides on pest infestation in brinjal plant: The percent plant infestation and reduction over untreated control was presented in Figure 1. The highest percent reduction of plant infestation by aphids, jassid, and whitefly over untreated control was attained from the treatment T_8, Sefina® 5 DC @ 2.0 ml L^{-1} of water (73.05%) and it was statistically similar with spraying with T_9 (Actara 25® WG) @ 0.2 g L^{-1} of water (71.48%) which was followed by T_5 (Biocure 2.0% WP), T_6 (Lycomax-M 2.0% WP) & T_7 (Lycomax-B 2.0% WP) where plant infestation over control (67.59%, 67.10% & 66.61%, respectively). The lowest percent reduction of plant infestation by aphids, jassid, and whitefly population over control was obtained from T_3 (Bio Power) treatment (61.20%).

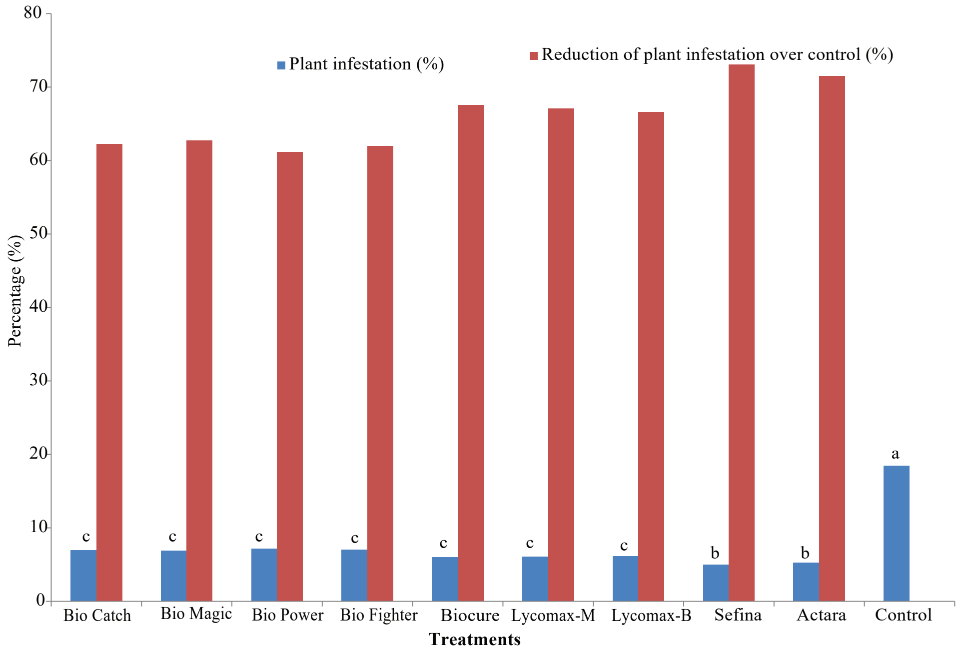

Fig. 1. Percent reduction of plant by aphid, jassid and whitefly population over control in brinjal as influenced by different treatments

Effect of different management options on the yield of brinjal: The principal objective of this research was to determine the comparative effectiveness of selected microbial pesticides and chemical insecticides in suppressing sucking pests as well as its impact on brinjal shoot and fruit borer (BSFB) infestation. The brinjal shoot and fruit borer (BSFB) remained the dominant pest throughout the cropping period. If no intervention was done for the management of BSFB that cause the marketable fruit yield loss of brinjal. More or less a poor yield was obtained due to severe infestation of BSFB. The marketable fruit yield was bit higher in chemical pesticides treatment plot than that of microbial pesticides plot. It might be the effect of chemical pesticides on BSFB population than that of microbial pesticides. From Table 4 it was revealed that significant differences in marketable fruit yield among the treatments ($p \leq 0.05$) during both cropping seasons (2020-2021 & 2021-2022). In the Rabi 2020-21 cropping season the highest marketable fruit yield (16.45 t ha^{-1}) was recorded in afidopyropen (Sefina® 5 DC) followed by spraying with thiamethoxam (Actara® 25 WG) where the yield was 14.98 t ha^{-1}. However, the lowest yield was obtained from untreated control plot (9.02 t ha^{-1}). In contrast, the microbial treatment *Bacillus* thuringiensis var. *kurstaki* (Biocure 2.0%WP) received 13.97 t ha^{-1} yields which were at par with the treatment *Metarhizium anisopliae* (Lycomax-M 2.0%WP) and *Beauveria bassiana* (Lycomax-B 2.0%WP). Similarly, the highest yield increase over control was calculated from afidopyropen (Sefina® 5 DC) treated plots (82.37%) followed by spraying with thiamethoxam (Actara® 25 WG) which was 66.08%. *Bacillus thuringiensis* var. *kurstaki* (Biocure 2.0%WP) treated plot had 54.88% yield increase over control followed by *Metarhizium anisopliae* (Lycomax-M 2.0%WP) which was 53.99%.

