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

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Research article

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LIFE HISTORY AND MORPHOLOGICAL DESCRIPTION OF *CYCLOSIA PAPILIONARIS* (DRURY) (LEPIDOPTERA: ZYGAENIDAE) MOTH: A SERIOUS PEST OF LOTKON IN BANGLADESH

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ABSTRACT

Cyclosia papilionaris (Durry 1773) is commonly known as the Drury Jewel moth. The larvae of this moth defoliate the delicate leaves of young trees and nursery plants of lotkon fruit (Burmese grape). There is a lack of sufficient biological information regarding the management of this pest. The aim of this study is to observe and record the developmental stages information (egg to adult) with descriptive images, including feeding behaviour and nature of damage. The biology of the moth was studied in laboratory conditions on their host plants. The study was carried out at a temperature of 27.61°C ± 3.85 and 69% ± 4.58 relative humidity. The female deposited eggs in clusters, and each cluster contains a maximum of 68 eggs and a minimum of 18 eggs with the mean of 36. The total larval period (1st instar to 4th instar) was 20.09± 1.61 days, and the pupal period was 28.09± 6.56 days. The pupal cocoon was constructed using a plastic substrate combined with leaves, thus offering substantial support for the laboratory rearing method. The female moth lived longer, 17.82± 2.48 days, than the male moth, 5.73± 0.65 days. The results of this study are expected to provide valuable support for managing this pest in an agroecosystem.

Keywords: Morphology, Drury Jewel moth, Lepidoptera, Zygaenidae, Lotkon

INTRODUCTION

Cyclosia papilionaris is commonly known as the Drury Jewel moth, which was described by Dru Drury in 1773. This moth belongs to the family Zygaenidae, and

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order Lepidoptera. *Cyclosia papilionaris* has eight subspecies, which are distributed throughout South-east Asia and also reported from the Andaman and Nicobar Islands, India (Leong 2012). The habitat is made up of humid deciduous forests and rainforests, and the moth is typically active during the day and can coexist with other diurnal insects, particularly with butterflies (Gardner *et al*. 2009, Endo and Kishida 1999). Adult moths consume pollen and nectar, and larvae feed on the young leaves of the host plant. The primary host plant is *Baccaurea ramiflora* (Robinson *et al*. 2011), but they also feed on the leaves of *Baccaurea sapida* and *Aporusa dioica* (Baksha 2008). However, it is a major and serious defoliator of the young *Baccaurea ramiflora* plants in Bangladesh (Islam *et al*. 2012, Baksha 2008). *Baccaurea ramiflora*, commonly known as the Burmese grape, belongs to the Phyllanthaceae family. The Burmese grape is known locally as lotkon in Bangladesh, and growing in Bangladesh, Thailand, Peninsular Malaysia, and several parts of South-east Asia (Rahman *et al*. 2014). It is estimated that approximately 1,890 hectares of land are used to cultivate this fruit in Bangladesh (Hossain *et al*. 2017, Rahman *et al*. 2014). Following satisfying the domestic demand, local growers generate foreign currency through the export of this fruit (Islam *et al*. 2012). Burmese grapes are naturally rich with many bioactive compounds and have nutritional benefits (Paul *et al*. 2020, Pradhan *et al*. 2015, Francesca *et al*. 2012, Kermasha *et al*. 1987b). The nursery plants and young trees are severely attacked by the larvae of the *Cyclosia papilionaris* moth. As a result, there is poor growth of the trees and low yield of fruit production (Islam *et al*. 2012). The biological information is very scarce regarding the management of this pest. The studied literature and website-based information demanded the detailed biological information about the *Cyclosia papilionaris* moth in the recent emergence and invasion of lotkon trees. The majority of the literature and website-based information are sporadic, lacks description of developmental stages, and does not identify distinct growth stages, i.e., egg, specific larval instar, prepupae, and pupa characteristics. Although Islam *et al*. (2012) studied the biology and management of this pest in Bangladesh, they could not provide precise identification of embryonic stages with detailed descriptions. However, biological data is crucial for tracking and managing the pest in the agroecosystem, including life cycle, behaviour, ecology, pest aggregation, and number of generations. This research aims to study different aspects of biology in detail with descriptive images, including feeding behaviour and the nature of damage, which would provide good support for controlling this pest in agriculture sectors.

MATERIALS AND METHODS

Experimental site: The study was conducted in the Laboratory of Radiation Entomology and Acarology Division, Institute of Food and Radiation Biology (IFRB), Atomic Energy Research Establishment (AERE), Savar, which is located at 23°51′30″N and 90°16′00″E with an altitude of 15 m above sea level. This research was carried out from May 2019 to November 2019, October 2020 to December 2020, and September 2022 to November 2022, subsequently.

Larvae collection and rearing: To investigate the biology under laboratory conditions, larvae of *Cyclosia papilionaris* were collected from the host plant and kept in a rearing cage (44 cm × 38 cm × 38 cm) covered with net. The larvae were fed with host plant (*Baccaurea ramiflora*) leaves that are kept fresh by placing the moist piece of cotton around the cut tip and wrapped with aluminium foil. The leaves were changed at an interval of 12 hours during the rearing period. Larvae were grown up to adult emergence and sexual maturity under the laboratory conditions. Adults were given access to a 10% sugar solution on small cotton balls. Larvae were reared in a cooled incubator (VS-3250BipC-L, KTR Europe GmbH, Vision Scientific Co., Ltd., made in Korea).

Oviposition: For oviposition, males and females (1:2 ratios of male and female) were placed inside the cylindrical tubes (radius 4.5 cm and height 10 cm) that were made from hard paper and a paper sheet was placed at the bottom of the tube where young tender leaves of host plant were given for oviposition (Fig. 1a). Female moths laid eggs around the tube and on a paper sheet. Eggs were collected from tubes and paper sheets, and maintained in a plastic container (26 cm × 17 cm × 7 cm) for hatching.

Morphometric measurements: Morphometric measurement analysis of different life stages and different body parts was carried out by taking 4-10 replications of each stage, viz., egg stage, larval stages (first to fourth instar), pupal stage, and adult stage linearly. The larval instar, pupal stage duration, and life span of the adult moths were observed daily and recorded. The length and width were measured using a Vernier calliper (Mitutoyo, Model 500-196-20, Japan), while the weight was measured using an electronic balance (HT224RCEN, Shinko Co., Ltd., made in Japan). In addition to the above parameters, colour, shape, size, moulting, and feeding behaviour, and nature of damage were also recorded.

Temperature and humidity maintenance: The entire experiment was maintained at an average temperature of 27.61 °C ±3.85 with an average 69% ±4.58 relative humidity (RH) and a light: dark ratio (L:D) of 14:10. The RH and temperature were maintained by using a digital Max-Min Thermo Hygro and Clock (Zeal).

RESULTS AND DISCUSSION

Eggs: Eggs are laid by egg laying apparatus (Fig. 1a). Eggs are oval and light yellow (Fig. 1b & 1c), and the size was 1.16± 0.09 mm in length, and 0.19± 0.01 mm in breadth (Table 1), and they were laid in clusters (Fig. 1b) that contain a maximum of 68 eggs and a minimum 18 with a mean of 36. Islam *et al.* (2012) found light brown colour eggs, and 6–8 eggs in each cluster, which differs from present finding. Moreover, in captive breeding females showed more interest in depositing their eggs in a white paper sheet and tube wall than host plant leaves. In our present observation, eggs did not hatch under laboratory conditions. Though rearing was maintained for three years, eggs did not hatch despite adopting many strategies for hatching. However, this moth species deposited eggs four times in her lifespan, and the ovipositional pattern is shown in Fig. 2. Larvae: The *Cyclosia papilionaris* moth has four larval instars. The first instar larvae appearance is totally different from the others three instar larvae. The newly hatched larvae are covered with a hairy spine structure and is grey-black in colour. After 1-2 days later, a yellow-coloured circle band appear on the middle of the body and the before the abdominal end (Fig. 3a). The newly hatched larvae keep it up for 3.68± 0.33 days (Table 2). First-instar larvae had a body length of 4.6±1.17 mm, a breadth of 2.03± 0.09 mm, and a

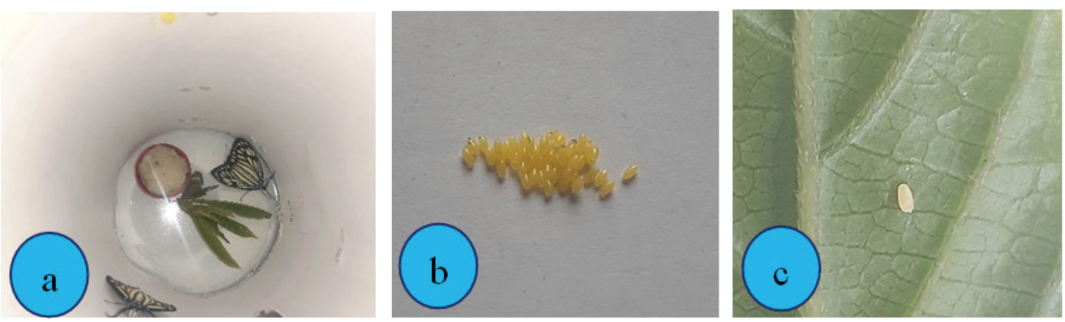

Fig. 1. Oviposited eggs of *Cyclosia papilionaris*; a. egg laying apparatus, b. oviposited eggs in cluster and c. single egg.

weight of 15.15± 1.71mg (Table 1). The size of the larvae in the second, third, and fourth instars appeared to be too similar, with the exception of the body length, body parts, and protrusion (spine and stalk) size. In the beginning, the body colour is pale blue, but as they mature, they turned in to blackish hue before pupa formation. The larvae have a black head with black mandible and hairy structure present in front of the head and around the body. The nipple-like stalks (tubercles) present on the dorsal and lateral surfaces of the body, which are brilliant yellow and red in colour. Each thoracic (T1 to T3) and abdominal (A1 to A9) segment bears six stalks, where segments T1 and T2 had yellow stalks, but T3 bears a pair red stalk. The abdominal segments A1 and A2 exhibited a pair of red stalks, while other segments (A3 to A9) had yellow stalks. And all stalks were encircled by a yellow ring at its base (Figs. 3b, 3c & 3d). Similar works were done on another nearest species *Cyclosia sordidus* by Leong (2012). The second and third instar larvae extended 4.04± 0.47 days and 5.10±0.58 days. The fourth instar larvae hang around for 7.27± 1.01 days. The total period of larvae (first-fourth instar) was 20.09± 1.61 days (Table 2). The body length of second-instar instar larvae was 11.3± 2.22 mm, breadth was 4.00± 0.82 mm, and weight was 54.95± 22.63 mg. The third instar was measured 15.85 ± 1.35 mm in length, 5.70 ± 0.54 mm in breadth, and 198.43 ± 63.82 mg in weight. The fourth instar larvae were 23.0± 2.58 mm in length, 6.78± 0.816 mm in breadth, and 619.44± 171.13 mg in weight (Table 1).

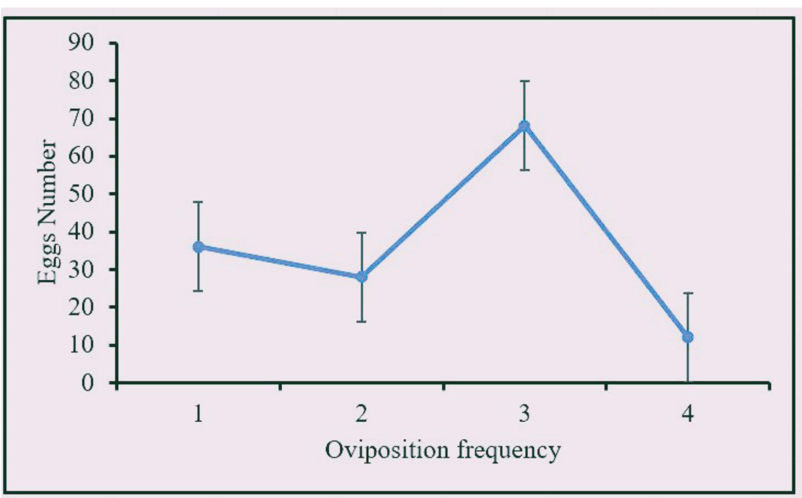

Fig. 2. Ovipositional pattern of *Cyclosia papilionaris*.

Table 1. Morphometric data of egg and larvae stages of *Cyclosia papilionaris* moth

Developmental stages (n=10)	Size		
	Length (mm)	Width (mm)	Weight (mg)
Egg	1.16± (0.09)	0.19± (0.01)	-
I- instar	4.6± (1.17)	2.03± (0.09)	15.15± (1.71)
II-instar	11.3± (2.22)	4.00± (0.82)	54.95± (22.63)
III- instar	15.85± (1.35)	5.70± (0.54)	198.43± (63.82)
IV-instar	23.0± (2.58)	6.00± (0.816)	619.44± (171.13)

Table 2. Developmental period of *Cyclosia papilionaris* moth

Developmental stages (n=10)		Duration (Days)		
Minimum		Maximum	Mean±Sd	
Larval period	I- instar	3.0	4.0	3.68± (0.33)
	II-instar	3.0	4.5	4.04± (0.47)
	III- instar	4.0	6.0	5.10± (0.58)
	IV-instar	6.0	9.0	7.27± (1.01)
Total larval period		16.0	23.0	20.09± (1.61)
Pupa period		20.0	42.0	28.09± (6.56)
Male Longevity		5.0	7.0	5.73± (0.65)
Female Longevity		14.0	22.0	17.82± (2.48)

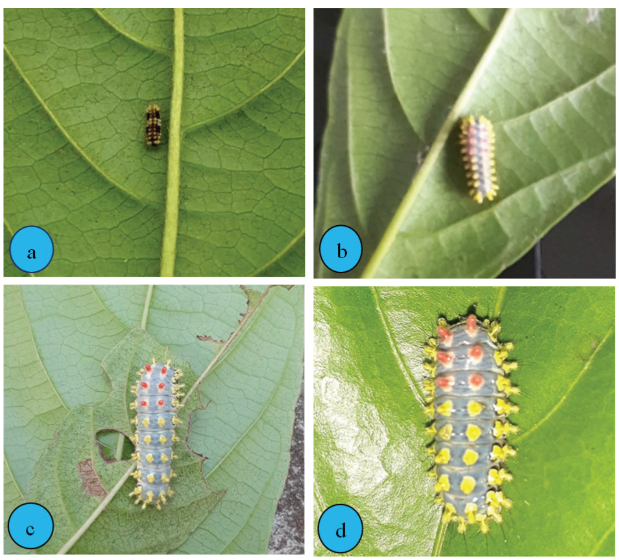

Fig. 3. Larval instar of *Cyclosia papilionaris*; a. 1st instar, b. 2nd instar, c. 3rd instar and d. 4th instar.

Pupa formation: At the end of the final instar, larvae turn blackish in colour, stop feeding, and become sluggish before pupae formation (Fig. 4a). Pupa form within a cocoon. Many moths, caterpillars, and other holometabolous insect larvae spin silk to form cocoons, which serve as protective coverings for the pupa (Darby 1958). They made cocoon on the ventral surface of the leaves that wrapped in silk covering (Fig. 4b). Butterflies and moths can make cocoons on the underside of leaves, in cracks, close to the base of tree trunks, hanging from twigs, or hidden in leaf litter (Scoble 1992). Islam *et al*. (2012), and Leong (2012) reported similar observations for pupa formation in *Cyclosia papilionaris* species. In this study, it was found that they were able to build cocoons by using plastic substrate, which will provide good support for laboratory rearing (Fig. 4d). Cocoon could make individually or in combination in host plant leaves (Figs. 4b & 4c). Pupal cocoon length was 24.36 ± 4.61 mm (Table 3). Prepupae is the first stage of the pupal life cycle, they are

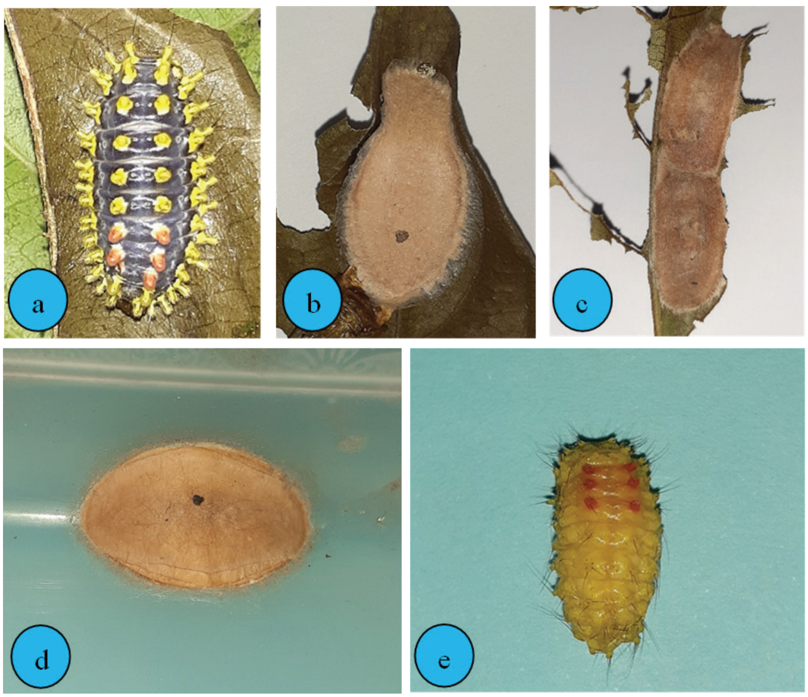

Fig. 4. Pupa formation process of *Cyclosia papilionaris*; a. Non feeding stage of larvae before pupa formation, b. single cocoon, c. combined cocoon, d. cocoon on plastic substrate and e. prepupae.

orange, and all the larva characteristics disappeared in this stage (Fig. 4e), and the length was 11.60± 0.49 mm an average (Table 3).

Pupa characteristics: Pupa is a stage of life that occurs between the larval and adult phases and develops all kinds of organs in this stage through the complete metamorphosis (Borror *et al*. 2004). Male pupae are black-brown in colour and slender in shape (Figs. 5a & 5b). Female pupae are apparent to be chubby and light brown in colour (Fig. 5c & 5d). Female pupa is larger than the male pupa. Male pupae in several species are often smaller than female pupae (Carvalho *et al*. 2014). Male pupae are black and have rounded knob (Fig. 5a), whereas females pupa opening knob are brown in colour (Fig. 5c). According to Walt *et al*. (2008), female pupae have a noticeable longitudinal suture on the ventral side of the eighth and ninth abdominal segments, while male pupae have a brief slit on the ventral side of the ninth abdominal segment, frequently encircled by tiny, rounded knobs. Carvalho *et al*. (2014) illustrated that genital lobe shape could be reliable identification of male and female pupae in *Aedes aegypti* mosquitos. Pupal duration was 28.09± 6.56 days (Table 2). The length of female pupa was 16.10± 0.70 mm and male pupa was 12.12± 0.85 mm (Table 3).

Adults moth characteristics: Sexual dimorphism is prevalent and easy to identify based on the adult coloration and ornamentation. Males and females both have pectinate antennae. Male is pale brown with white spots on fore and hind wings (Fig. 6a). Female is also pale brown in colour with white spots on fore and hind wings (Fig.6b). Males have less wing spots than females. In comparison to male, female is longer than male in fore and hind wing, antennae, and body length (Fig. 7). The characteristics of the adult moth are similar to those observed by Islam *et al*.

Table 3. Length of prepupa, pupa and pupal cocoon of *Cyclosia papilionaris* moth

Developmental stages	Length (mm)		
	Minimum	Maximum	Mean± Sd
Pre pupa (n=5)	11.0	12.0	11.60±0.49
Female pupa (n=4)	15.0	17.0	16.10±0.70
Male pupa (n=4)	11.0	13.0	12.12±0.85
Pupal cocoon (n=11)	16.0	35.0	24.36±4.61

Fig. 5. Pupa of *Cyclosia papilionaris*; a-b. ventral and dorsal view of male Pupa, c-d. ventral and dorsal view of female pupa.

Fig. 6. Adult of *Cyclosia papilionaris*; a. male, b. female.

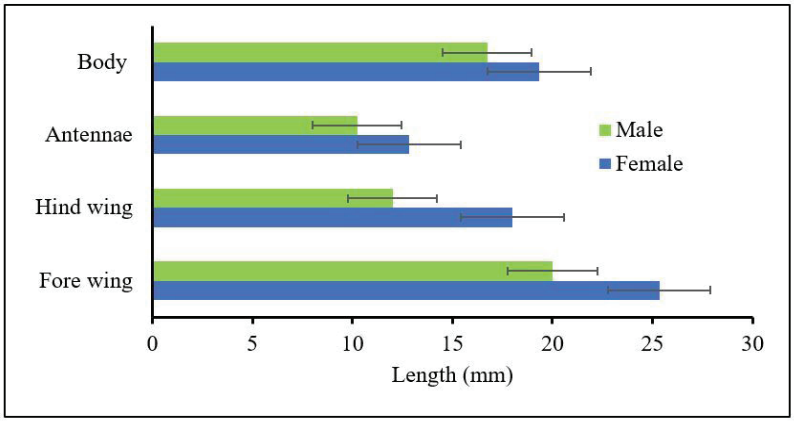

Fig. 7. Comparison of body parts length of male and female of *Cyclosia papilionaris*.

(2012), Rahman and Hossain (1985), and Beeson (1941). The male lived for 5.73± 0.65 days, while the female lived for 17.82± 2.48 days, respectively (Table 2).

Feeding behaviour: The larvae of *Cyclosia papilionaris* preferred the host plant of *Baccaurea ramiflora*. There have been previous reports of at least four different species of *Cyclosia* sp. using the genus *Baccaurea* (Phyllanthaceae) as a preferred larval host plant. These include: (i) *Cyclosia macularia* on *Baccaurea motleyana* and *Baccaurea racemosa*, (ii) *Cyclosia nivipetens* on *Baccaurea motleyana*, (iii) *Cyclosia panthona* on *Baccaurea ramiflora*, and (iv) *Cyclosia papilionaris* on *Baccaurea ramiflora* (Robinson *et al*. 2011). Larvae of the first instar made longitudinal and circular holes, and consumed the soft portion of delicate leaves without consuming veins (Fig. 8a). Second instar larvae feed the young leaves of the host plants by creating a circle or ring and also feed edge of the tender leaves (Fig. 8b). First and second instar larvae did not eat the midribs and veins in the early stages of their development. The first and second instar caterpillars spent more time searching their plant leaves and also spent more time resting. Third and fourth instar larvae prefer to consume the mature leaves of the host plant (Fig. 8c). At the end of the third instar, larvae turn into voracious feeders. The centre and edge of the leaf feeding were begun. Larvae were more voracious in their fourth or final instar (Fig. 8d). The third and fourth instar caterpillars spent less time searching for selecting plant leaves and also spent more time resting. Johnson and Zalucki (2007) discovered that different instar larvae of *Helicoverpa armigera* have distinct eating behaviours, including

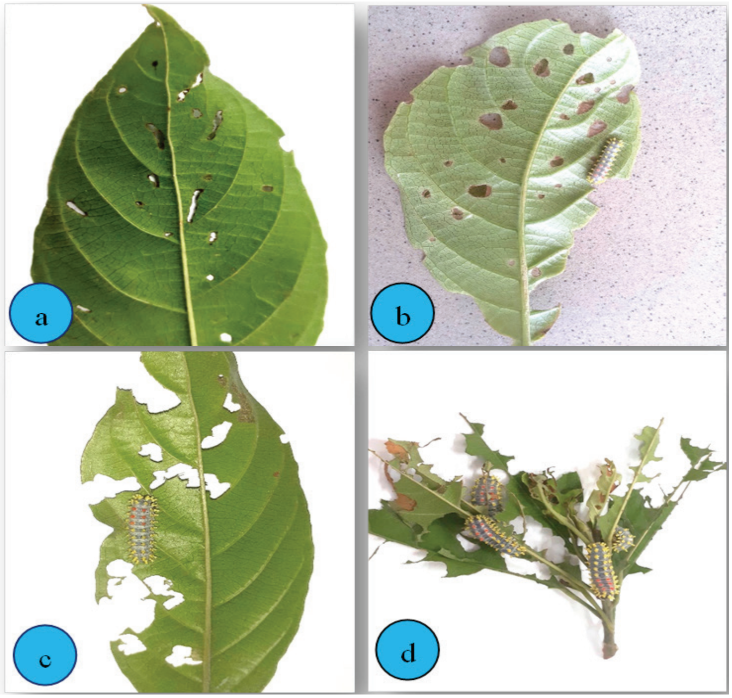

Fig. 8. Feeding behaviour of *Cyclosia papilionaris* caterpillar; a. First instar feeding, b. Second instar feeding, c. Third instar feeding and d. Fourth instar feeding.

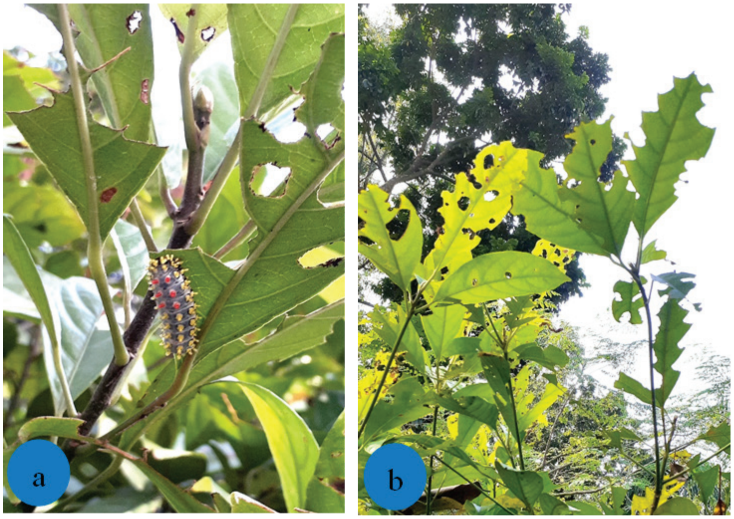

Fig. 9. Damage caused by *Cyclosia papilionaris* caterpillar; a. Fourth instar caterpillar feed the leaf margin and proceeds inward, b. Caterpillars feed the leaves and eventually turned into yellow.

searching, feeding, and resting. According to them, third-instar larvae prefer to feed on exposed plant leaf sections and spend less time resting and foraging, and the first instar larvae are choosy to select plant leaves and spend more time for searching and resting. Islam *et al*. (2018, 2019) found that caterpillars of the butterfly *Papilio polytes* and *Papilio demoleus* showed comparable feeding habits.

Nature of damage: It is observed that larvae of the *Cyclosia papilionaris* moth in the beginning of May. The peak infestation was found in July and August. It is observed 2-3 generations per year. The last generation was completed from September to October. Young trees with severe infestations lose all of their leaves except the midribs, which results in the defoliation of the trees (Fig. 9a). Leaves that are severely impacted wither and drop to the ground. Although the trees are not destroyed, there are unquantifiable effects on their growth and fruit production (Fig. 9b). Similar plant damage caused by the *Cyclosia papailionaris* caterpillar was observed by Islam *et al*. (2012). Islam *et al*. (2012) also observed adults appearing in May, abundance of larvae in June, peak infestation in July and August, and three generations per year, which is more or less similar to the present study.

CONCLUSION

The lotkon fruit cultivation is expanding day by day in Bangladesh. Regarding the pest and disease management of this fruit, the details of the life history and their ecology of *the Cyclosia papilionaris* moth are very essential for lotkon growers to take timely action. Biological data is crucial for tracking and managing pest species in the agroecosystem. The present findings on the biology of *Cyclosia papilionaris* would be important to develop proper management strategies to control this pest.

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EVALUATION OF DIFFERENT IPM PACKAGES USED AGAINST LEAF BEETLE, *CEROTOMA TRIFURCATA* (COLEOPTERA: CHRYSOMELIDAE) OF FRENCH BEAN

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ABSTRACT

Experiment was carried out to evaluate the effectiveness of four IPM packages and an untreated control against leaf beetle of French bean. Results revealed that the lowest number of plant infestation by leaf beetle and the highest per cent (82.88%) of plant infestation reduction over control was found in package 1 (Yellow sticky trap + Bioneem plus) treated plots at 38, 48 and 58 days after sowing (DAS). The lowest mean number of leaf beetle (1.05/Plant) and the highest percentage of leaf beetle population reduction (79.00%) over control were recorded from package 1. The lowest percent leaf area damaged (2.19%) and the highest percentage (90.45%) of leaf area damage reduction over control was found in package 1 treated plots. There was a strong negative correlation of total yield with number of leaf beetle, percent plant infestation and percent leaf area damage package 1 comprising yellow sticky trap + Bioneem plus 1% EC @ 1ml/1litre of water was found to be the best integrated management package for the management of leaf beetle and produced maximum fresh pod yield (15180.50 kg/ha) and highest percent yield increase over control of French bean while the second highest (21.02) MBCR was obtained by adopting the package 1. Though the highest (33.91) MBCR was obtained by adopting the IPM package 3 but IPM package 1 could be the best package for the management of leaf beetle as eco-friendly package.

Keywords: French bean, insecticides, IPM package, leaf beetle, yellow sticky trap

INTRODUCTION

The French bean, *Phaseolus vulgaris* (Linnaeus) is a photo insensitive and self-pollinated vegetable crops belong to the Fabaceae (formerly Leguminosae) family

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derived from a wild species. The French bean is synonymies as bush bean, kidney bean, snap bean, pinto bean, green bean, raj bean, common bean, basic bean, haricot bean, navy bean, pole bean, wax bean, string bean and bonchi in different parts of the world (Salukhe *et al*. 1987). In Bangladesh, the crop is known in different names in different locations such as in Sylhet it is known as Farashi Ori and Farashi Choi in Chittagong and Jharshim in most part of the country. French bean is the second largest legume producing vegetable in the world (Rashid 1999). It is an important food in most tropical and subtropical countries of the world and is second to cereals as a food source for humans and animals (Graham and Vance 2003). It is a dual purpose crop grown as pulse and also consumed as immature tender fruits. The French bean is highly nutritious and provides one of the most important sources of protein (Arulbalachandran and Mullainathan 2009) and is rich in vitamins, minerals and dietary fibre (Ndegwa *et al*. 2006). French bean is an important source of several essential micronutrients for both men and domestic animals. Yield potential of French bean is generally very low due to lack of high yielding varieties, poor production technology, including optimum date of sowing and spacing, poor fertility and irrigation management (Saini and Negi 1998). Worldwide, yield losses due to insect pests alone have been estimated to be from 35% to 100% annually (Singh and Schwartz 2011). The major constraints of French bean production include marketing, transport diseases and insect pests (Monda *et al*. 2003). The crop is attacked by a number of insect pests during its life span. Thirty nine species of insect pests were found to infest soybean crop at their different growth stages in Noakhali region of Bangladesh during January to May, 2010 and 2011 (Biswas 2013). Fifteen to 20% of the total bean production is lost directly or indirectly by the attack of insect pests every year (Biswas 2008). An estimated 35 to 100% of crop losses worldwide are attributed to insect pests alone each year (Singh and Schwartz 2011). Sahoo and Giraddi (2023) reported five species of insects and one mite species infesting pole bean at various phases of crop growth. These include- the serpentine leaf miner (*Liriomyza trifolii*), pod fly (*Melanagromyza obtusa*), seed fly (*Anthomyia* sp.), leafhopper (*Ianagallia bifurcate*), tobacco caterpillar (*Spodoptera litura*), and red spider mite (*Tetranychus urticae*). The natural enemies include- *Brachymeria* sp. (Chalcididae), *Ichneumon* sp. (Ichneumonidae) and *Microplitis* sp. (Braconidae). In Bangladesh, bean leaf beetle and whitefly have become a serious threat to French bean cultivation in Sylhet and Chittagong regions. Adult bean leaf beetles prefer to eat tender young plant tissue. They feed primarily on the undersides of leaves, creating round, 0.31 cm diameter holes. High populations of adults can defoliate the first true leaves and kill young seedlings. Extensive feeding can reduce the vigor and yields of bean plants. The grubs of bean leaf beetle feed on soybean root nodules, whereas the adults feed on the above ground parts of soybean such as cotyledon, leaves, and pods. Bean leaf beetle is also a very efficient vector of Bean pod mottle virus, a widespread virus of soybean in the south and south-eastern United States with recent expansion into the north central region of the country (Hadi *et al.* 2012). Most of the farmers reported that use of pesticides effectively controlled the pests and diseases (Ndungu *at al.* 2004, Monda *et al.* 2003, Ndegwa *et al.* 2006). Chemical control is generally being advocated for the management of insect pests of French bean. Many workers have tried to control pest with varying degrees of success by frequent application of insecticides as foliar treatments (Chowdhury and Roy 1975). But indiscriminate use of chemicals led to impose certain well known undesirable side effects including environmental pollution, secondary pest outbreaks, pest resurgence, upset, resistance to pesticide, and health hazards killing beneficial organisms,' residues in food and feeds. Due to high yield loss caused by insect pests, the deleterious effects of insecticides and the inability of small scale farmers to afford expensive chemical pesticides, there is a need of developing a sustainable strategy for controlling insect pests. Considering above fact the experiment was undertaken to evaluate the effectiveness of integrated pest management packages for the management of leaf beetle attacking French bean.

MATERIALS AND METHODS

The experiment was carried out in the research field of Regional Horticultural research Station, Shibpur, Narsingdi to know the effectiveness of different IPM packages for the management of leaf beetle attacking French bean during November 2018 to February 2019. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The whole field was divided into 4 unit blocks represented replications and each unit block was divided into 5 sub unit plots. The total number of plots was 20 and the size of the individual plot was 3.0m × 3.0m. The distance between two unit plots was 0.75m and between block to block was 1m. The treatments were randomly distributed to the plots within a block. HYV

BARI Jharshim-2 was used as study material. The seeds were sown on 15 November 2018 at the rate of 120-125 kg/ha depending on the variety. The seeds were placed in the line continuously at a depth of 4-5 cm and covered by loose soil with the help of hand. The spacing was 30 cm between rows and 15 cm between plants. At first trifoliate stage, seedlings were carefully thinned to retain one seedling hill $^{-1}$. Seed germination occurred from 7th day after sowing. On the 12th day the percentage of germination was more than 80% while on the 15th day nearly all the seedlings came out from the soil. Intercultural operations were done as and when necessary to ensure normal growth and development of crops.

The packages of the experiment assigned were package 1: Yellow sticky trap + Bioneem plus 1% EC @ 1ml/L of water, package 2: Yellow sticky trap + Nitro 505 EC @ 1 ml/L of water, package 3: Bioneem Plus 1% EC @ 1ml/L of water +Nitro 505 EC @ 1 ml/L of water, package 4: Yellow sticky trap+ Bioneem Plus 1% EC @ 1ml/L of water +Nitro 505 EC @ 1 ml/L of water and an untreated control. Data on number of insects were recorded at an interval of 10 days commencing from first incidence. Population of leaf beetle were recorded at 38, 48, and 58 days after sowing (DAS) depending on the commencing from first incidence. The number of infested and healthy leaves were recorded from the selected 1 m^2 area of the centre of each unit plot to determine the level of infestation by leaf beetle at 38, 48, and 58 days after sowing.

Statistical analysis: The collected data were statistically analysed following the analysis of variance (ANOVA) using MSTAT C program and the mean differences were adjudged by LSD (Least significant difference).

RESULTS AND DISCUSSION

Effect of different IPM packages on leaf beetle at 38 DAS: The effect of different IPM packages at 38 DAS on leaf beetle population and its infestations are presented in Table 1. The number of leaf beetle varied significantly and it ranged from 0.77 to 4.50/plant. The lowest number of leaf beetle (0.77/plant) was observed in package 1 (0.77) treated plots followed by package 4 (0.78), package 2 (0.93) and package-3 (0.93) treated plots. Although the package 2 and package 3 were statistically similar but the highest number of leaf beetle was recorded in untreated control plots (4.50/

plant) which was statistically different from all other treatments. Accordingly, the highest percentage of leaf beetle reduction (82.88%) over control was found in package 1 treated plots followed by package 4 (82.66%), package 2 (79.33%) and package 3 (79.33%).

In case of infested plant by leaf beetle sqm^{-1} varied significantly and ranged from 2.75 to 23.50/sqm. The lowest number of plant infestation by leaf beetle (2.75/square meter) was observed in package 1 (Yellow sticky trap + Bioneem plus) treated plots followed by package 4 (3.50), package 2 (4.25) and package 3 (4.75). But the highest number of plant infestation per square meter was observed in untreated control plots (23.50/square meter) which was statistically different from all other treatments. Accordingly, the highest percentage of plant infestation reduction (88.29%) over control was found in package 1 treated plot followed by package 4 (85.10), package 2 (81.91%) and package 3 (79.78%) treated plot (Table 1).

Table 1. Efficacy of different IPM packages on the incidence of leaf beetle on French bean at 38 DAS

IPM packages	Number of leaf beetle /plant	Reduction of leaf beetle over control (%)	Number of infested plant by leaf beetle /sqm	Reduction of infested plant over control (%)
Package 1	0.77	82.88	2.75	88.29
Package 2	0.93	79.33	4.25	81.91
Package 3	0.93	79.33	4.75	79.78
Package 4	0.78	82.66	3.50	85.10
Untreated control	4.50	-	23.50	-
LSD (0.5)	0.17	-	1.23	-
CV (%)	6.96		10.34	-

Package 1- Yellow sticky trap + Bio-neem Plus @ 1 ml/L of water

Package 2 - Yellow sticky trap + Nitro 505 EC @ 1 ml/ L of water

Package 3 - Bioneem Plus @ 1ml/ L of water + Nitro 505EC @ 1 ml/ L of water

Package 4 -Yellow sticky trap + Bioneem Plus @ 1ml/ L of water+ Nitro 505 EC @ 1 ml/ L of water

Untreated control

Effect of different IPM packages on leaf beetle at 48 DAS: The effect of different IPM packages on leaf beetle population and its infestations are presented in Table 2. At 48 DAS, the number leaf beetle varied significantly and ranged from 0.71 to 5.25. The lowest number of leaf beetle (0.71/plant) was found in package 1 (Yellow sticky trap + Bioneem plus) treated plots followed by package 2 (0.78), package 3 (0.86) and package 4 (0.86). Here the package 1, package 2, package 3 and package 4 were statistically similar. The highest number of leaf beetle was observed in untreated control plots (5.25 /plant) which was statistically different from all other treatments. Accordingly, the highest percent of leaf beetle reduction (86.47%) over control was found in package 1 treated plots followed by package 2 (85.14%), package 3 (83.61%) and package 4 (83.617%) where package 3 and package 4 were statistically similar.