In the *Rabi* 2021-22 cropping season the highest yield (15.71 t ha^{-1}) was also recorded in afidopyropen (Sefina® 5 DC) followed by spraying with thiamethoxam (Actara® 25 WG) which was (14.88 t ha^{-1}). However, the lowest yield was obtained from control plot (9.01 t ha^{-1}). Similarly, the highest yield increase over untreated control was intended from afidopyropen (Sefina® 5 DC) treated plots (74.36 %) followed by spraying with thiamethoxam (Actara® 25 WG) which was 65.15%. *Bacillus thuringiensis* var. *kurstaki* (Biocure 2.0%WP) treated plot received 61.15% yield increase over control followed by *Metarhizium anisopliae* (Lycomax-M 2.0%WP) which was 57.49%.

Table 4. Effect of different treatments on the marketable yield of brinjal in two cropping seasons at BARI, Gazipur

Crop growing season	Treatments	Marketable yield (t/ha)	Yield increase over control (%)
2020-2021	Bio Catch 1.15% WP	13.17 d	46.00
	Bio Magic 1.15%WP	13.32 d	47.67
	Bio Power 1.15% WP	12.05 d	33.59
	Bio Fighter 1.15% WP	12.65 d	40.24
	Biocure 2.0% WP	13.97 c	54.88
	Lycomax-M 2.0%WP	13.89 c	53.99
	Lycomax-B 2.0%WP	13.78 c	52.77
	Sefina 5 DC	16.45 a	82.37
	Actara 25 WG	14.98 b	66.08
	Untreated control	9.02 e	-
	CV %	4.48	-

Crop growing season	Treatments	Marketable yield (t/ha)	Yield increase over control (%)
2021-2022	Bio Catch 1.15% WP	12.85 d	42.62
	Bio Magic 1.15%WP	14.06 c	56.05
	Bio Power 1.15% WP	12.22 d	35.63
	Bio Fighter 1.15% WP	13.97 cd	55.05
	Biocure 2.0% WP	14.52 c	61.15
	Lycomax-M 2.0%WP	14.19 c	57.49
	Lycomax-B 2.0%WP	13.05 d	44.84
	Sefina 5 DC	15.71 a	74.36
	Actara 25 WG	14.88 b	65.15
	Untreated control	9.01e	-
	CV %	5.01	-

Means within the same column for a crop growing season that share the same letter are not significantly different at $P > 0.05$ according to the LSD test.

Ecological and practical implications: The novel biopesticides such as Matrine, D-limonene, Sodium lauryl ether sulphate, *Celastrus angulatus* extract, azadirachtin preparation, *Saccharopolyspora spinosa* and *Bacillus thuringiensis* var. *kurstaki* both mixture preparation, potassium salt of fatty acid preparation and *Bacillus thuringiensis* var. *kurstaki* alone were demonstrated the efficacy of multi component strategies for sustainable brinjal pest management very recently at Entomology Division, BARI, Gazipur and the findings were very promising. The findings of this newly designed research with microbial pesticides have been played a vital role for the management of sucking pests of other high value vegetable crops such as country bean, okra, chilli, yard long been, cabbage, cauliflower etc. Unlike conventional programs relying on repetitive synthetic insecticide applications, these biorational interventions operate through diverse biochemical modes of action, thereby reducing the risk of pest resistance and preserving natural enemy populations. Moreover, they minimize environmental contamination, safeguard beneficial arthropods, and enhance ecological stability within brinjal ecosystems. The study highlights a paradigm shift toward ecologically synchronized pest management, where adoption of multi component packages can substantially reduce pesticide dependency, lower production costs, improve fruit quality, and support safer, more sustainable vegetable production systems in Bangladesh and other South Asian agro ecological regions.

CONCLUSION

The present study demonstrated that the new-generation biorational insecticide provides an effective, eco-friendly, and economically viable approach for the sustainable management of sucking pests of brinjal. All the treatments significantly reduced the populations of sucking pests (aphid, jassid, and whitefly). Among the tested treatments, chemical pesticides exhibited the highest suppression of pest populations and plant infestation, coupled with superior marketable yields. The efficacy of microbial pesticides was also upright and successfully managed the sucking pests of brinjal. This integrated strategy can substantially reduce pesticide dependency in intensive vegetable systems, aligning with the national goal of promoting safe, residue-free vegetables for domestic and export markets. Due to unavailability of some newer microbial pesticides price, economic evaluation has not been done. Future research should focus on the long-term ecological impacts, compatibility with natural enemies, and optimization of these biorational IPM components under varying agro-climatic conditions for broader adoption by smallholder farmers.

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DESCRIPTION OF A NEW SPECIES OF *ALLOTROPA* FÖRSTER 1856 (HYMENOPTERA: PLATYGASTRIDAE), AN ENDOPARASITOID OF THE CASSAVA MEALYBUG

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ABSTRACT

The genus *Allotropa* Förster 1856 (Hymenoptera: Platygastridae: Sceliotrachelinae) comprises a group of primary endoparasitoids known for their critical role in controlling mealybug populations. In this study, authors reported the discovery and description of a new species within this genus, reared from *Phaenacoccus manihoti* (Matile-Ferrero) collected in a cassava (*Manihot esculenta* Crantz) field in Kanchanaburi Province, Thailand. The collected mealybugs were reared in a laboratory setting, where the emergence of the parasitoid led to the identification of a previously undocumented species. This new species, *Allotropa suasaardi* Sarkar sp. nov. was distinguished by several unique morphological characteristics. The holotype female and allotype male exhibit unusual yellow body coloration, in contrast to the typically blackish appearance of other described *Allotropa* species. Additionally, the male is characterized by exceptionally long bristles on the antennomeres. Other defining features include reduced wing venation and distinct sculpturing of the mesosoma. This discovery not only expands to the known diversity within the genus *Allotropa* but also highlights the potential of this new species as a biological control agent for managing mealybug infestations in cassava crops, thereby enhancing our understanding of parasitoid biodiversity in Southeast Asia.

***Keywords*:** *Allotropa suasaardi*, new record, parasitoid, *Phaenacoccus manihoti*, unusual yellow body

INTRODUCTION

The genus *Allotropa* Förster 1856 (Hymenoptera: Platygastridae: Sceliotrachelinae) is globally distributed and primarily known as a group of primary endoparasitoids

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of mealybugs (Hemiptera: Pseudococcidae) (Masner and Huggert 1989, Vlug 1995). Taxonomic reviews by Masner and Huggert (1989), Vlug (1995), and subsequent revisions (Buhl 2002, 2019) have emphasized the diversity and ecological importance of this genus. However, knowledge remains fragmentary, especially in the Oriental region (van Noort 2021). Ecologically, *Allotropa* species play a vital role in the natural suppression of mealybug populations across a wide range of agroecosystems. For example, *Allotropa* sp., a gregarious endoparasitoid of the cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero, was found in Paraguay and Mato Grosso do Sul State of Brazil (Lohr *et al*. 1990). In East Asia, it is one of the most important native parasitoids of *Pseudococcus cryptus* Hempel in Japan as it can parasitize all the nymphal stages of the mealybug (Arai and Mishiro 2004). Such interactions underscore their potential in augmentative biological control programs. However, as emphasized by Ricciardi *et al*. (2021), taxonomic accuracy and host-specificity studies are crucial before parasitoids can be safely and effectively applied in pest management. *Allotropa* Förster in the subfamily Sceliotrachelinae of Platygastridae is distributed worldwide. The genus *Allotropa* Förster currently includes approximately 33 recognized species as of 2020, though taxonomic revisions are ongoing with new species periodically described from various regions (Masner and Huggert 1989, Vlug 1995, Buhl 2002, Veenakumari *et al*. 2013, Johnson 2020), including five species reported from the Nearctic region (Muesebeck 1979). Diversity is highest in North America, where at least 5 species have been recorded as of 2004, while Europe hosts a smaller number of species, such as 2 in the British Isles as of 2016 (Buhl *et al*. 2016). Most of these are primary endoparasitoids of various mealybugs However, many of these early descriptions were brief and lacked diagnostic illustrations or comparative morphology. As a result, most of the species have not been fully described or re-described in sufficient detail following modern taxonomic standards (Table 1), including revisions by Muesebeck (1954, 1970), Annecke and Prinsloo (1977), Masner *et al*. (2004), Asadi-Farfar *et al*. (2020), and van Noort (2021). This discrepancy highlights the need for further revisionary work and demonstrates that the genus remains incompletely characterized despite its global distribution.