In case of infested plant by leaf beetle sqm^{-1} varied significantly and ranged from 0.71 to 23.50. The lowest number of leaf infestation by leaf beetle (0.71/square meter) was found in package 1 (Yellow sticky trap + Bioneem plus) treated plots followed by package 4 (0.78), package 3 (0.86) and package 2 (0.93). The highest number of infested plant per square meter was observed in untreated control plots (23.50 /square meter) which was statistically different from all other treatments. Accordingly, the highest percent of plant infestation reduction (96.97%) over control was found in package 1 treated plot followed by package 4 (96.68), package 3 (96.34%) and package 2 (96.04%) treated plot (Table 2).

Effect of different treatments on leaf beetle at 58 DAS: After 58 days of sowing, the effect of different IPM packages on leaf beetle population and its infestations are presented in Table 3. At 58 DAS, the number leaf beetle varied significantly and ranged from 0.71 to 7.00. The lowest number of leaf beetle (0.71 /plant) was observed in package 1 (Yellow stick trap + Bioneem Plus), package 2 (0.71) and package 4 (0.71) treated plots followed by package 3 (0.86). Here package 1, 2, 3 and package 4 were statistically similar. The highest number of leaf beetle was observed in untreated control plots (7.00 /plant) which was statistically different from all other treatments. Accordingly, the highest percentage of leaf beetle reduction (89.85%) over control was found inpackage1 treated plots which was statistically similar with package 2 (89.85%), package 4 (89.85%) followed by package 3 (87.71%).

Table 2. Effectiveness of different IPM packages on the incidence of leaf beetle on French bean at 48 DAS

IPM packages	Number of leaf beetle/plant	Reduction of leaf beetle over control (%)	Number of infested plant by leaf beetle /m^2	Reduction of infested plant over control (%)
Package 1	0.71	86.47	0.71	96.97
Package 2	0.78	85.14	0.93	96.04
Package 3	0.86	83.61	0.86	96.34
Package 4	0.86	83.61	0.78	96.68
Untreated control	5.25	-	23.50	-
LSD (0.5)	0.45	-	0.93	-
CV (%)	9.65	-	11.25	-

Package 1- Yellow sticky trap + Bio-neem Plus @ 1 ml/L of water

Package 2 - Yellow sticky trap + Nitro 505 EC @ 1 ml/ L of water

Package 3 - Bioneem Plus @ 1ml/ L of water + Nitro 505EC @ 1 ml/ L of water

Package 4 -Yellow sticky trap + Bioneem Plus @ 1ml/ L of water+ Nitro 505 EC @ 1 ml/ L of water

Untreated control

Infested plant by leaf beetle varied significantly and ranged from 0.71 to 24.25. The lowest number of infested plants by leaf beetle was observed in package 1 (Yellow stick trap + Bioneem Plus) and package 4 (0.71) treated plots followed by package 3 (0.73) and package 2 (0.86). The highest number of plant infestation per square meter was observed in untreated control plots (24.25 /square meter) which was statistically different from all other treatments. Accordingly, the highest percentage of plant infestation reduction (97.07%) over control was found in package 1 and package 4 treated plot followed by package 3 (96.98) and package 2 (96.45%) treated plot (Table 3).

Efficacy of different IPM packages on leaf beetle and its infestation on French bean: Effect of IPM packages on leaf beetle population, its reduction over control and leaf area damaged are presented in Table 4 and Plate 1. The mean number of leaf beetle varied significantly and it ranged from 1.05 to 5.00 leaf beetle/plant. The lowest mean number of leaf beetle (1.05/Plant) was observed in package 1 (Installing Yellow sticky trap + spraying Bio-neem plus 1 EC @ 1ml/L of water) followed

Table 3. Effect of different IPM packages on the incidence of leaf beetle on French bean at 58 DAS

IPM packages	Number of leaf beetle/ plant	Reduction of leaf beetle over control (%)	Number of infested plant by leaf beetle /m^2	Reduction of infested plant over control (%)
Package 1	0.71	89.85	0.71	97.07
Package 2	0.71	89.85	0.86	96.45
Package 3	0.86	87.71	0.73	96.98
Package 4	0.71	89.85	0.71	97.07
Untreated control	7.00	-	24.25	-
LSD(0.5)	0.56	-	0.66	-
CV (%)	8.32	-	7.86	-

Package 1- Yellow sticky trap + Bio-neem Plus @ 1 ml/L of water

Package 2 - Yellow sticky trap + Nitro 505 EC @ 1 ml/ L of water

Package 3 - Bioneem Plus @ 1ml/ L of water + Nitro 505EC @ 1 ml/ L of water

Package 4 -Yellow sticky trap + Bioneem Plus @ 1ml/ L of water+ Nitro 505 EC @ 1 ml/ L of water

Untreated control

by package 4 (1.15/plant), package 2 (1.17/Plant), and package 3 (1.22/Plant). The highest number of leaf beetle was observed in untreated control plots (5.00/Plant) which were significantly different from all other treatments. Accordingly, the highest percentage of leaf beetle population reduction (79.00%) over control was found in package1 treated plots followed by package 4 (77.00%), package 2 (76.60%) and package 3 (75.60%).

In case of leaf area damage, the percent leaf area damaged varied significantly and ranged from 2.19% to 22.94%. The lowest leaf area damaged (2.19%) was observed in package 1 treated plots followed by package 4 (2.42%), package 3 (2.45%) and package 2 (2.75%) while the highest (22.94%) was observed in untreated control plots which were statistically different from all other treatments. Accordingly, the highest percentage (90.45%) of leaf area damaged reduction over control was found in package 1 followed by package 4 (89.45%), package 3 (89.31%) and package 2 (88.01%) treated plot (Table 4).

Table 4. Efficacy of different IPM packages on the incidence of leaf beetle and its infestation on French bean

Treatments	Number of leaf beetle/ plant	Reduction of leaf beetle population over control (%)	Leaf area damaged by leaf beetle (%)	Reduction of leaf area damaged over control (%)
Package 1	1.05 b	79.00	2.19	90.45
Package 2	1.17 b	76.60	2.75	88.01
Package 3	1.22 b	75.60	2.45	89.31
Package 4	1.15 b	77.00	2.42	89.45
Untreated control	5.00 a	-	22.94	
LSD (0.5)	0.12	-	0.98	-
CV (%)	4.11	-	9.70	-

Package 1- Yellow sticky trap + Bio-neem Plus @ 1 ml/L of water
Package 2 - Yellow sticky trap + Nitro 505 EC @ 1 ml/ L of water
Package 3 - Bioneem Plus @ 1ml/ L of water + Nitro 505EC @ 1 ml/ L of water
Package 4 -Yellow sticky trap + Bioneem Plus @ 1ml/ L of water+ Nitro 505 EC @ 1 ml/ L of water Untreated control

Relationship between leaf beetle incidence and yield of French bean: Total yield influenced by the incidence of leaf beetle per plant. The result revealed that there was a strong negative correlation between number of leaf beetle and total yield. It indicated that with the increase of leaf beetle there was progressive fall in the yield. A linear regression was fitted between leaf beetle abundance and total yield (Fig. 1). The correlation coefficient (r) was 0.929 and the contribution of the regression (R^2 = 0.863, when Y = - 1.369x + 15.41) was 86.30%.

Relationship between plant infestation by leaf beetle and yield of French bean: A negative relationship between percent plant infestation and total yield was found in different treatments, which indicated that with the increase of leaf beetle infestation there was progressive fall in the yield. A linear regression was fitted between leaf beetle infestation and total yield (Fig. 2). The correlation coefficient (r) was 0.924 and the contribution of the regression (R^2 = 0.853, when Y = - 0.287x + 23.92) was 85.30%.

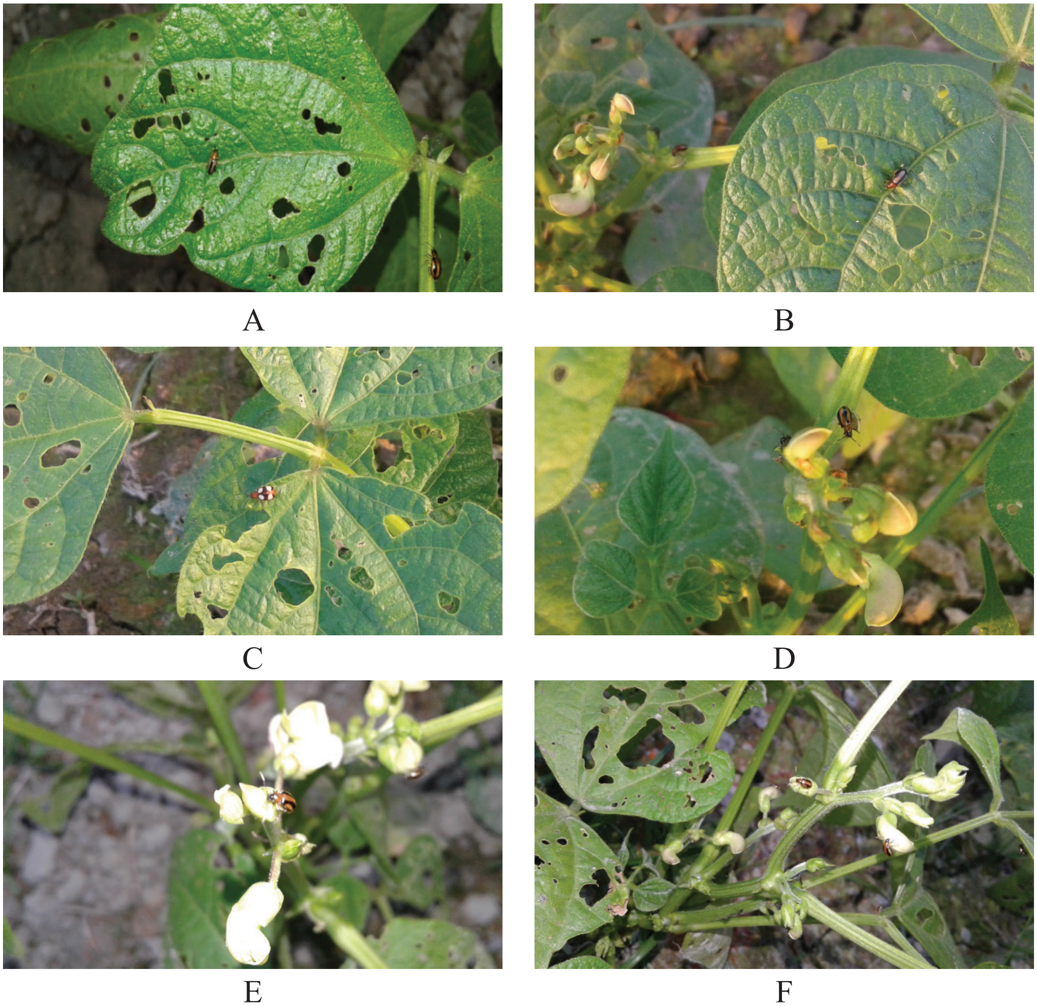

Plate 1. Leaf and flower area damaged by leaf beetle on French bean leaves (A-C) and flowers (D-F)

Relationship between leaf area damage and yield of French bean: A negative relationship between percent leaf area damage and total yield was found in different treatments, which indicated that with the increase of leaf beetle infestation there was progressive fall in the yield. A linear regression was fitted between leaf beetle infestation and total yield (Fig. 3). The correlation coefficient (r) was 0.925 and the contribution of the regression ($R^2 = 0.856$, when $Y = -0.256x + 14.47$) was 85.60%.

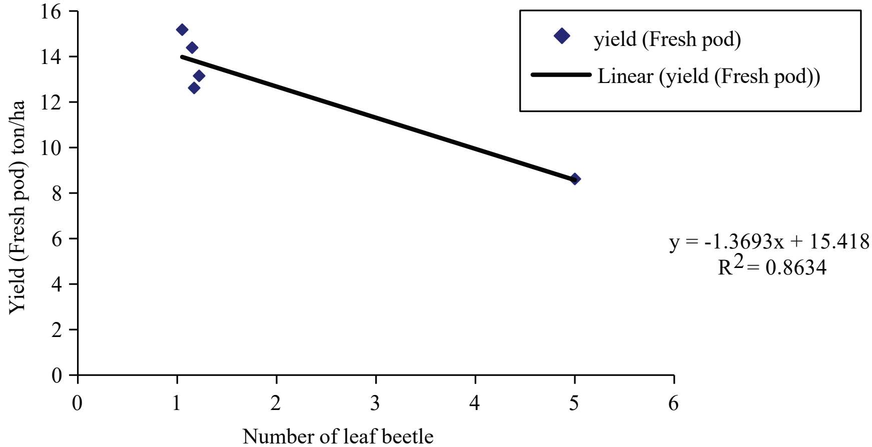

Fig. 1. Relationship between leaf beetle incidence and yield of French bean during growing season 2018-2019

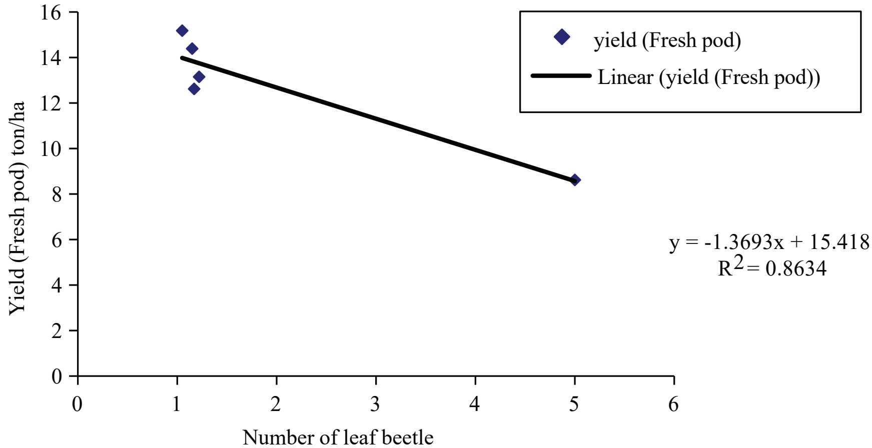

Fig. 2. Relationship between plant infestation by leaf beetle and yield of French bean during growing season 2018-2019

Return and marginal benefit cost ratio (MBCR): Return and marginal benefit cost ratio are presented in Table 5. The net return and marginal benefit cost ratio was varied depending on the cost of treatment application. As a fresh pod, the highest net return (Tk.156397/ha) was recorded from package 1 (Yellow sticky trap + Bio-neem plus) treated plots followed by package 4 (Tk. 13997/ha), package 3 (Tk.109878/ha) and package 2 (Tk. 92487/ha). But, the highest marginal benefit cost ratio (MBCR

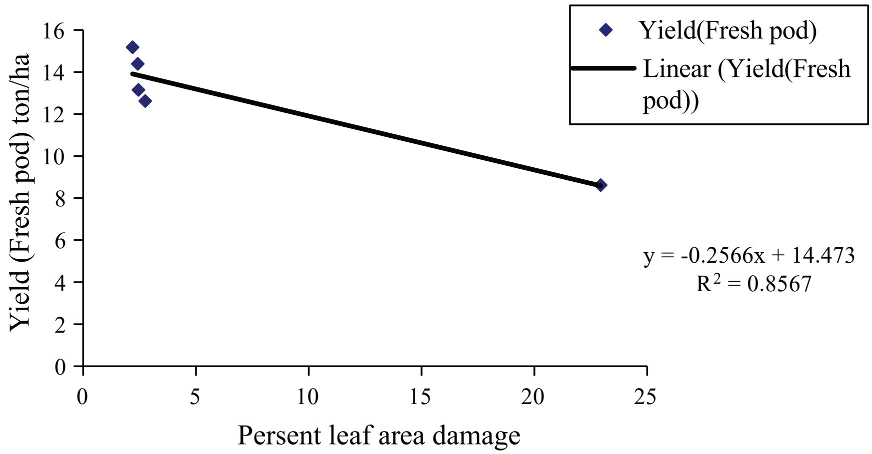

Fig. 3. Relationship between leaf area damage and yield of French bean during growing season 2018-2019

Table 5. Effect different IPM packages on net return and marginal benefit cost ratio in French bean yield as a fresh pod.

IPM packages	Yield (kg/ha) As a fresh pod	Addl. yield over control (kg/ha)	Addl. Income over control (Tk/ha)	Cost of insecticide appl. (Tk/ha)	Net return (Tk/ha)	Marginal benefit cost ratio
Package 1	15180.50 a	6553.50	163837.50	7440	156397.50	21.02
Package 2	12622.50 d	3995.50	99887.50	7400	92487.50	12.49
Package 3	13151.75 c	4524.75	113118.75	3240	109878.75	33.91
Package 4	14396.50 b	5769.5	144237.50	8240	135997.50	16.50
Untreated control	8627.00 e	-	-	-	-	-
Level of significance	**	-	-	-	-	-
CV (%)	1.03	-	-	-	-	-

Addl. = Additional, appl. = application ** Significant at p=0.01

Means within column followed by the same letter are not significantly different from one another by CD (critical difference) values. Values are average of three replications.

Package 1- Yellow sticky trap + Bio-neem Plus @ 1 ml/L of water

Package 2 - Yellow sticky trap + Nitro 505 EC @ 1 ml/ L of water

Package 3 - Bioneem Plus @ 1ml/ L of water + Nitro 505EC @ 1 ml/ L of water

Package 4 -Yellow sticky trap + Bioneem Plus @ 1ml/ L of water+ Nitro 505 EC @ 1 ml/ L of water

Untreated control

For calculating income and benefit the following market prices were used: French bean as vegetables =Tk. 25/ kg, Yellow sticky trap = Tk. 50/trap, Bioneem plus 1% EC = Tk. 210/100 ml, Nitro 505 EC = Tk. 200/100 ml, Labor wages for spraying pesticides =Tk. 400/day/labour (8 hours day).

33.91) was recorded from package 3 (Bio-neem plus + Nitro 505EC) treated plots followed by package 1 (MBCR 21.02), package 4 (MBCR 16.50) and package 2 (MBCR 12.49). This was mainly due to incurring costs of these treatments.

Considering the efficacy and benefit, spraying of Bioneem plus 1 EC is the most profitable insecticidal management approach against insect pests of French bean followed by Nitro 505 EC and yellow sticky trap. The efficacy of different treatments of this experiment are in conformity with the reports of Wambua (2004) and Pest Control Products Board (2014) where they reported that use of conventional insecticides is the most frequently used method to suppress insect pests of French beans in Kenya. Roy *et al.* (2014) conducted an experiment to study the efficacy of some insecticides against whitefly and aphid insect pests of French bean. They found that Chlorpyriphos 20 EC @ 3 ml/L of water performed best to suppress the whitefly and aphid of French bean followed by Foratap 50 SP @ 3g/l of water. The lowest number of whitefly plant^{-1} (3.28 at 60 DAS) and aphid plant^{-1} (4.82 at 60 DAS), the lowest infestation intensity by whitefly (5.92%) and aphid (14.25%), the lowest infested bean yield plant^{-1} (52.80 at 60 DAS), highest healthy bean yield plant^{-1} (166.40 g at 60 DAS), highest total healthy yield (11.28 t ha^{-1}), lowest total infested yield (0.64 t ha^{-1}) and highest gross return (Tk. 232000.00 ha^{-1}) were obtained from the use of Chlorpyriphos. They also reported that lowest infested fruits, highest total healthy fruit yield and highest gross return were obtained by the application of Chlorpyriphos. Sharmah and Rahman (2017) reported four IPM modules including the control treatment were tested against major insect and mite pests of French bean and out of which IPM module –I with seed treatment by Captan @ 3gm/kg seed, weeding frequency (3 times at 15 days interval), yellow sticky trap @ 20nos./ha, mechanical destruction(removing by hand picking and destroying them), intercrop with coriander (2:1 ratio), release of *C. transversalis* of aphid and TSSM was found to be most effective as compared to the other IPM modules tested. Chandrashekara *et al*. (2022) reported that among different insect pest management strategies under field conditions, cartap hydrochloride and batain seed extract registered low sucking bug (*Chauliops choprai*) population. Integrated approaches including bio-agents, botanicals along with chemicals for managing these diseases and insect-pests were found appropriate options.