Table 1. Thirty-three species of *Allotropa* Förster and their body color with references

Sl. No.	Name of the species	Body color	Reference
01.	*Allotropa*	Dark brown to black	Förster 1856
02.	*Allotropa mecrida*	Black	Walker 1835
03.	*Allotropa ashmeadi*	Blackish	Muesbeck 1939
04.	*Allotropa utilis*	Dark brown to shiny black	Gilliatt 1939
05.	*Allotropa convexifrons*	Yellowish brown to piceous	Muesebeck 1942
06.	*Allotropa burreli*	Black	Muesebeck 1942
07.	*Allotropa scutellata*	Black	Muesebeck 1954
08.	*Allotropa merrilli*	Black	Muesebeck 1954
09.	*Allotropa citri*	Black	Muesebeck 1954
10.	*Allotropa subclavata*	Black	Muesebeck 1970
11.	*Allotropa magnini*	Black	Risbec 1955a
12.	*Allotropa pauliani*	Black	Risbec 1955b
13	*Allotropa canopyana*	Black	Buhl 1995
14.	*Allotropa fusca*	Medium brown	Buhl 1995
15.	*Allotropa antennalis*	Blackish	Buhl 2001
16.	*Allotropa muesebecki*	Blackish	Bhul 2002
17.	*Allotropa pallidicornis*	Brown	Bhul 2002
18.	*Allotropa transversiceps*	Blackish	Bhul 2002
19.	*Allotropa musae*	Black	Buhl 2005
20.	*Allotropa fusca*	Dark brown	Bhul 2011
21.	*Allotropa delottococci*	Black	Bhul 2019
22.	*Allotropa japonica*	Black	Ashmead 1904, Mukerjee 1978
23.	*Allotropa loundsburyi*	Polished black	Ashmead 1901
24.	*Allotropa meridionalis*	Blackish	Brethes 1913
25.	*Allotropa kamburovi*	Black to dark	Annecke and Prinsloo 1977
26.	*Allotropa oracellae*	Black	Masner *et. al.* 2004
27.	*Allotropa phenacocca*	Black	Chen *et al.* 2011
28.	*Allotropa gundlupetensis*	Black	Veenakumari *et al*. 2013
29.	*Allotropa vanajae*	Black	Veenakumari *et al*. 2013
30.	*Allotropa nigra*	Black	Veenakumari *et al*. 2013
31.	*Allotropa conventus*	Dark / standard integument	Asadi-Farfar *et al*. 2020
32.	*Allotropa* sp.	Dark blackish	van Noort *et al*. 2021
33.	*Allotropa* sp.	Black	Kiran *et al*. 2024

However, the taxonomy and species identification within *Allotropa* remain challenging for females, as their antennal structures are often very similar across species. Females are difficult to distinguish due to conserved antennal structures and subtle morphological variation, whereas males are generally more diagnostic because of their diverse antennal modifications (Muesebeck 1954, Ricciardi *et al*. 2021). The subtle differences in the morphology, sculpture, and coloration of females require detailed study to develop reliable identification keys (Muesebeck 1954). The very small body size of these wasps (<1mm) and their morphological conservatism complicate species delimitation and hinder the development of reliable identification keys.

Recent advances in Platygastridae systematics have revealed substantial hidden diversity within Sceliotrachelinae. Awad *et al*. (2023) reviewed the Förster genera of Platygastridae through re-examination of type specimens and detailed comparative morphology, while Asadi-Farfar *et al*. (2020) documented new records of *Allotropa* and related sceliotracheline taxa from Iran, thereby exposing significant taxonomic gaps. Although molecular approaches are increasingly applied in Platygastridae to resolve cryptic taxa, morphology continues to serve as the foundation for species description, particularly in cases where molecular-grade material is unavailable. This reliance on detailed morphological analysis follows established precedents in sceliotracheline taxonomy (Kamalanathan *et al*. 2019).

Given the ecological and applied importance of *Allotropa* in regulating mealybug populations, there is a pressing need for regional surveys and species-level revisions. In Southeast Asia, particularly in cassava-based systems where *P. manihoti* has emerged as a major invasive pest, the diversity of *Allotropa* remains poorly documented. Here, authors describe a new species of *Allotropa* from Thailand, reared from *P. manihoti* infesting cassava (*Manihot esculenta* Crantz). This species exhibits distinctive morphological character states, including unique coloration and antennal structures, which justify its recognition as a novel taxon. The discovery contributes not only to the taxonomy of the genus but also to the potential deployment of native parasitoids in sustainable mealybug management programs.

MATERIAL AND METHODS

Field Collection: Specimens of the parasitoid *Allotropa* sp. were obtained from a cassava (*Manihot esculenta* Crantz) field naturally infested with cassava mealybug (*Phenacoccus manihoti* Matile-Ferrero) in Kanchanaburi Province, Western Thailand (14°00′15″ N, 99°32′57″ E). Kanchanaburi, the third-largest province of Thailand, is located ~130 km northwest of Bangkok and is characterized by tropical evergreen and mixed deciduous forest vegetation, which provides favorable habitats for cassava cultivation and associated pest–natural enemy complexes.

Sample handling and rearing: Cassava shoots and leaves heavily infested with *P. manihoti* were carefully excised from the field and placed into ventilated plastic containers to prevent condensation and fungal growth during transport. Samples were immediately transferred to the National Biological Control Research Center (NBCRC), Kasetsart University, Kamphaeng Saen Campus, Thailand. In the laboratory, infested plant material was maintained under controlled ambient conditions (25 ± 2 °C, 70 ± 10% RH, and natural photoperiod). The material was inspected daily under a stereomicroscope to record parasitoid emergence.

Parasitoid recovery and preservation: Emerging *Allotropa* specimens were aspirated daily and transferred into labeled glass vials. Specimens for morphological examination were preserved in 95% ethanol, while a subset was processed for slide mounting following standard entomological techniques (i.e., critical-point drying, mounting in Canada balsam or Hoyer’s medium), and later examined using a stereomicroscope and compound microscope equipped with an ocular micrometer. Voucher specimens were deposited in the insect collection of NBCRC, Kasetsart University, for future reference.

Morphological identification: The emerged parasitoid was identified based on external morphology, following the diagnostic keys of Masner and Huggert (1989) and Buhl (2019). Diagnostic characters examined included antennal segmentation, mesoscutal sculpture, scutellar structure, wing venation, and body coloration. High-resolution images were taken using a digital imaging system attached to the Olympus SZ61 stereo zoom and compound microscope. Scanning electron microscope photographs were taken with a, JEOL (JSM-6490LA) Analytical SEM and Morphological terminology followed Talamas *et al*. (2017). The following abbreviations are used: A1, A2 , . . . , A9: antennomeres 1, 2 , . . . , 9; T1, T2 , . . . , T7: metasomal tergites 1, 2 , . . . , 7.

Allotropa suasaardi Sarkar sp. nov. (Fig. 1a-r)

The parasitoid obtained from *P. manihoti* infesting cassava in Kanchanaburi Province, Thailand, was identified to represent a new species of *Allotropa* (Hymenoptera: Platygastridae: Sceliotrachelinae). Detailed morphological analysis revealed several unique character states distinguishing it from all congeners. Most notably, the new species exhibits bright yellow body coloration in both sexes, in contrast to the predominantly black to dark brown body color typical of described *Allotropa* species worldwide (Table 1, Vlug 1995, Buhl 2002, Masner *et al*. 2004). Such coloration is taxonomically significant as body color in *Allotropa* has proven to be stable within species and diagnostic across lineages.

A second diagnostic feature is the presence of exceptionally long bristles on the male antennomeres. These bristles, extending up to four times the length of the antennal segments in A3–A4, and twice as long on A5-A6, are unprecedented among described species (Fig. 1q-r). In most congeners, male antennae possess short, decumbent setae that are never longer than the segment itself (Muesebeck 1954, Buhl 2001, 2005). Together, the unique yellow body coloration and the extreme antennal bristle length in males establish robust diagnostic characters justifying the recognition of this taxon as a new species.

Additional characters that reinforce the distinctiveness of this species include; Reduced forewing venation, with only a sub-marginal vein present and bearing crenulae along its posterior margin. A finely sculptured meso-scutum with posteromedial smoothening, combined with a rugulose scutellum. A slender and elongated metasoma with distinct furrows on T1 and striated basal foveae on T2 (Fig. 1f-h). These features conform to the generic concept of *Allotropa* (Masner and Huggert 1989, Vlug 1995), yet differ markedly in their specific expression relative to other species described from the Oriental and Afrotropical regions (Annecke and Prinsloo 1977, van Noort 2021)

In the present paper one species is described; that can be separated from the other species by use of the key below. The key is based on the descriptions in Ashmed (1901, 1904), Brethes (1913), Kleffer (1926), Muesebeck (1939, 1942, 1954), Bhul (2002, 2005), Masner (2004), Chen (2011), Veenakumari (2013), van Noort (2021) and Kiran (2024).