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RICEPLANT INHABITING LONG-JAWED SPIDERS GENUS *TETRAGNATHA* LATREILLE, 1804 FROM DISTRICT JHENAIDAH, SOUTHWEST BANGLADESH (ARANEAE: TETRAGNATHIDAE: TETRAGNATHINAE)

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ABSTRACT

Taxonomic account of two species of rice-plant inhabiting long-jawed spiders genus *Tetragnatha* Latreille, 1804 are presented. Of these, species *T. okumae* n. sp. is identified as new to science and *T.boydi* Cambridge is recorded first time from the area of present study. Brief generic diagnosis together with illustrated description, distribution and key to the species is provided. The web-building behaviour of the new species is briefly discussed.

Keywords: *Tetragnatha, T. okumae, T. boydi,* Araneae, Tetragnathidae, Tetragnathinae

INTRODUCTION

Spiders inhabiting rice-plant ecosystems are very much important due to their active predatory role in the management of pest insects. In Asia, more specifically in Bangladesh, the role of these spiders as a potential biological control agent is well known and accepted earlier. Orb-weaving spiders appear to be of special importance among them as they trap more than a number of pest insects in their webs what they actually consume. About 64 species of rice-field spiders are reported in Bangladesh (Chowdhury and Nagari 1981, Chowdhury and Pal 1984, Okuma *et al.* 1993, Biswas and Raychaudhury 1996, 2013, Biswas *et al.* 1993) and among them spiders of the genus *Tetragnatha* Latreille, 1804 (family Tetragnathidae Menge) were found dominant (Kamal *et al.* 1992, Okuma *et al.* 1993, Biswas *et al.* 1993). Members of the family Tetragnathidae are distributed all over the world and till date, it contains a total of 991 valid species belonging to 47 genera.

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Genus *Tetragnatha* Latreille are tropical, moisture-loving, nocturnal spiders mostly abundant during monsoon. They are inhabitants of vegetations and commonly found in the surroundings of streams, lakes, tanks, wetland rice-fields etc. stretching the legs forward on leaves of plants. They make typical circular or nearly-circular webs below which they stay long times directing upward for the preys. They are one of the important predatory components in the rice-agroecosystems.

Genus *Tetragnatha* (Gk. *Tetra* = four + *gnatha* = jaw) was first established by Pierre Andre Latreille in 1804 with the type-species *Tetragnatha extensa* (Linnaeus 1758). These spiders are distributed all over the world with majority are tropical and sub-tropical countries but species are rich in Asia (Okuma *et al.* 1993). The genus at present composed of 349 valid species worldwide of which only 14 (fourteen) species are recorded in Bangladesh (World Spider Catalog 2025, Okuma *et al.* 1993, Biswas 2009, Biswas and Raychaudhuri 1996). Significant contributors on the genus *Tetragnatha* Latreille are – Gravely (1921), Seeley (1928), Okuma (1987, '88), Barrion (1998), Barrion and Litsinger (1981, '84, '95), Gillespie (1987, '91,'92, '93, '94, 2002), Gillespie *et al.* (1997), Dimitrov and Hormigera (2009), Basu and Raychaudhuri (2016), Tikader (1966), Yin (1976), Zhu *et al.* (2002, 2003), Zhu and Shi (1988), Tanikawa (1997, 2003, 2009), Chickering (1957, '62), Vungsilabutr (1988), Kim and Lee (2013), Kim *et al.* (2008) and Dippenaar-Schoeman *et al.* (2023). The present paper contains description of 2 (two) species of which *T. okumae* n. sp. is described as new and another one *T. boydi* O. P. -Cambridge is recorded first time from Jhenaidah (area of the present study), Bangladesh.

MATERIALS AND METHODS

Collection and Preservation: Specimens were collected from different rice-fields of village South Shikerpur and Bamonail, from 12th April, 2024 to November 2025 in different crop seasons, district Jhenaidah by hand and hand-sweeping net from the webs and plant leaves and collected in a large glass jar containing chloroform. After collection, these were transferred to a large Petri dish for sorting. After sorting, the specimens were put in separate glass vials filled with 70% ethyl alcohol for identification (Lincoln and Sheals 1985).

Identification and Deposition: The preserved specimens were identified following different books and journals of home and abroad; these were – Tikader (1987), Barrion and Litsinger (1995), Zhu *et al.* (2003), Yaginuma (1986), Tanikawa (2009), Biswas (2009), Basu and Raychaudhuri (2016), Kim and Lee (2013) and Dippenaar-Schoeman *et al.* (2023).

After identification, the specimens were preserved separately in Audmans' preservatives (90 parts 70% alcohol + 5 parts glycerine + 5 parts acetic acid) and preserved in the laboratory of the Department of Zoology, Khulna Government Women's College, Khulna, Bangladesh.

Illustration and Photographs: Illustrations of whole body and different body-parts were made by the Camera lucida fitted with the Stereo zoom Binocular Microscope. Measurements of different body-parts are taken in millimeters (mm). Photographs were taken by DSLR Camera fitted with macro zoom lens (both in the field and laboratory).

RESULTS AND DISCUSSION

Taxonomy

Family : TETRAGNATHIDAE Menge, 1866

Subfamily : Tetragnathinae Menge, 1866

Genus : *Tetragnatha* Latreille, 1804

Type-species : *T. extensa* (Linnaeus, 1758)

1804. *Tetragnatha* Latreille, *Nauv. Dict. d' Hist. Nat.*, **24** : 135.

Cambridge, 1884 : 243 ; Simon, 1894 : 723 ; Thorell, 1895 : 1390 ; Pocock, 1900 : 214 ; Gravely, 1921 : 426 ; Comstock, 1940 : 423 : Kaston, 1948 : 268 ; Locket & Millidge, 1954 : 94 ; Tikader, 1966 : 8 ; Okuma, 1968 : 98 ; Tikader & Biswas, 1981 : 45 ; Yaginuma, 1986 : 130 ; Koh, 1989 : 53 ; Chen & Zhang,1991 : 124 ; Gillespie, 1992 : 1 ; Okuma *et al.,* 1993 : 35 ; Barrion & Litsinger, 1995 : 494 ; Biswas & Raychaudhuri, 1996 : 45 ; Mikhailov, 1997 : 108 ; Platnick,1997 : 463 ; Song *et al.*,1999 : 221 ; Gillespie, 2002 : 159 ; Zhu *et al.,* 2003 : 109 ; Gajbe, 2004 : 32 ; Majumder, 2004 : 983 ; Tanikawa, 2007 : 104 ; Kim *et al.,* 2008 : 37 ; Biswas, 2009 : 321 ; Marusik, 2010 : 199 ; Barrion *et al.,* 2011: 385; Kim & Lee, 2013 : 54 ; Basu & Raychaudhuri, 2016 : 210 ; World Spider Catalog, 2025, Version 25.5, Nat. Hist. Mus. Bern., http ://www.wsc.nmbe.ch.

Diagnosis: Members of the genus *Tetragnatha* Latreille, 1804 have body prominently long, narrow, sub-cylindrical, several times longer than wide. Cephalothorax longer than wide, basally broad and wider nearer the middle, flattened above with conspicuous thoracic groove. Eyes in two rows, parallel, divergent or convergent; lateral eyes never contiguous. Chelicerae usually very long, especially in males and margins of furrow provided with numerous teeth. Maxillae long, parallel and dilated at distal ends. Legs and palpi very long and slender clothed with spines, hairs and trichobothria (Okuma *et al.* 1993).

Abdomen long, sometimes like a pointed tail beyond spinnerets. Spinnerets may be present at the end or nearer to the end of abdomen. Epigynal slit posterior to lung slits in the procurved epigastric furrow.

Biological note: All these are orb-weaving spiders and make circular or semi-circular webs in the crop-fields and gardens. They are commonly found on grasses, leaves of rice-plants and other foliages in the vicinity of water. They spin large horizontal webs during dusk under which they stay directing upward. They are nocturnal predators and take rest in the day stretching the legs forward on the leaves or under the webs appearing boat-shaped. All members are biological control agents of small insect pests.

Distribution: All over the world with majority in Asia (Okuma *et al.* 1993; Zhu *et al.* 2003).

Key to the species of genus *Tetragnatha* Latreille

1. Cephalothorax medially wide with deep median fovea and distinct cervical furrows; abdomen long, dumbbell-shaped, with dorsal net-like decoration; lateral eyes distantly placed; chelicerae without anterior dorsal spine and fang with black basal band; leg formula 4123 and epigyne as in figure ………….. …… *T. okumae* n. sp.

_ Cephalothorax posteriorly wide, without median fovea and cervical furrows ; abdomen long, cylindrical with long dorsal wavy-decoration ; lateral eyes close each other ; chelicerae with a long, dorsal spine and fang without black basal band ; leg formula 1243 and epigyne as in figure …………………………......... ………. *T. boydi* Cambridge

Description of the species

1. *Tetragnatha boydi* O. P. -Cambridge

(Figs. Ia-g ; Figs. 3a-b)

1898. *Tetragnathaboydi* O. P.- Cambridge, *Proc. zool. Soc. London* : 389.

1921. *Tetragnathamandi bulatabidentata* : Gravely, *Rec. Indian Mus.*, **22** : 442.

1966. *Tetragnathamandi bulatabidentata* : Tikader, *J. Assam Sci. Soc.,* **22** : 9.

1983. *Tetragnathaboydi* : Okuma, *Esakia,* **22** : 69.

1996. *Tetragnathaboydi* : Biswas & Raychaudhuri, *Ann. Entomol.,***14** (1) : 52.

2006. *Tetragnathaboydi* : Platnick, *World Spider Catalog,* Version 6.5, : 986.

2009. *Tetragnathaboydi* : Biswas, *Ency. Flora & fauna Bangladesh, Arachn.,***18** (1) : 322.

2016. *Tetragnathaboydi* : Basu & Raychaudhuri, *World Scientific News*, **55** : 210.

2025. *Tetragnathaboydi* : *World Spider Catalog,* Version 25.5, Nat. Hist. Mus. Bern., http ://www.wsc.nmbe.ch. (Accessed on 7th July, 2025).

Material examined: 2 females, Rice-fields, South Shikerpur, district Jhenaidah, 12.IV.20024, Coll. V. Biswas; 3 females, Bamonail rice-field, district Jhenaidah, 17.III. 2025, Coll. V. Biswas; 2 females, again from rice-fields, South Shikerpur, district Jhenaidah, 07.IV.2025, Coll. V. Biswas.

General: Body long, sub-cylindrical and narrowing posteriorly. Colour brown, cephalothorax dark brown, legs pale and abdomen brown. Total body length (female) 12.20 mm. Carapace 2.20 mm long, 1.40 mm wide; abdomen 10.00 mm long and 2.80 mm wide. Total body length (male) 10.40 mm. Carapace 2.40 mm long, 1.40 mm wide; abdomen 8.00 mm long and 2.60 mm wide.

Cephalothorax: Long, narrowing anteriorly, clothed with fine pubescence. Cephalic region slightly raised; cervical furrows deeply distinct, radial furrows deep and distinct. Eyes black, with black bands basally, anterior row strongly recurved, posterior row faintly so, laterals separated, ocular quad wider than long. Chelicerae long, little longer than carapace; first tooth in female largest and situated at the base of fang; second tooth nearer the first with a series of small teeth (Figs. 1b-c); fang in female with one inner cusp. Maxillae long, posteriorly curved, scopulate anteriorly (Fig. 1d). Labium bell-shaped, scopulate anteriorly (Fig. 1d). Sternum elongate, posteriorly narrowing, anterior margin little concave (Fig. 1e). Legs very long and slender, clothed with fine hairs and spines; leg formula 1243 and the measurements (mm) of leg segments are shown in Table 1.

Table 1. Measurements (mm) of leg segments of female *T. boydi* Cambridge.

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
I	7.49/7.49	0.45/0.45	5.90/5.90	4.15/4.15	2.50/2.50	20.49/20.49
II	7.10/7.10	0.40/0.40	5.50/5.50	3.80/3.80	2.00/2.00	18.80/18.80
III	1.90/1.90	0.40/0.40	2.00/2.00	2.20/2.20	1.10/1.10	7.60/7.60
IV	3.65/3.65	0.40/0.40	4.10/4.10	2.45/2.45	1.55/1.55	12.15/12.15

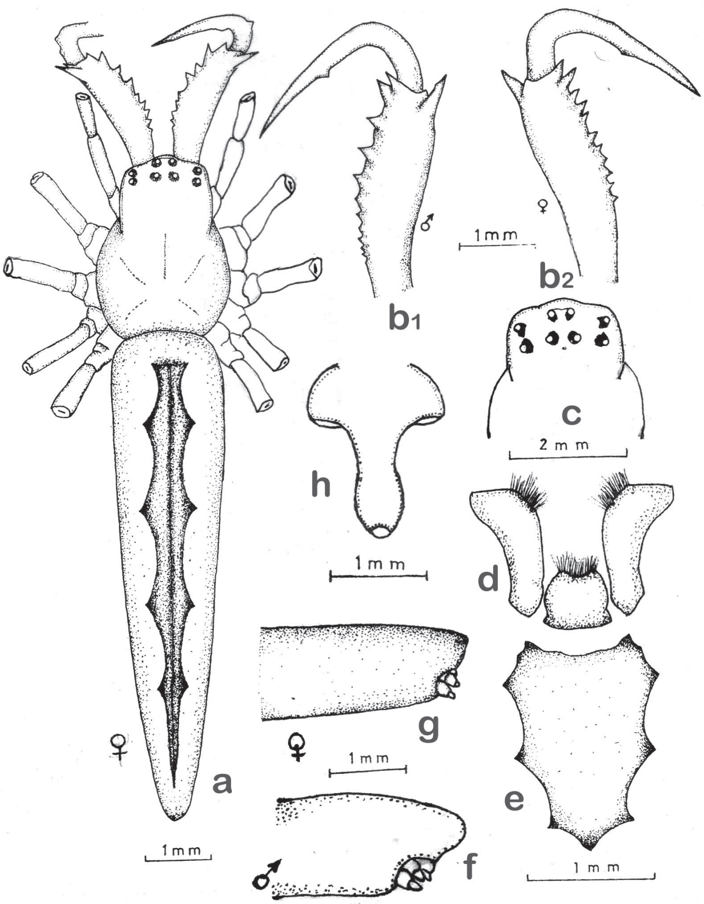

Fig. 1. *Tetragnatha boydi* O. P. –Cambridge
a. Whole body (dorsal view); b1-b2. Chelicerae; c. Ocular area; d. Maxillae & Labium; e. Sternum; f. Posterior part of abdomen (male) showing spinneretes; g. Do (female showing spinneretes; h. Epigynum.

Abdomen: Very long, anteriorly broad, posteriorly tapering, clothed with fine pubescence; dorsum with brownish long scaly decorations, anteriorly ridged, posteriorly with two longitudinal ridges; epigyne long, tongue-like as in Figure 1i.

Distribution: BANGLADESH: Jhenaidah, Bagerhat, Tangail; INDIA; NEPAL; AFRICA; BRAZIL (Tikader 1966; Okuma 1988; Biswas and Raychaudhuri 1996).

2. *Tetragnatha okumae* n. sp.

(Figs. 2a-i; Figs. 3c-d)

Material examined: 1 female (Holotype), Village South Shikerpur, District Jhenaidah, 22.IX.2024, Coll. V. Biswas; 2 females (Paratypes), collected from same locality, 17.IV.2025, Coill. V. Biswas.

General: Body very long, nearly dumbbell-shaped, anteriorly wide. Colour yellow-brown with deep brown chelicerae. Cephalothorax dark-brown with black dorsal fovea. Legs long, pale yellow-brown. Total body length (holotype) 14.00 mm. Carapace 2.70 mm long, 1.60 mm wide; abdomen 11.30 mm long and 1.70 mm wide (Fig. 3a).

Cephalothorax: Holotype: Broad, elongate, flat, wider medially with a black median fovea and two lateral distinct cervical furrows; some radiating striae present around the fovea. Eyes black, each encircled with small black basal bands; anterior row slightly recurved and posterior row faintly so; lateral eyes separated; ocular quad wider than long. Chelicerae long, strong, deep brown with many sharp pointed teeth on each margin; fang with black basal band (Fig. 3b-c). Maxillae long, backwardly curved, anteriorly broad and scopulate (Fig.3d). Labium small, nearly apple-shaped, anteriorly scopulate (Fig. 3d). Sternum brown, broad, nearly heart-shaped, pointed posteriorly (Fig. 3e). Legs yellowish, very long and slender, clothed with fine hairs and spines; leg formula 4123 and the measurements (in mm) are shown in Table 2.

Table 2. Measurements (mm) of leg segments of female *T. okumae* n. sp.

Leg	femur	Patella	Tibia	Metatasus	Tarsus	Total
I	7.00/7.00	0.50/0.50	5.45/5.45	3.85/3.85	2.05/2.05	18.85/18.85
II	3.65/3.65	0.45/0.45	4.10/4.10	2.60/2.60	1.60/1.60	12.40/12.40
III	1.90/1.90	0.35/0.35	2.10/2.10	2.10/2.10	1.00/1.00	7.45/7.45
IV	7.60/7.60	0.50/0.50	6.50/6.50	4.15/4.15	2.50/2.50	21.25/21.25

Abdomen: Long, yellowish-brown, nearly dumbbell-shaped; anteromedially wide; dorsum with scaly decoration; posteriorly blunt; spinnerets broad, situated at the end; ventrally light-yellow; epigyne as in Figure - 2h.

Male unknown. This will be described in detail after collection (when will be available).

Holotype: 1 female in spirit.