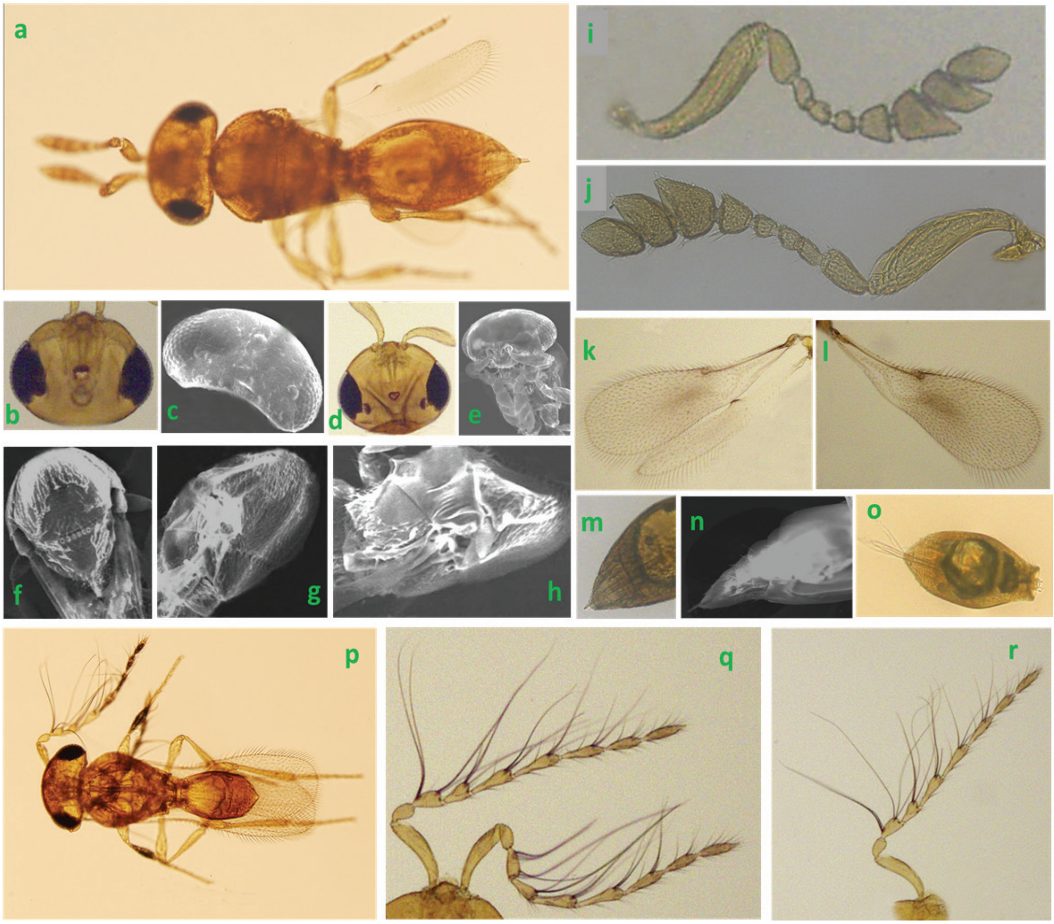

Fig. 1. Morphological features of *Allotropa suasaardi* Sarkar **sp. nov.** a) Adult female; b) Head, dorsal view (female, stereo zoom microscope); c) Head, dorsal view (female, scanning electron micrograph, SEM); d) Head, frontal view (female, compound microscope); e) Head, frontal view (female, SEM); f) Mesosoma, dorsal view (female, SEM); g) Mesosoma, lateral view (female, SEM); h) Mesosoma, ventral view (female, SEM); i) Antenna (female); j) Antennomeres showing hair (female); k) Fore and hind wings; l) Fore wing; m) Ovipositor (stereo zoom microscope); n) Ovipositor (SEM); o) Ovipositor sheaths; p) Adult male; q) Antennae, both (male); r) Ditto, single (male).

Key to World species *of Allotropa*

1. Body yellow; frons is highly polished (Fig. 1a) .... *A. suasaardi* **sp. nov.**
- Body black; frons is not polished 2
2. Antenna short, with 3-segmented club, with only short hairs (females) 3
- Antenna long, filiform, with long hairs (males) 12
3. Scutellum smooth and shiny 4
- Scutellum at least sculptured lateraliy 7
4. Scutellum strongly convex (USA) .... *A. burrelli* Muesebeck 1942
- Scutellum rather flat 5
5. Frons smooth (USA) .... *A. convexifrons* Muesebeck 1942
- Frons at least partly sculptured 6
6. A3 about 1.75 x as long as wide (China, introduced to USA) .... *A. citri* Muesebeck 1954
- A3 about 1.33 x as long as wide (Panama) .... *A. muesebecki* Bhul 2002
7. A3 fully twice as long as wide 8
- A3 hardly twice as long as wide 11
8. Scutellum medially smooth (Canada) .... *A. utilis* Muesebeck 1939
- Scutellum sculptured all over 9
9. Frons mostly smooth (Brazil) .... *A. scutellata* Muesebeck 1954
- Frons coriaceous except a small median area 10
10. Mesoscutum somewhat shiny; scutellum rather flat (USA) ...... *A. ashmeadi* Muesebeck 1939
- Mesoscutum dull; scutellum convex (USA) .... *A. merrilli* Muesebeck 1954
11. Basal flagellar Segments relatively slender; legs pale yellow (Panama) .... *A. pallidicornis* Bhul 2002
- Basal flagellar Segments relatively short; legs partly brownish (Panama) .... *A. transversiceps* Bhul 2002
12. Preapical antennal Segments hardly longer than wide .... *A. burrelli* Muesebeck 1942
- Preapical antennal Segments distinctly longer than wide 13
13. Scutellum entirely or partly smooth 14
- Scutellum sculptured all over 17
14. Hairs of basal flagellar Segments about 5 x as long as length of Segments .... *A. convexifrons* Muesebeck 1942
- Hairs of basal flagellar Segments at most about 2 x as long as length of Segments 15