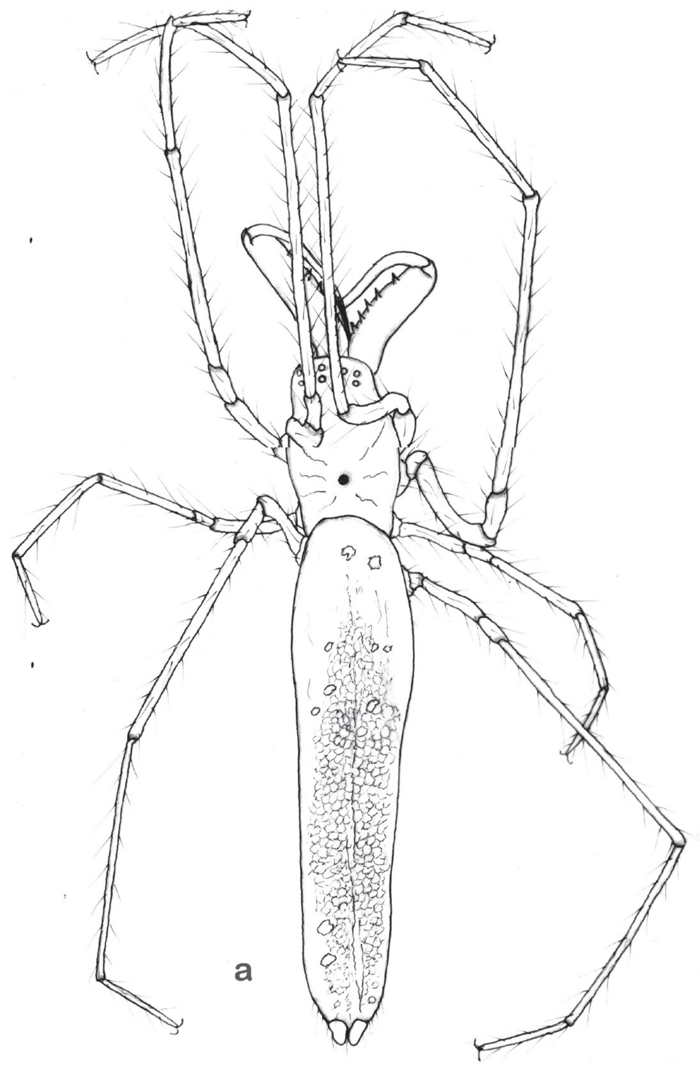

Fig. 2. ***Tetragnatha okumae*** **n. sp.** a. Whole body (dorsal view)

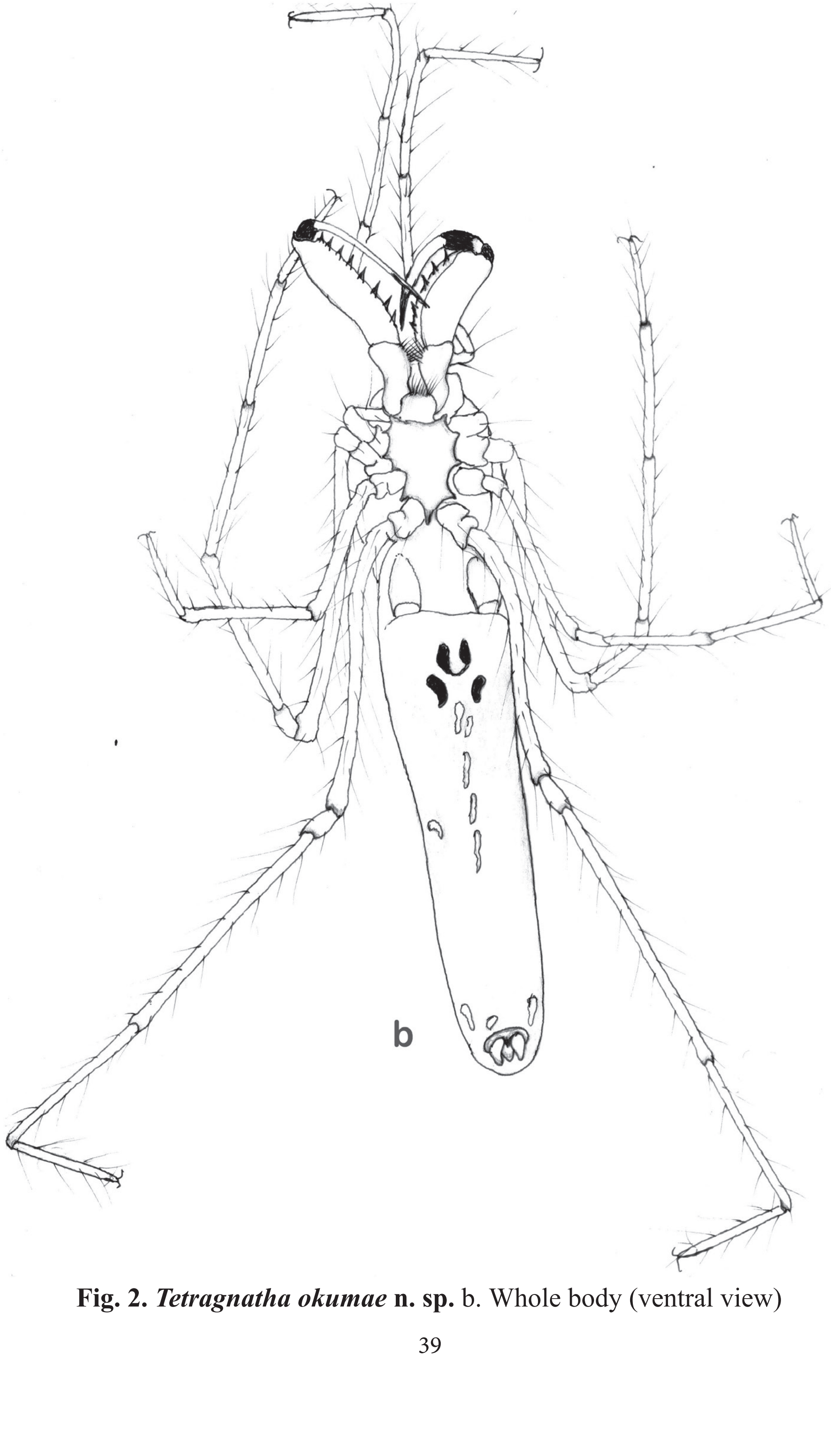

Fig. 2. ***Tetragnatha okumae*** **n. sp.** b. Whole body (ventral view)

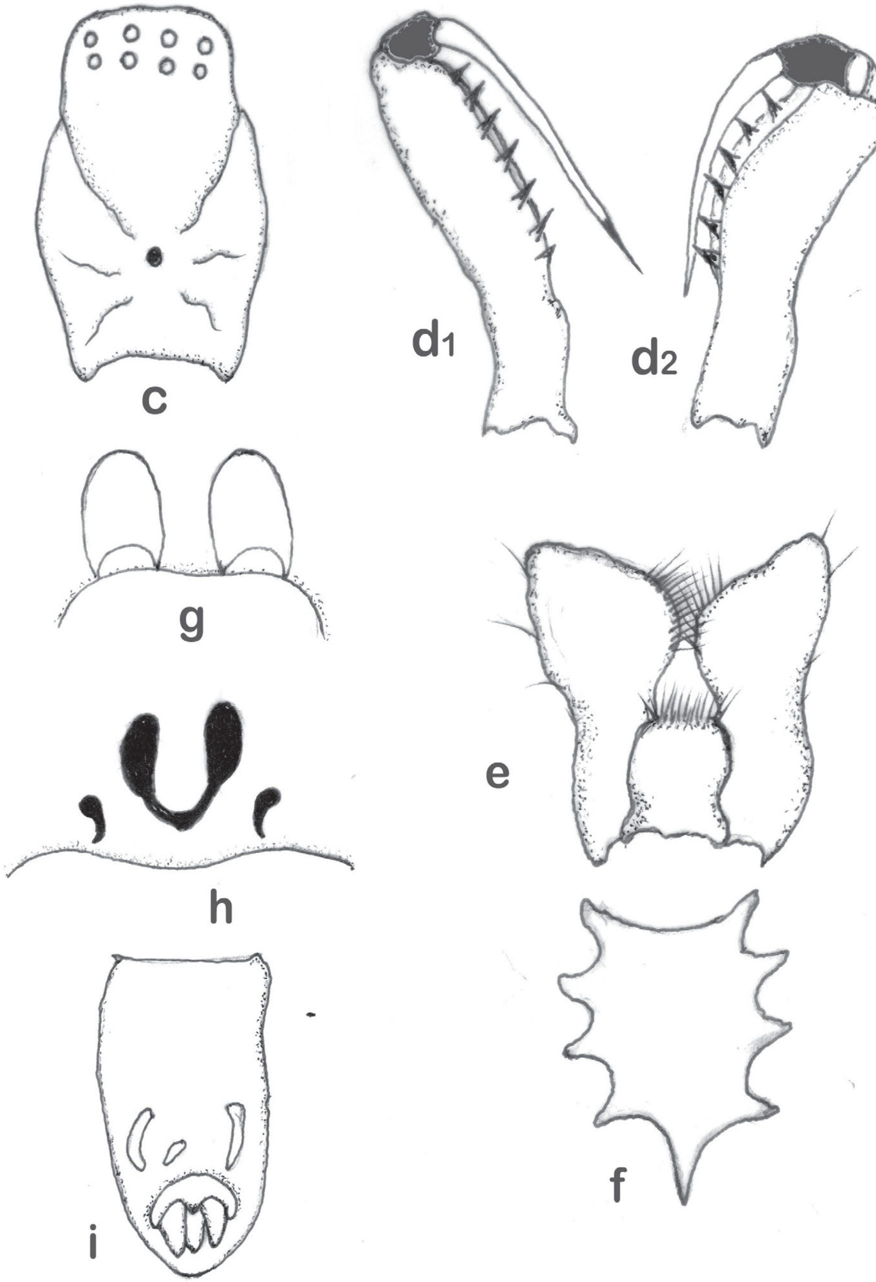

Fig. 2. ***Tetragnatha okumae*** **n. sp.**
c. Cephalothorax; d1 - d2. Chelicerae; e. Maxillae & labium; f. Sternum; g. Book-lung; h. Epigynum; i. Posterior end showing spinneretes

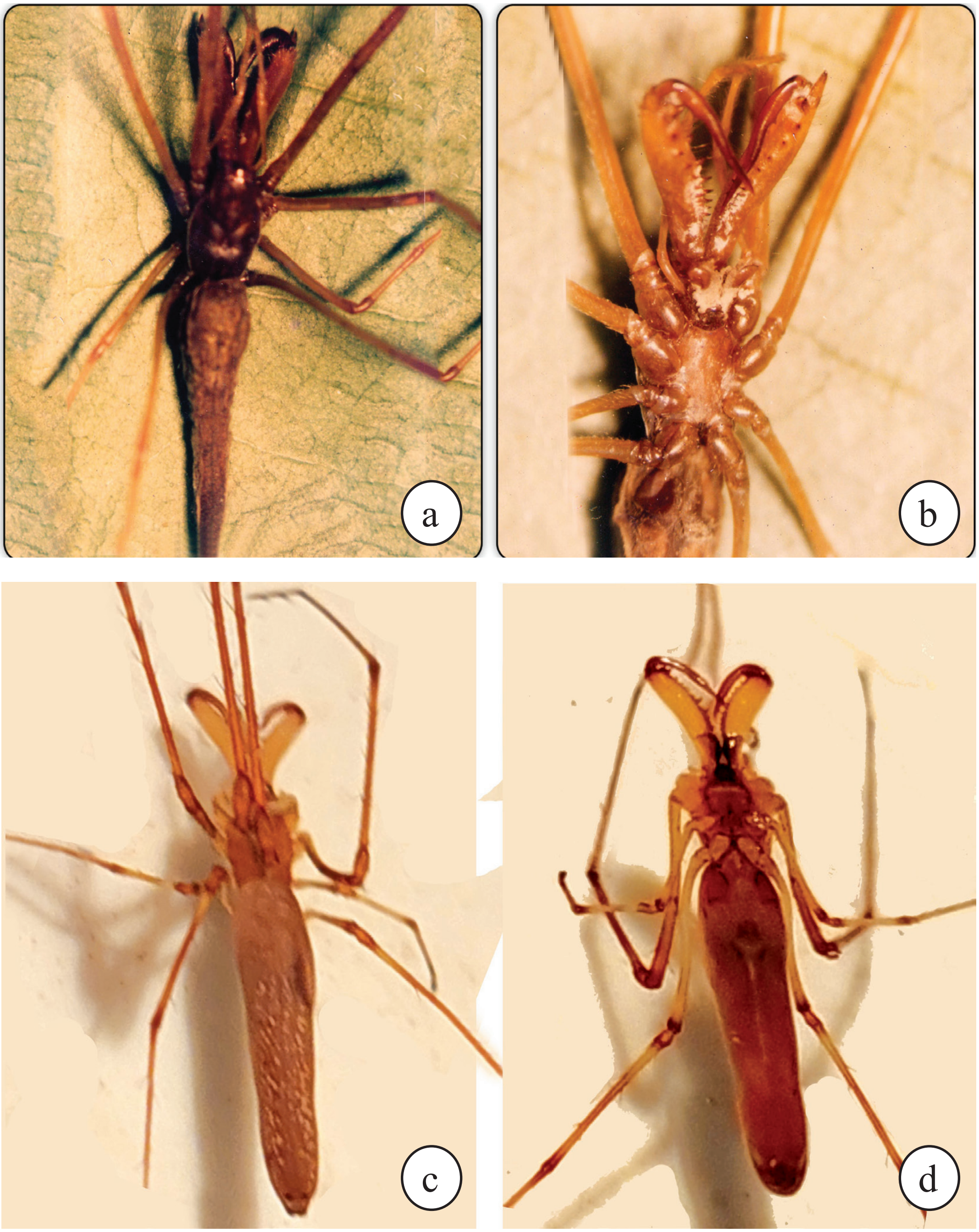

Fig. 3. a. *T. boydi* Cambridge (dorsal view); b. Do, Chelicerae, maxillae, labium & sternum; c. *T. okumae* n. sp. (dorsal view); d. Do, ventral view showing chelicerae, maxillae, labium & sternum.

Paratypes: 2 females, collected from the same locality and data were same as for the holotype.

Etymology: The species is named in honour of the Japanese Arachnologist late Dr. Chyuku Okuma who helped a lot in my research on the tetragnathids of Bangladesh.

Distribution: Bangladesh: Village South Shikerpur, District Jhenaidah (Type locality).

Remarks: The species *T. okumae* n. sp. appears close to *T. boydi* Cambridge in general appearance but stands distinct in the following characters ----

1. Cephalothorax broad medially with distinct median fovea and cervical furrows.
2. Cheliceral fang basally with black band.
3. Abdominal dorsum with scaly decoration and
4. Typical female genitalia or epigynum.

The species, is therefore, described as new to science.

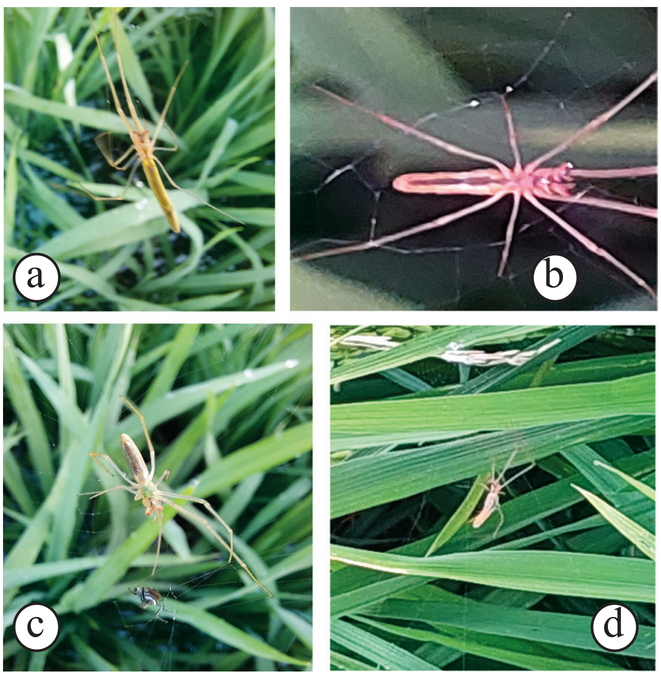

Fig. 4 (a, b, c, d) Illustration of the web-building behaviour of *Tetragnatha okumae* n.sp.

Web-building behaviour of *Tetragnatha okumae* n. sp. : The species *T. okumae* n. sp. is an orb-weaver long-jawed spider commonly found in different rice-fields of Village South Shikerpur and Bamonail, district Jhenaidah, Bangladesh. It can spin a typical geometric web within rice-plants during dusk. During building the web, first the spider secrets the threads from the spinnerets which it catches by the metatarsal spines and trichobothria by which they first connect it to the rice-plants. After completion of lateral connections, the spider then moves in circular way over the threads and spin the circular web-lines by their metatarsal spines. Thus, a circular or semi-circular orb-web is formed. After completion of construction, the spider stays below the web directing the ventral side upward (Fig. 4a-d).

The spider thus stays whole day and consume the prey insect pests continually. Their foods composed of different types of small moths, green leaf hoppers (GLH), brown plant hoppers (BPH), aphids etc. and the numbers of insect pests caught by the webs are more than their expectations. It was observed that a mature long-jawed spider can consume more than 30 small insect pests per day.

CONCLUSION

In the taxonomic history of rice-plant inhabiting long-jawed spiders of Bangladesh (Biswas 2009; Biswas and Raychaudhuri 1996; Okuma *et al.*1993), it is found that *T. okumae* n. sp. is new and *T. boydi* Cambridge is a new record for the area of present study. From the earlier description it is found that there are some variations with the previous ones (in colour, shape, size etc.) which distinctly identify the present species.

Both these species of spiders are orb-weavers and predatory in habit. They consume many kinds of small pest insects of different crop-field ecosystems by their webs. Thus, they help as an important biological control agent in the pest management system of different crops of Bangladesh. Therefore, conservation of these important predators is necessary for crop cultivation.

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SEASONAL INCIDENCE AND DAMAGE SEVERITY OF MAJOR INSECT PESTS ON BORO RICE IN KHULNA AND SATKHIRA DISTRICTS OF BANGLADESH

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ABSTRACT

Study was conducted at farmers boro rice field in Khulna and Satkhira districts of Bangladesh to find out the incidence and damage of stem borer, leaf folder and BPH at different growth stages of rice during December 2023 to June 2024. Results revealed that the highest number of white stem borer larvae was recorded from Asashuni upazila and the lowest was from Koyra. The highest number of dead heart symptoms was found in Satkhira sadar and the lowest in Paikgasa. The highest number of white head was recorded from Dumuria upazila and the lowest was from Kaliganj. At 40 DAT, the highest number of stem borer larva was found in Koyra (1.4/10 hills) and the lowest number of larva was recorded from Paikgasa (0.4/10 hills). The highest number of dead heart symptoms was recorded from Sathkhira sadar (1.4/10 hills). At 60 DAT, the highest number of stem borer larva was found in Assashuni (0.8/10 hills), the highest number of moth was recorded from Kaligonj (2/10 hills) and the lowest was from Sathkhira sadar (0.8/10 hills). The highest number of dead heart symptoms was recorded from Kaligonj (2.4/10 hills) and the lowest was in Sathkhira sadar (0.8/10 hills). At 90 DAT, the highest incidence of rice stem borer larva (2.8/10 hills) and moth (3/10 hills) was observed in Paikgasa. The highest number of white head damage was recorded in Paikgasa (3.2/10 hills) and the lowest was in Koyra (1.4/10 hills). At 110 DAT, the highest incidence of rice stem borer larva was observed in Paikgasa (2.8/10 hills) but the highest number of stem borer moth was recorded in Assashuni (1.8/10 hills) and the lowest was in Sathkhira (1.4/10hills). The highest number of white head damage was recorded in Kaligonj (4.4/10 hills) and the lowest was in Sathkhira sadar (1.8/10 hills). In case of rice leaf folder, at 40 DAT, the highest number of leaf folder larva (2/10 hills) and folded leaves (0.8/10 hills) was observed in Satkhira sadar followed by Assashuni (0.4/10 hills)

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but incidence of leaf folder larva and its damage were not found in Kaligonj, Koyra and Paikgasa. At 60 DAT, the highest number of leaf folder larva was observed in Satkhira sadar (1/10 hills) and the lowest number of leaf folder larva was in Koyra (0.4/10 hills) but the highest number of folded leaves was observed in Kaligonj (1.2/10 hills). No folded leaf was recorded from Dumuria. In case of BPH, the highest number (114/10 hills) of Brown Plant Hopper (BPH) was recorded from BR 26 rice field and the number infested tiller was 10. But from rod miniket rice, the number of BPH was 112 and the number of infested tiller was 5. No BPH was found in remaining 5 studied locations.

Keywords: White head, dead heart, WSB, BPH, rice leaf folder, YSB, seasonal incidence

INTRODUCTION

Rice (*Oryza sativa* L.) commonly known as Asian rice is a cereal food plant belongs to the family Gramineae and it is the main staple food of Bangladesh. Bangladesh is the 3rd rice production country in the world. In Bangladesh rice grows in three seasons like Aus, Aman and Boro. Boro is the best rice-growing season in Bangladesh showing moderate pest attack and highest yield with irrigation. In 2022-2023, the Bangladesh Bureau of Statistics (BBS 2024) reported a total Boro rice production of 20.77 million metric tons from 4.70 million hectares of land. The magnitude of insect damage varies depending on seasons, years and locations. The injury from feeding leads to damage symptoms of skeletonized and defoliated leaves, dead hearts, white heads, stunted and wilted plants and unfilled or pecky grains which ultimately affects the plant physiology leading to a considerable reduction in measurable yield, utility or economic return (Nasiruddin and Roy 2012). A total of 159 species of rice insect pests have been recorded (Rahman *et al*. 2018). Among these brown plant hopper (*Nilaparvata lugens*), rice stem borer (*Sciropophaga* spp.), green leafhopper (*Nephotettix* spp.), white-backed plant hopper (*Sogatella furcifera*), rice gall midge (*Orseolia oryzae*), rice hispa (*Dicladispa armigera*), and rice leaf folder (*Cnaphalocrocis medinalis*) are the major pests (Alam 2013, Nasiruddin and Roy 2012, BRRI 2009). Rice stem borer can cause 95% yield loss and leaf folder can cause 63 to 80% yield loss. Some insects act as vectors and transmit viral diseases in rice crop and cause colossal yield loss. In South and South East Asia, rice is grown in warm, humid environment which are favorable for the survival and spread of key insect pests such as yellow stem borer, leaf folders, brown plant-hoppers and green leaf-hoppers (Gianessi 2014). A group of entomologists have been surveying the rice insect pests from several agro-ecological zones considering different rice crops, growing seasons and growth stages (BRRI 2014). Rice crop is attacked by several insect pests from seedling to harvest, which cause severe yield loss in one region of the country of Bangladesh. The yellow stem borer, *Scirpophaga incertulas* (Walker) is the principle devastator causing 'dead heart' and 'white ear' leading to major economic damage (Satpathi *et al.* 2012). The rice leaf folder, *Cnaphalocrocis medinalis* (Guenee), so far, was considered as a minor pest, has assumed major pest status during the last two decades (Nanda *et al.* 2000). BPH cause orange-yellowish leaves before turning brown and dry and this condition is called hopper burn that kills the plant. YSB feed upon tillers and causes dead hearts or drying of the central tiller, during vegetative stage; and causes whiteheads at reproductive stage. Generally, rice growers do not apply insecticides in proper doses or appropriate chemical to control those insect pests. This often led to severe reduction of natural enemies. Population dynamics of insect pest and natural enemies in different rice growing seasons could help us to understand incidence pattern of major insect pest as well as their natural enemies which could facilitate biological control rather than chemical control. In general, the fauna which are harmful to rice plant and cause economic loss in paddy fields are termed as insect pests of rice while the fauna which acts as biological control agents of those harmful insect pests are known as beneficial insects (Khan 2013). Moreover, incidence of insect pests and abundance of their natural enemies vary greatly depending on climate and crop growing conditions of each location. For this reason, there was no scientific survey and study on major insect pest of rice basically insect pest of boro in Satkhira and Khulna, coastal districts of Bangladesh. Considering above facts, the present study was undertaken to record the major insect pests in boro season and their incidence and damage in Satkhira and Khulna districts of Bangladesh.

MATERIALS AND METHODS

Figure 1 illustrated the geographical areas of coastal region of Khulna and Satkhira districts of Bangladesh. To study the incidence of major insect pests and their infestation on rice, roving survey was carried out in 30 fields of Satkhira and Khulna districts where 5 from Satkhira sadar, 5 from Assashuni, 5 from Kaligonj upazila of Satkhira district and 5 from Dumuria,5 from Paikgasa and 5 from Koyra upazila of Khulna district during January to April 2024. Satkhira and Khulna districts were under the AEZ -no. 11 and 13. This area is High ganges Flood plain area and Ganges Tidal Flood plain area and is 2 m elevation from sea level mainly cropping pattern and diversity totally differ from other area of AEZ of Bangladesh. In each upazila 5 fields were inspected at different crop growth stages of the crop. In this study, the random samplings of ten hills were carried out for the purpose of population fluctuation of the BPH, RSB, RLF and RGM in the 30 rice fields. These plants were observed regularly at 20 days interval at different growth stages of rice. The stage of eggs, larvae, nymph and adult of insect population of BPH, RSB, RLF and RGM in the 30 rice fields among 6 upazilas of two districts was recorded per hill starting from the seedling stage till the harvest of the rice plant. Observations were taken from 10 randomly selected plants from each field at 7.00 - 10.00 am and 4.00-6.00 pm during seedling (at 20 DAS), vegetative (at 40 DAS), flowering (at 60 DAS), dough stage (at 90 DAS) and maturity or harvesting (at 110 DAS) stages of rice plant. The insect species from rice fields were collected by hand picking and with a fine nylon cloth sweep net (25 cm dia.). Sweeping was done from the plant canopy level including the inter spaces between plants as well as close to basal region as far as possible. In each field, 20 complete sweeps were made to collect the

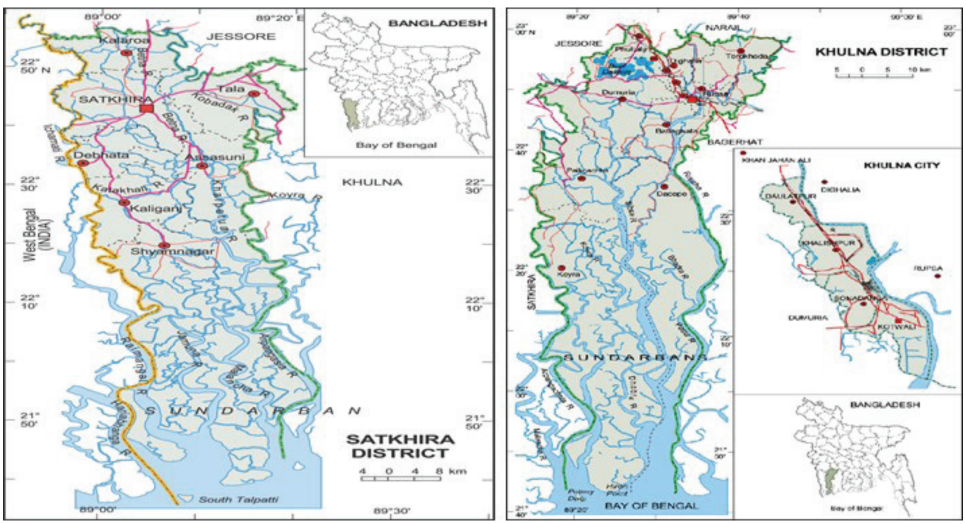

Fig. 1. Geographical area of Coastal region of Khulna and Satkhira districts of Bangladesh

insect species from each growth stage at 5 growth phase. Sweeping was done in the morning from 9:00 to 11:00 am in all the experimental plots. Data were recorded on the number of nymph and adult of BPH/plant, number of leaf folder and larvae/10 plant, number of folded leaves/10 plants, and number of larvae of rice stem borer/per plant; number of white heart/dead-heart, number of infested and healthy panicle/10 randomly selected plants of each plot. Data were analyzed statistically using SPSS and MS Excel programs.

RESULTS AND DISCUSSION

Incidence and damage of white rice stem borer and yellow rice stem borer: The highest number larvae of white stem borer was recorded from Asashuni upazila followed by Kaliganj and Satkhira sadar while the lowest was from Koyra followed Paikgasa and Dumoria upazila of Khulna district. In case of adult moth, the highest number moth was recorded from Paikgasa followed by Satkhira sadar and Dumuria upazila while the lowest was from Asashuni followed by Kaliganj and Koyra. The highest number of white head symptoms was observed from Dumuria upazila followed by Paikgasa and Koyra where the lowest was observed from Satkhira sadar followed by Asashuni and Kaliganj. The highest number of dead heart symptoms was found at Satkhira sadar followed by Asashuni and Dumuria while the lowest was in Paikgasa followed by Koyra and Kaliganj. In case of yellow stem borer, the number of larvae was lower than that of white stem borer in all locations but the adult moth was maximum in Koyra upazila followed by Satkhira sadar, Paikgasa and Dumuria while the lowest was in Asashuni followed by Kaliganj. In case of damage symptoms, the highest number of white head was recorded from Dumuria upazila followed by Koyra and Satkhira sadar while the lowest was from Kaliganj followed by Asashuni and Paikgasa. The number of dead heart symptoms by yellow stem borer was lower than that of white stem borer in all locations (Fig. 2).

Incidence and damage of rice stem borer at 40 DAT: The number of stem borer larva and dead heart symptom in different locations at 40 days after transplanting is shown in Fig. 3. The highest number of stem borer larva was found in Koyra (1.4/10 hills) followed by Sathkhira sadar (1.2/10 hills). The lowest number of larva was recorded from Paikgasa (0.4/10 hills) followed by Dumuria (0.8/10 hills). No larva was recorded from Kaligonj and Assashuni upazila. The highest number of dead

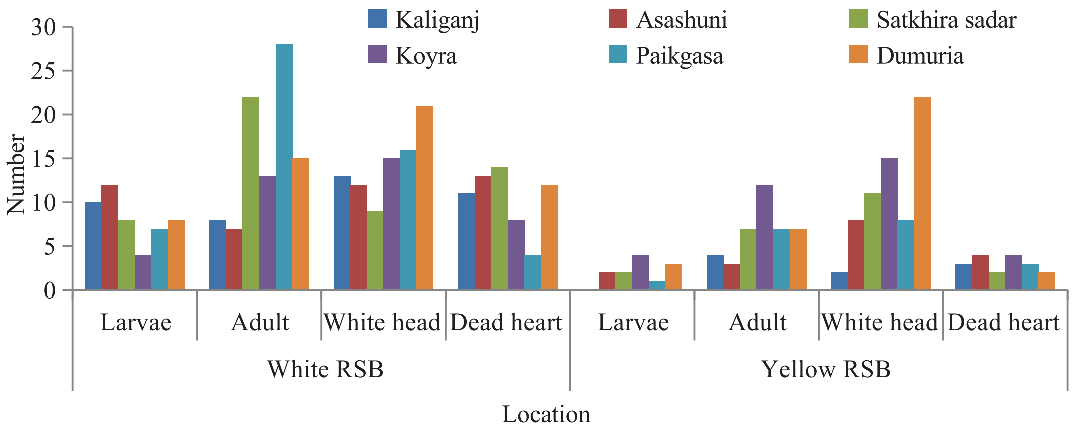

Fig. 2. Incidence and damage of white rice stem borer and yellow rice stem borer at different upazila of Satkhira and Khulna districts during January to April 2024

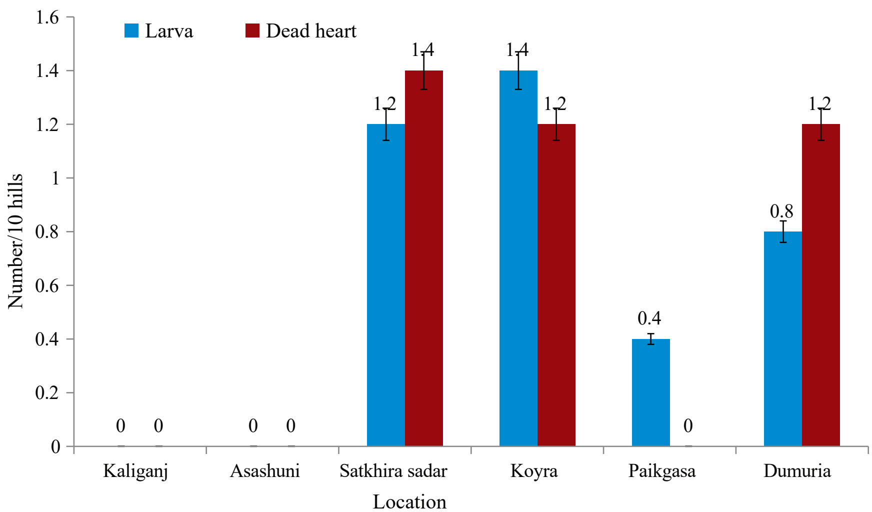

Fig. 3. Number of stem borer larva and dead heart symptom in different locations at 40 days after transplanting

heart symptoms was recorded from Sathkhira sadar (1.4/10 hills) followed by Koyra (1.2/10 hills) which was identical to that of Dumuria (1.2/10 hills). No dead damage was found in Kaligonj, Assashuni and Paikgasa upazila.

Incidence and damage of rice stem borer at 60 DAT: The number of stem borer larva, moth and dead heart white head symptom in different locations at 60 days after transplanting is shown in Fig. 4. The highest number of stem borer larva was found in Assashuni (0.8/10 hills) and Sathkhira sadar (0.6/10 hills). No larva was recorded from other 4 study locations. The highest number of moth was recorded from Kaligonj (2/10 hills) followed by Paikgasa (1.8/10 hills) and the lowest was from Sathkhira sadar (0.8/10 hills) and was followed by Assashuni (1.4/10 hills). No moth was found in Koyra and Dumuria. The highest number of dead heart symptoms was recorded from Kaligonj (2.4/10 hills) followed by Assashuni (2.2/10 hills). The intermediate level of dead heart damage was observed in Koyra (1.4/10 hills) followed by Paikgasa (1.2/10 hills) which was identical to Dumuria and the lowest was in Sathkhira sadar (0.8/10 hills). No white head symptom was found in all locations.

Incidence and damage of rice stem borer at 90 DAT: The number of stem borer larva, moth and white head symptom in different locations at 90 days after transplanting is shown in Fig. 5. The highest incidence of rice stem borer larva was observed in Paikgasa (2.8/10 hills) followed by Dumuria (2/10 hills). No stem borer larva was found in Kaligonj, Assashuni, Sathkhira sadar and Koyra. The highest number of stem borer moth was recorded in Paikgasa (3/10 hills) followed by Dumuria (2.6/10 hills) and the lowest was in Sathkhira (1.4/10hills) while no moth was recorded from Kaligonj, Assashuni and Koyra. The highest number of white head damage was recorded in Paikgasa (3.2/10 hills) which was identical to

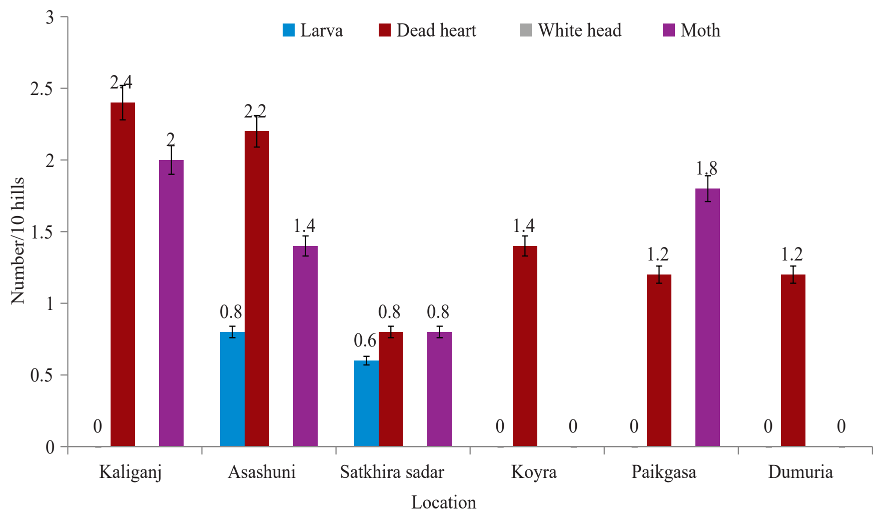

Fig. 4. Number of stem borer larva, moth, dead heart and white head symptom in different locations at 60 days after transplanting

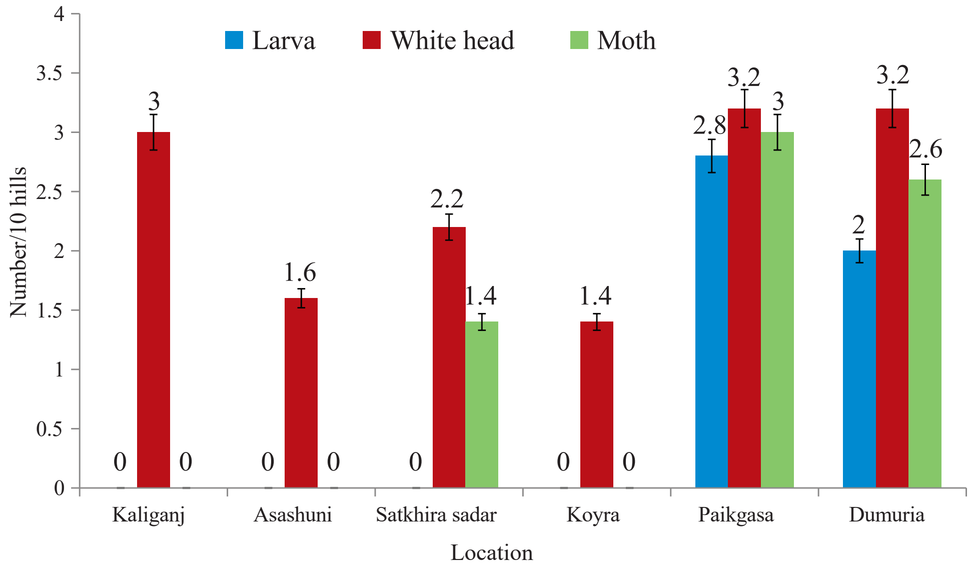

Fig. 5. Number of stem borer larva, moth and white head symptom in different locations at 90 days after transplanting

that of Dumuria (3.2/10 hills) followed by Kaligonj (3/10 hills). The intermediate level of white head damage was observed in Sathkhira sadar (2.2/10 hills) followed by Assashuni (1.6/10 hills) and the lowest was in Koyra (1.4/10 hills).