15. Hairs of basal flagellar Segments about 2 x as long as length of Segments; A8 about 4x as long as wide .... *A. muesebecki* Bhul 2002
- Hairs of basal flagellar Segments less than twice as long as length of Segments; A8 at most about 3 x as long as wide 16
16. Scutellum entirely smooth .... *A. citri* Muesebeck 1954
- Scutellum reticulate laterally .... *A. utilis* Muesebeck 1939
17. Hairs of basal flagellar Segments less than twice as long as length of Segments 18
- Hairs of basal flagellar Segments at least twice as long as length of Segments 19
18. Body length 0.6 mm .... *A. ashmeadi* Muesebeck 1939
- Body length 0.95 mm (Brazil) .... *A. meridionalis* Brethes 1913
19. Legs pale yellow; scutellum hardly convex .... *A. pallidicornis* Bhul 2002
- Legs brown; scutellum slightly convex .... *A. musae* Bhul 2005
- Legs darker; scutellum convex 20
20. Frons mostly smooth; legs brownish yellow .... *A. scutellata* Muesebeck 1954
- Frons coriaceous except a small median area; legs piceous .... *A. merrilli* Muesebeck 1954
21. Legs brown or brown-black; abdomen conically pointed; thorax united .... *A. loundsburyi* Ashmed 1901
- Legs yellowish; abdomen smooth; thorax longitudinally striate .... *A. japonica* Ashmed 1904
22. Body length 0.935mm; metasoma shining brown to black except orangish T1; mesosoma slightly convex anteriorly .... *A. gundlupetensis* Veenakumari 2013
- Body length 0.819 mm; metasoma brownish black except brownish T1........................... 23
23. Mesosoma flattened.. *A. vanajae* Veenakumari 2013
- Mesosoma anteriorly convex; body length 0.901 mm; metasoma black except T1 .... *A. nigra* Veenakumari 2013
24. Body length 0.96 mm; wings membranous; fore wing 2.37 x as long as wide .... *A. phenacocca* Chen 2011
- Body length 0.8 mm; wings hyaline; fore wing 2.3 x as long as wide .... *A. phenacocca* Kiran 2024
25. Subellipsoidal transverse; metasoma distinctly elongate .... *A. oracellae* Masner 2004
- Subellipsoidal lens-like; metasoma lateral edge indistinct .... *Allotropa* species van Noort 2021

Description

Holotype (Female): The body length ranges from 0.65-0.70mm. The entire body, including the head, antennae, and legs, is yellow (Fig. 1a). The head, when viewed dorsally, is slightly wider than the thorax with a concave posterior margin and a harshly convex anterior margin. The head is wider than high in anterior view, with a distinct but somewhat effaced hyperoccipital carina. The lateral ocelli are widely separated and nearly touch the inner orbit of the eye. The frons is highly polished with a narrow transverse strip above the antennae insertion and finely reticulate areas adjacent to the eyes. The antennal sockets are close to the mouth margin, separated by a narrow interscrobal prominence (Fig. 1b-e). The antennomeres (A1-A9) are dissimilar in proportion, with A1 being the longest, followed by A2 and A3. A7 and A8 are distinctly elongated and pointed, with tiny setae on both sides (Fig. 1i-j).

Mesosoma: In dorsal view, it is slightly narrower than the head. The pronotum is barely visible and overlaps the mesoscutum laterally. The mesoscutum exhibits dense coriaceous microsculpture that smoothens posteromedially. The scutellum is finely rugulose, slightly convex, and separated from the mesoscutum by a foveolate furrow. The pronotum sides are covered with coriaceous sculpture, while the mesopleuron is smooth and hairless, with some wrinkles. The mesopleural depression is distinct, and the metapleuron shows irregular coriaceous sculpture with a distinct hairy propodeum (Fig. 1f-h).

Wings: The forewing exhibits reduced venation, is slightly curved, and faintly infuscated. The submarginal vein is strong, with a single long seta beyond the middle, and the hind edge of the submarginal vein has distinct crenulae from near the base to near the apex. The apex of the venation is clavate, with setation present in the wing disc, and a strong marginal fringe. The hind wing is narrow with a rounded apex, sparsely setose in the apical two-thirds, and devoid of setae in the basal part (Fig. 1k-l).

Metasoma: The metasoma is distinctly elongated. T1 has longitudinal furrows, T2 has two slightly striated basal foveae, and T3-T5 are short with sparse hairs. T6 is largely triangular, wider than long, sharply pointed apically, and slightly longer than the mesosoma. The ovipositor assembly is extended and protected by a pair of ovipositor sheaths (Fig. 1m-o).

Allotype (Male): The body length ranges from 0.59-0.64 mm, distinctly shorter than the female (Fig. 1p). The male resembles the female closely but differs primarily in the structure of the antenna. The antennomeres (A1-A9) are dissimilar, with A1 being the longest, followed by A5-A9. The funicle segments are plainly longer than wide and subequal in size. A3-A9 have long upright bristles, with the hairs on A3-A4 being about four times as long as the segment, while A5-A6 have hairs about twice as long as the antennomeres. In A7, the hair is shorter than in A3-A6, and A8-A9 have distinctly shorter bristles than the other antennomeres (Fig. 1q-r).

Etymology: The new species is named *Allotropa suasaardi* Sarkar **sp. nov.** in honor of the collectors (Wiwat Suasa-ard & Md. Akhataruzzaman Sarkar) of the material, recognizing their contribution to parasitoid biodiversity research in Thailand.

Host, Biology, and Distribution: *Allotropa suasaardi* Sarkar **sp. nov.** was obtained from *P. manihoti* infesting cassava in Kanchanaburi. The mealybugs were pinkish in coloration. Based on rearing, *A. suasaardi* Sarkar sp. nov. appears to be a primary, possibly gregarious, endoparasitoid (multiple individuals sometimes emerge from a single host). No hyperparasitoids were detected in this system during the rearing period. Geographic distribution is currently known only from the type locality in western Thailand.

Comparison with Closely Related Species: The yellow coloration and the long bristles on the male antennae, traits, distinguish *A. suasaardi* Sarkar **sp. nov.** as new species from previously described species such as *A. burrelli, A. delottococci*, and *A. phenacocca*. For example, *A. phenacocca* described from China parasitizing *Phenacoccus solenopsis* has darker integumentation and more conventional antennal setation (Chen *et al*. 2011). *A. delottococci* from South Africa also carries a darker body and differing meso-scutal sculpture (Buhl 2019). Further, molecular data (DNA barcoding) should be sought to confirm phylogenetic placement and divergence from known species (as in recent *Allotropa* studies from India) (Kiran *et al*. 2023).

Significance of the Newly Identified Parasitoid: The discovery of *A. suasaardi*

Sarkar **sp. nov.** expands the known diversity of *Allotropa* in Southeast Asia and provides a candidate for further evaluation as a biocontrol agent against *P. manihoti* on cassava. The remarkable yellow coloration is unusual in the genus and merits reconsideration of coloration as a diagnostic character in *Allotropa*. It is essential to complement morphological taxonomy with molecular data. Recent integrative studies of *Allotropa* lineages from India have applied both morphological diagnosis and molecular markers to refine species delimitation (Kiran *et al*. 2023). Such an approach could help verify whether *A. suasaardi* Sarkar sp. nov. is indeed distinct and to elucidate its phylogenetic affinities. From a biological control perspective, pre-release host range testing under no-choice and choice assays should be conducted (akin to those done for *A. burrelli*) to evaluate non-target risk (Quaglietti *et al*. 2017). Additionally, life-history parameters (development time, fecundity, host-stage preference) must be determined in controlled experiments to assess its suitability. Furthermore, interactions with existing parasitoids, possible hyperparasitoids, and environmental compatibility need evaluation.

Given the prevalence of mealybugs in cassava cropping systems and the limitations of chemical control, novel native parasitoids such as *A. suasaardi* Sarkar **sp. nov.**, could contribute to integrated pest management (IPM) in Southeast Asia. Finally, further field surveys in Thailand and neighboring countries may reveal a broader distribution or additional species of *Allotropa* in cassava ecosystems.

CONCLUSION

Authors formally describe *Allotropa suasaardi* Sarkar **sp. nov.**, (Platygastridae) as a new endoparasitoid species associated with *P. manihoti* in Thailand. Key distinguishing features include yellow body pigmentation and extremely elongate antennal setae in males. This addition to *Allotropa* enhances regional taxonomic knowledge and suggests potential for exploitation in the biological control of cassava mealybugs. Additional molecular, ecological, and parasitism-performance studies were recommended to validate its utility in IPM frameworks.

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