Incidence and damage of rice stem borer at 110 DAT: The number of stem borer larva, moth and white head symptom in different locations at 110 days after transplanting is shown in Fig. 6. The highest incidence of rice stem borer larva was observed in Paikgasa (2.8/10 hills) followed by Kaligonj (2/10 hills) which was identical to that of Dumuria (2/10 hills) while the lowest incidence was in Assashuni (0.2/10 hills) which was identical to Satkhira (0.2/10 hills). No incidence of stem borer was found in Koyra. The highest number of stem borer moth was recorded in Assashuni (1.8/10 hills) and the lowest was in Sathkhira (1.4/10hills) while no moth was recorded from Kaligonj, Koyra, Paikgasa and Dumuria. The highest number of white head damage was recorded in Kaligonj (4.4/10 hills) followed by Assashuni (3.2/10 hills) which was identical to that of Dumuria (3.2/10 hills). The intermediate level of white head damage was observed in Paikgasa (3.0/10 hills) followed by koyra (2.4/10 hills) and the lowest was in Sathkhira sadar (1.8/10 hills).

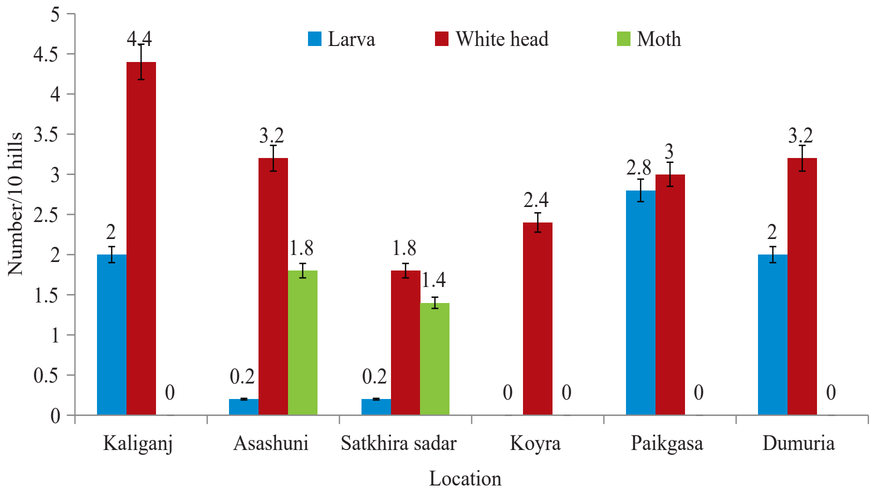

Fig. 6. Number of stem borer larva, moth and white head symptom in different locations at 110 days after transplanting

Incidence and damage of leaf folder at 40 DAT: The number of leaf folder larva and folded leaves in different locations at 40 days after transplanting is shown in Fig. 7. The highest number of leaf folder larva was observed in Satkhira sadar (2/10 hills) followed by Assashuni (0.4/10 hills) which was identical to that of Dumuria (0.4/10 hills). No incidence of leaf folder larva was found in Kaligonj, Koyra and Paikgasa. The highest number of folded leaves was also observed in Satkhira sadar (0.8/10 hills) followed by Dumuria (0.6/10 hills) and Assashuni (0.4/10 hills). No folded leaf was recorded from Kaligonj, Koyra and Paikgasa.

Incidence and damage of leaf folder at 60 DAT: The number of leaf folder larva and folded leaves in different locations at 60 days after transplanting is shown in Fig. 8. The highest number of leaf folder larva was observed in Satkhira sadar (1/10 hills) followed by Assashuni (0.8/10 hills) which was identical to that of Kaligonj (0.8/10 hills) while the lowest number of leaf folder larva was in Koyra (0.4/10 hills) followed by Paikgasa (0.6/10 hills). No incidence of leaf folder larva was in Dumuria. The highest number of folded leaves was observed in Kaligonj (1.2/10 hills) followed by Assashuni (0.8/10 hills) which was identical to those of Satkhira sadar (0.8/10 hills) and Paikgasa (0.8/10 hills). No folded leaf was recorded from Dumuria.

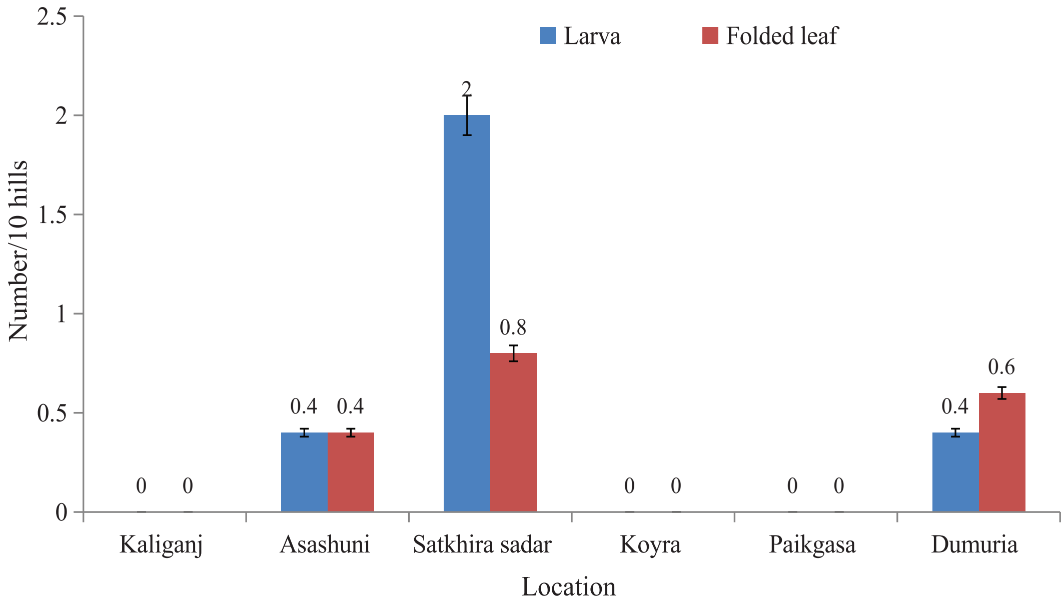

Fig. 7. Number of leaf folder larva and infested Folded leaf at 40 DAT in Satkhira and Khulna districts

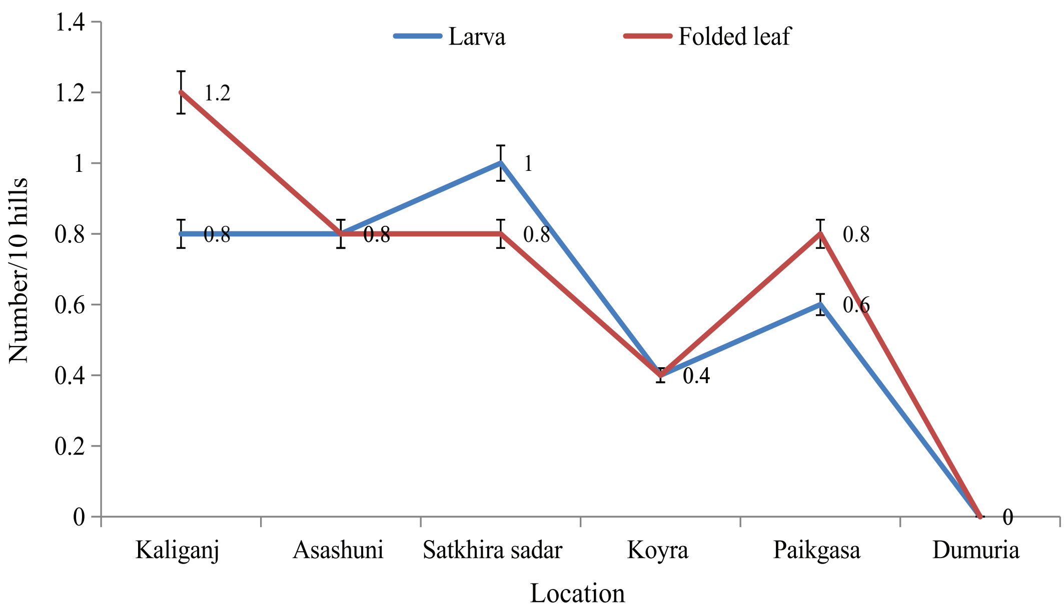

Fig. 8. Number of leaf folder larva and infested Folded leaf at 60 DAT in Satkhira and Khulna districts

Number of BPH and infested hills at 110 DAT: Figure 9 revealed that the highest number (114/10 hills) of Brown Plant Hopper (BPH) was recorded from BR 26 rice field and the number infested tiller was 10. In case of rod miniket rice, the number of BPH was 112 and the number of infested tiller was 5. No BPH was found in remaining 5 locations. The scenario of BPH infestation was sudden and unexpected due to climate change. In that time, suddenly heavy rain fall occurred at the end of April month.

Most of the rice plant parts are vulnerable to insect feeding from the time of sowing till harvesting. In present study, populations of stem borer, leaf folder and BPH, and their damages are measured at 6 upazila of Khulna and Satkhira districts. The number of stem borer larvae, dead heart and white head damaged symptoms varied among 6 locations. These variations may be due to changing climatic condition of the study sites. The warm and humid climate of Bangladesh is conductive to the proliferation of insect pests. The three rice crops grown under diverse ecological conditions are attacked throughout the growing periods by a number of insect pests. YSB is the most destructive insect pests of rice crop (Mahar *et al*. 1985) and responsible for an annual yield loss of 10-15% with local catastrophic outbreaks causing up to 60% damage (Daryaei 2005). Feeding of stem borers during the reproductive stage (panicle initiation to milk grain) causes

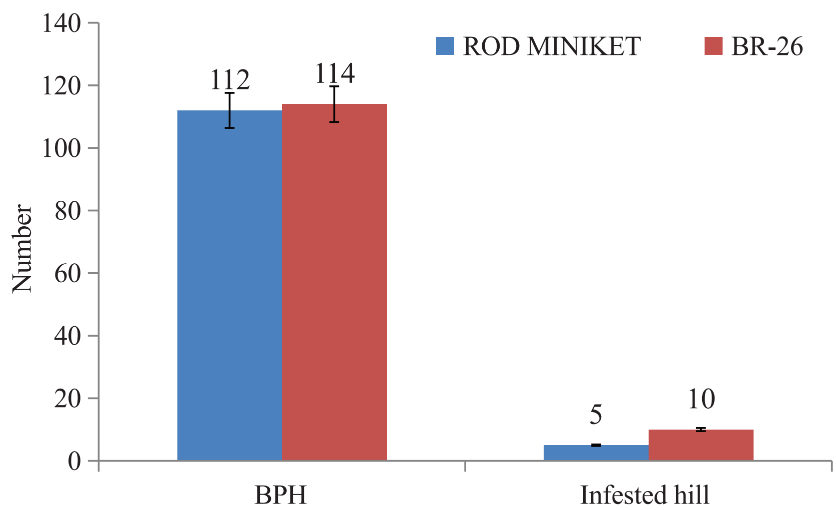

Fig. 9. Number of BPH and infested hills at 110 DAT in Satkhira sadar upazila

a severing of the developing panicle at its base. As a result, the panicle is unfilled and whitish in color, rather than filled with grain and brownish in color. Such empty panicles are called “whiteheads”. The average yield loss in rice have been accounted for 30% by stem borers, while plant hoppers 20%, gall midge 15%, leaf folder 10% and other pests 25% (Krishnaiah 2015). Sucking pests cause huge damage to rice by sucking plant sap, devitalizing plants and also act as vectors of several viral diseases (Mohanta *et al.* 2020). Plant hoppers such as brown plant hopper, *Nilaparvata lugens* (Stal.) infest the rice crop severely during tillering to panicle initiation stage. The brown plant hopper (BPH) is one of the serious pests responsible for large-scale devastation of rice crop, causing yield losses amounting to as high as 60% (Kumar *et al.* 2012, Srivastava *et al*. 2009). In producing more rice, farmers are using modern varieties, fertilizers, pesticides, water and other technologies intensively which have eventually changed the ecology and escalated pest proliferation (Parvin 2010). Population density of borer pest complex in different growth stages of the rice plant would be useful to decide appropriate time of insecticide application.

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EFFICACY EVALUATION OF METHYL EUGENOL-BASED STICKY TRAP FOR CAPTURING ORIENTAL FRUIT FLY, *BACTROCERA DORSALIS* IN LYCHEE ORCHARD

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ABSTRACT

Methyl eugenol containing yellow and blue sticky traps were evaluated for their efficacy in attracting and trapping fruit flies in two lychee orchards located in two different areas at Dinajpur Sadar, Bangladesh. In both type of traps, only the males of *Bactrocera dorsalis* were trapped. In both locations, yellow sticky traps captured more fruit flies (174.00 ± 19.41) than the blue sticky traps (114.75 ± 4.57). In both traps, the maximum number of fruit flies was trapped on the first day of trap setting, which continued but gradually decreased up to the last date of fruit fly collection (7th day). On the first day of trapping, the yellow trap captured 60 more fruit flies than the blue trap in Bontara, Luxmitola of Dinajpur Sadar. In Ukundi in Luxmitola of Dinajpur Sadar, on the first day, there was no difference differences but from day 2 to day 7, the yellow trap captured almost double as the blue trap. These findings suggest that the yellow trap is preferable to capture the fruit fly, *Bactrocera dorsalis,* when applied in combination with Methyl eugenol.

Keywords: Lychee, Efficacy, Methyl eugenol, Sticky trap, *Bactrocera dorsalis*

INTRODUCTION

Lychee, *Litchi chinensis* Sonn. (Sapindaceae: Sapindales), is a popular fruit in Bangladesh due to its refreshing taste, flavoured juice, and attractive colours. It can be consumed as fresh fruit or processed products (Singh *et al.* 2012). In Bangladesh, lychee cultivation includes more than 12545 ha of land with an annual production of more than 82,000 metric tons (BBS 2023). Due to high economic return and increased demand, its production is increasing day by day. Infestation

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of insects and mites is the major constraint for lychee cultivation. Lychee fruit borer *(Conopomorpha sinensis*), lychee leaf roller (*Pletypeplus aprobola*), and lychee mites (*Aceria litchi*) are the most common pests that interrupt the production and market value of the lychee in Bangladesh (Taher *et al.* 2023). In the northeastern part of Bangladesh, infestation of lychee stink bug, *Tessaratoma javanica* Thunberg (Hemiptera: Tessaratomidae) found to be prominent (Mondal *et al.* 2020). In Bangladesh, fruit fly infestation in lychee is not reported. However, the Mediterranean fruit fly (*Ceratitis capitata* Wied.), the Natal fruit fly (*Ceratitis rosa* Karsch), and the Marula fruit flies (*Ceratotis cosyra* Walker) are reported to infest lychee in Africa (Grove and De Beer 2014). In Hawaii, the oriental fruit fly, *Bactrocera dorsalis*, is reported to infest the lychee at the later ripening stage, causing deterioration of fruit flesh and secondary infection by bacteria and fungi (Kawabata and Nakamoto 2013).

The fruit fly belongs to the family Tephritidae under the order Diptera. Tephritidae includes around 5000 species under 500 genera. Fruit flies are the major pest of some commercially important fruits, especially mango, guava, lychee, apple, etc. (Doorenweerd *et al.* 2018; Ahmad *et al.* 2021; Jamil *et al.* 2022). Fruit flies are polyphagous and severely affect the fruits and vegetables, causing up to 30-100% loss (Mohanpuria *et al.* 2021). Female fruit flies deposit eggs in tender fruits using their telescopic ovipositors, and after emergence, the larvae feed on the fleshy part of the fruits. Various management practices have been implemented to control fruit fly pests, but chemical applications have been found effective (Ahmad *et al.* 2021). However, almost all the chemical insecticides lead to the development of insecticide resistance in insect pests (Ullah *et al.* 2019). These are also detrimental to non-target (Mollah *et al.* 2022; Mollah *et al.* 2017) and beneficial insects including predator (Mollah *et al.* 2012) and parasitoid (Mollah and Khatun 2023).

The bait application technique (BAT) using different attractants has become an essential component of fruit fly management programs worldwide (El-Sayed *et al.* 2009). Methyl eugenol (4-allyl-1,2-dimethoxybenzene-carboxylate) and cue lure (4-(p-acetoxyphenyl)-2-butanone) are two well-known and widely used attractants (Barclay *et al.* 2014). These are components of male annihilation techniques (MAT) which attract and capture the adult male flies before they mate with females, and therefore ensure the control of fruit flies in the target area for many years (Kim *et al.* 2019; Kim *et al.* 2018). In the present study, methyl eugenol-based attractant applied in yellow and blue coloured sticky traps. However, 0.5% abamectin was incorporated with the methyl eugenol to kill the captured flies. The objective of the study was to know the prevalence of fruit flies in the lychee orchard and to determine the role of sticky trap colour for attacking fruit flies, in addition to methyl eugenol.

MATERIALS AND METHODS

This study was conducted during June 2024 in two lychee orchard in different locations, namely Bontara and Ukundi in Luxmitola of Dinajpur Sadar, Bangladesh. This area located at 25.6333°N latitude and 88.6500°E longitude, having an elevation of 37 m above the sea level. Lychee was the main fruit plant in these two locations. A commercial bait named Zonatrac as an attractant was tested which is composed of methyl eugenol (35%) and abamectin (0.5%). Two types of sticky traps (10 cm × 25 cm), namely yellow sticky traps and blue sticky traps were used to capture and monitor the attracted fruit flies. Therefore, two combinations, namely Zonatrac in the yellow trap and Zonatrac in the blue trap, were used as treatment. Each combination was replicated thrice in both locations. Zonatrac was applied by dropping at two points in each sticky trap. A sticky trap containing the attractant 'Zonatrac' was hung in the canopy level (5 feet) in the branch of each lychee plant. One yellow and one blue trap were hung in two different branches of the same lychee tree. The experiment was conducted just after harvesting the lychee fruits. Fruit fly capture was recorded every day at 24 h interval and continued up to seven (7) days when some of the sticky trap was saturated with fruit flies and no or very few new fruit flies were captured. All raw data were analysed using Microsoft Excel, and graphs were prepared using SigmaPlot 12.5. All statistical analyses were performed using the R program.

RESULTS AND DISCUSSION

Speciality of 'Zonatrac' to capture *Bactrocera dorsalis*: In the Lychee orchard, males of the oriental fruit fly, *Bactrocera dorsalis* was captured in the eugenol based sticky traps (Fig. 1). Blue sticky traps captured only *Bactrocera dorsalis* (Fig. 1B) but few other Species found in yellow sticky trap (Fig. 1A). However, comparatively more *Bactrocera dorsalis* were captured in yellow sticky trap than the blue sticky trap.

Effect of sticky trap colour for trapping fruit flies: For location 1 (Bontara, Luxmitola, Dinajpur Sadar), the Color of the sticky trap significantly affects the capture of fruit flies ($P < 0.05$). On the first day of trap setting, a greater number of fruit flies were captured in the yellow trap (113 ± 5.66) than in the blue sticky trap (53 ± 4.24) (Fig. 2). This phenomena were also observed for other days, continuing up to the last day (7th day) of fruit fly trapping (187.5 ± 13.44 fruit flies in the yellow trap and 113.5 ± 4.95 fruit flies in the blue trap). However, for both cases, maximum number of fruit flies were trapping at the first day (113 ± 5.66 fruit fly in yellow trap and 53 ± 4.24 fruit fly in blue trap) of trap setting which gradually increased up to last day (7th day) of fruit fly trapping (187.5 ± 13.44 fruit fly in yellow trap and 113.5 ± 4.95 fruit fly in blue trap) (Fig. 2). Sowmiya *et al.* (2021) also reported that yellow color trap captured more oriental fruit flies, *Bactrocera dorsalis* as well as melon fruit fly, *Zeugodacus cucurbitae*. The reason might be due to the similar yellow color of the ripens fruits.

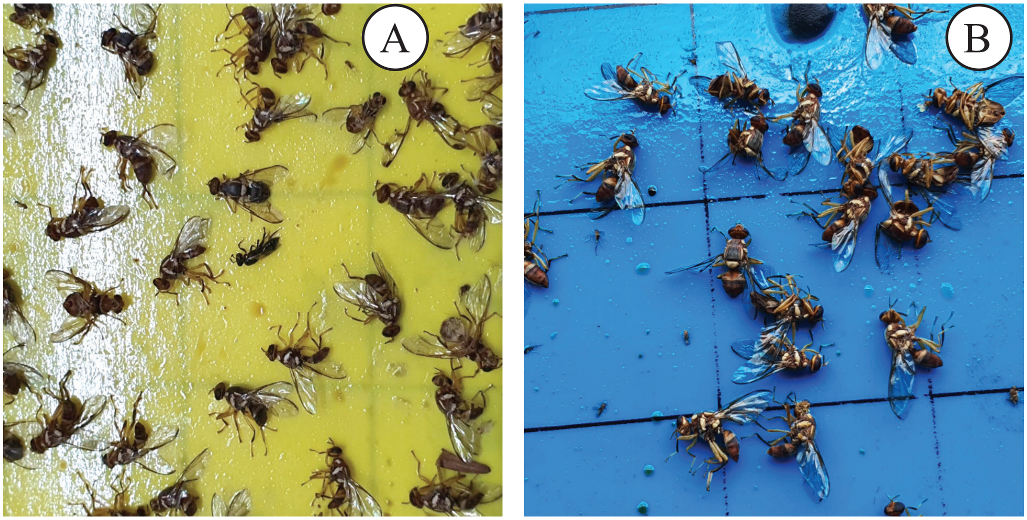

Fig. 1. *Bactrocera dorsalis* were captured more in yellow sticky trap with few other spp. (A). Blue sticky trap captured only *B. dorsalis* (B).

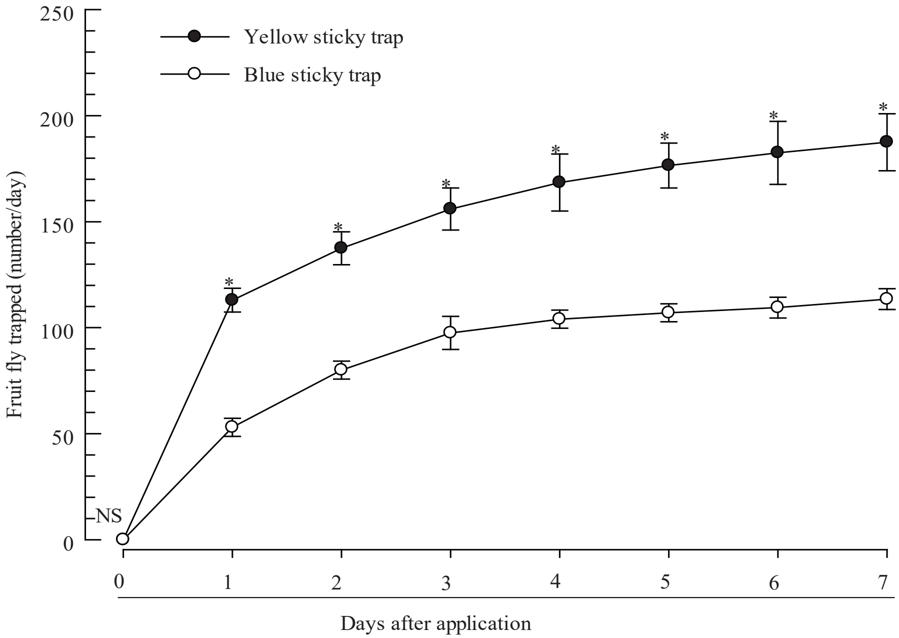

Fig. 2. Effect of yellow and blue sticky trap for capturing fruit flies in Bontara, Luxmitola, Dinajpur Sadar.

For location 2 (Ukundi, Luxmitola, Dinajpur Sadar), the color of the sticky trap also affects the capture of fruit flies (Fig. 3). On the first day of trap setting, capture of the yellow sticky trap (83.50 ± 3.54 fruit flies) was not significantly ($P < 0.05$) different from the capture of the blue sticky trap (84.50 ± 2.12 fruit flies). However, for day 2 significant ($P < 0.05$) difference were observed in fruit fly capture (114 ± 8.49 fruit fly in yellow trap and 101.50 ± 0.71 fruit fly in blue trap) and the same trends were observed up to the last day of trapping (7th day) (160.50 ± 14.85 fruit fly in yellow trap and 116 ± 5.66 fruit fly in blue trap) (Fig. 3). For both cases, maximum number of trappings were observed in first day (83.50 ± 3.54 fruit flies in yellow trap and 84.50 ± 2.12 fruit flies in blue trap) and increase gradually up to the last date (7th day) of trapping (160.50 ± 14.85 fruit fly in yellow trap and 116 ± 5.66 fruit fly in blue trap) (Fig. 3). From both locations, the mean number of fruit flies captured by the yellow trap (174.00 ± 19.41) was significantly ($P < 0.05$) more than the blue sticky trap (114.75 ± 4.57) (Figs. 4, 7).

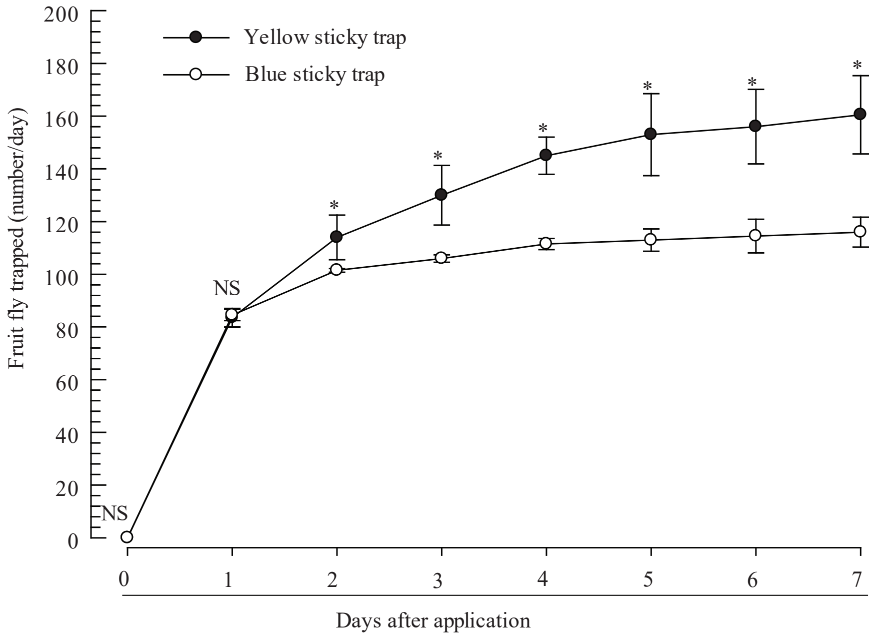

Fig. 3. Effect of yellow and blue sticky trap for capturing fruit flies in Ukundi, Luxmitola, Dinajpur Sadar.

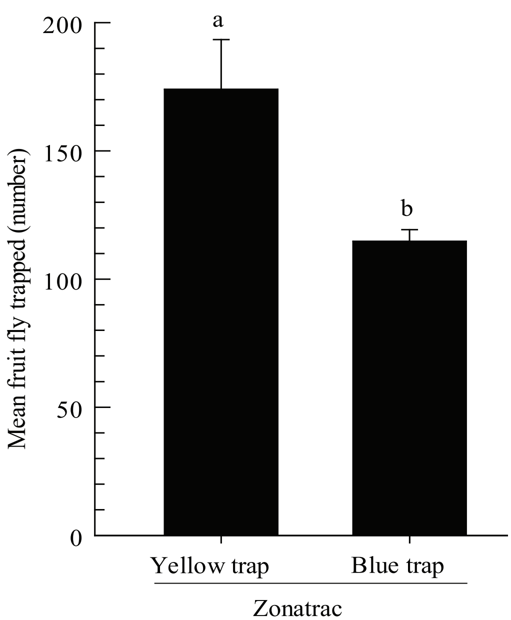

Fig. 4. Average trapping (Zonatrac) of fruit flies at two locations of Luxmitola, Dinajpur Sadar.

Comparative rate (trap/day) of fruit fly captured by the traps: In both locations, differences in the rate (capture/day) of fruit flies captured by the yellow trap and blue trap were observed. On most days, the yellow trap captured more fruit flies than the blue trap, although some exceptions exist. In location 1 (Bontara, Luxmitola, Dinajpur Sadar), maximum capture as well as difference in capture was observed on the first day (113 fruit flies by the yellow trap and 53 fruit flies by the blue trap) (Fig. 5A). However, the new capture of fruit flies decreased in the subsequent days. Capture of fruit flies in days 2, 3, 4, 5, 6, and 7 were 24.50 & 27.00, 18.50 & 17.50, 12.50 & 6.50, 8.00 & 3.00, 6.00 & 2.50, and 5.00 & 4.00, respectively, in yellow and blue traps (Fig. 5A). In location 2 (Ukundi, Luxmitola, Dinajpur Sadar), maximum capture in a day was observed for day 1 (83.50 in the yellow trap and 84.50 in the blue trap), where the blue trap captured 1 fruit fly more than the yellow trap (Fig. 5B). However, in the subsequent days, the per-day capture decreased gradually, but in every case, the yellow trap captured almost double compared to blue trap (Fig. 5B). Mean capture of fruit flies in days 2, 3, 4, 5, 6, and 7 were 30.50 & 12.00, 16.00 & 4.50, 15.00 & 5.50, 8.00 & 1.50, 3.00 & 1.50, and 4.50 & 1.50, respectively in yellow and blue sticky traps (Fig. 5B).

Differences in fruit flies captured by the traps: Differences were observed in the per-day capture of fruit flies by the yellow and blue traps. In location 1 (Bontara, Luxmitola, Dinajpur Sadar), the yellow trap captured 60 fruit flies more than the

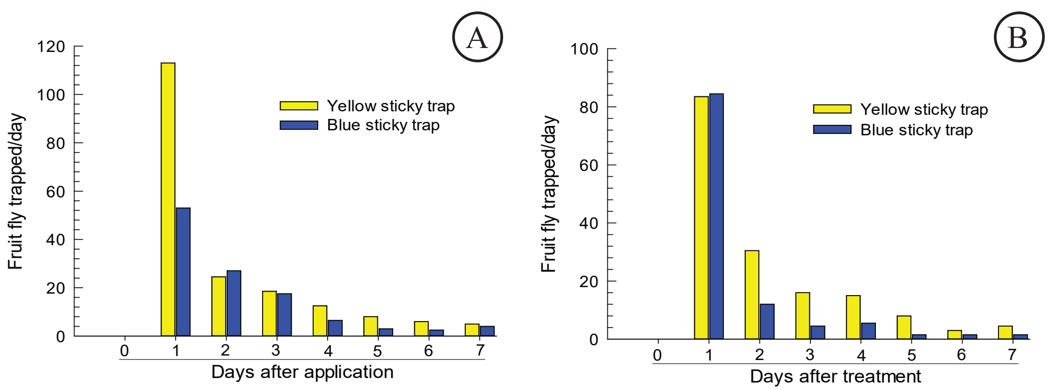

Fig. 5. Rate of fruit fly capture (trap/day) in sticky trap at two locations in Luxmitola, Dinajpur Sadar. (**A**) Bontara (**B**) Ukundi.

blue traps on the first day (Fig. 6A). However, the blue trap captured 2.5 fruit flies on day 2. In the subsequent days, yellow traps captured more than the blue traps, and it was 1, 6, 5, 3.5 & 1 in days 3, 4, 5, 6, and 7, respectively (Fig. 6A). In location 2 (Ukundi, Luxmitola, Dinajpur Sadar), the blue trap captured 1 more fruit fly than the yellow trap (Fig. 6B). However, in the subsequent days, the yellow trap captured more than the blue trap, and it was 18.5, 11.5, 9.5, 6.5, 1.5 & 3 more fruit flies on days 3, 4, 5, 6 & 7, respectively (Fig. 6B). Therefore, in both locations, the yellow traps captured more fruit flies than the blue traps (Fig. 7). Lizmah *et al.* (2025) reported that Methyl eugenol and yellow trap combination trapped the highest fruit flies than other combinations.

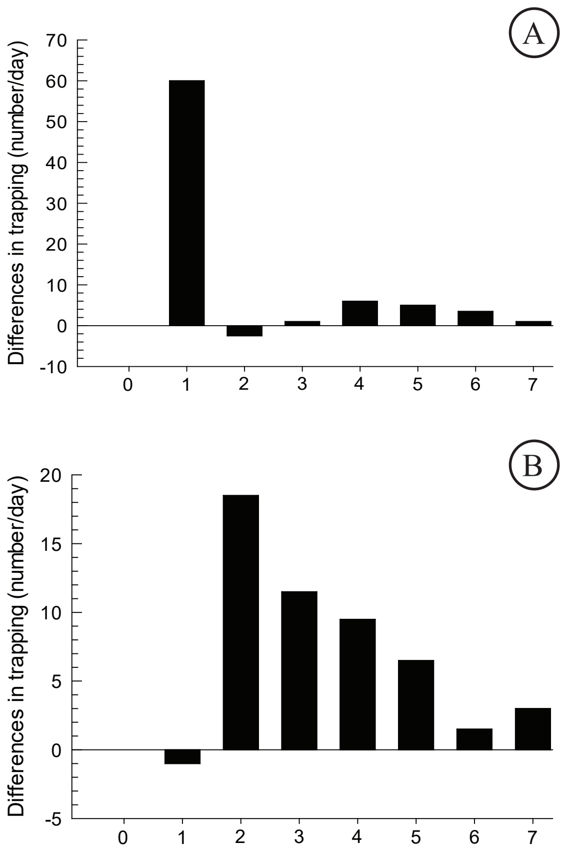

Fig. 6. More fruit flies were trapped in the yellow sticky trap than the blue trap at two locations in Luxmitola, Dinajpur Sadar. (A) Bontara (B) Ukundi.

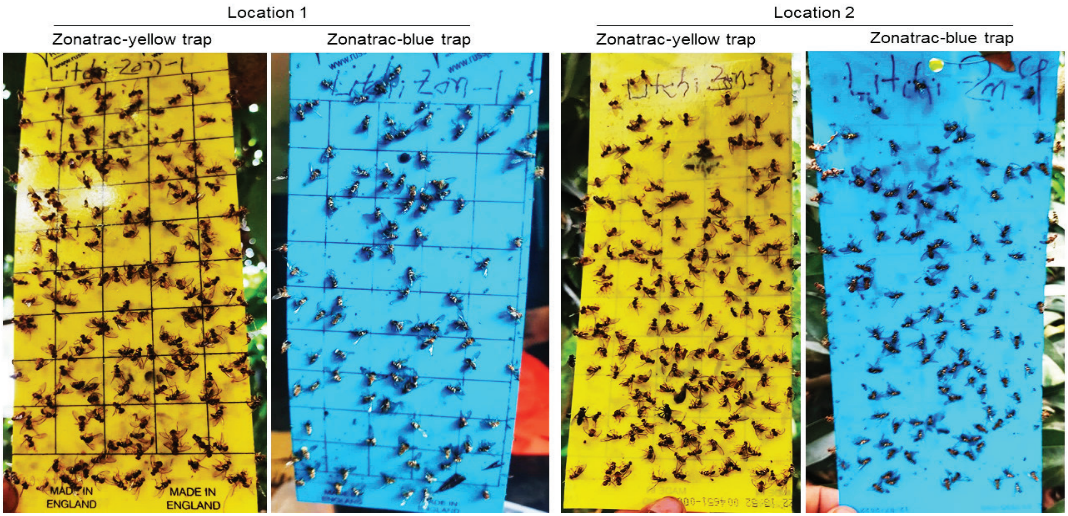

Fig. 7. Pictorial representation of comparative trapping of fruit flies in a yellow and blue sticky trap (Zonatrac) in locations 1 & 2.

CONCLUSION

Methyl eugenol based yellow and blue sticky traps captured only the male oriental fruit fly, *Bactrocera dorsalis*. However, very few other species were observed only in yellow trap. Yellow sticky traps captured more *Bactrocera dorsalis* than the blue traps in both areas. Yellow sticky traps also captured fruit flies very quickly.

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EFFICACY OF MULTI-COMPONENT INTEGRATED PEST MANAGEMENT STRATEGIES AGAINST KEY INSECT 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 four integrated pest management (IPM) packages combining mechanical, biological, and biorational components. Treatments included combinations of mechanical removal, pheromone trapping, and applications of new-generation bio-insecticides such as *Bacillus thuringiensis*, Spinosad (Success®, Sodium lauryl ether sulphate (Fizimite®), Matrine (Biotrin®), and *Celastrus angulatus* extract (Bio-Chamak®). All IPM packages significantly reduced populations of sucking pests including aphids, jassids, and whiteflies, as well as shoot and fruit infestation by *L. orbonalis*, compared with untreated control and farmers' conventional practices. Among them, IPM Package-2 (Mechanical control+Fizimite®+pheromone trapping+Spinomax®) and Package-3 (Mechanical control+Biotrin®+pheromone trapping+Bio-Chamak®) achieved the greatest pest suppression (≈76-74% reduction in shoot and fruit infestation) and resulted the highest marketable yields (27.0 and 26.7 t ha^{-1}, respectively). These treatments also provided superior marginal benefit-cost ratios (6.48-7.77), confirming their economic feasibility. The integration of mechanical, pheromone, and biorational tools offers a robust, residue-free alternative to pesticide-intensive management. Adoption of such bio-intensive IPM 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: *Leucinodes orbonalis*, jassids, whiteflies, aphids, biopesticides, pheromone trap

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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. However, its productivity and quality are severely constrained by a complex of insect pests that infest the crop from the nursery stage to harvest. Among these, the brinjal shoot and fruit borer (BSFB) (*Leucinodes orbonalis* Guenée) is considered to be the most destructive pest, capable of inflicting yield losses exceeding 70-85% in 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). 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.

The BSFB larvae bore into young shoots and developing fruits, disrupting the translocation of plant nutrients and water, which leads to shoot wilting, flower drop, and deformed fruits. 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).

In this context, the paradigm of Integrated Pest Management (IPM) offers a sustainable alternative to sole chemical dependence by integrating multiple eco-compatible components. Effective IPM combines mechanical removal of infested plant parts, biological and botanical insecticides, pheromone-based monitoring and mass trapping, and selective use of low-risk chemical molecules. Among recent advancements, new-generation biorational insecticides including plant-derived compounds such as *Celastrus angulatus* extract (Bio-chamak®), Matrine (Biotrin®), D-limonene (Bio-clean®), Sodium lauryl ether sulphate (Fizimite®) and microbial-based products like *Bacillus thuringiensis* 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 mechanical control and pheromone-based technologies in brinjal IPM remains poorly documented under Bangladesh agro-ecological conditions.

Therefore, the present study was designed to evaluate and compare the efficacy of four newly developed IPM packages, each combining different mechanical, biological, and biorational components, against the major insect pests of brinjal. The specific objectives were to (i) determine the comparative effectiveness of IPM packages in suppressing both sucking and borers pests, (ii) assess their influence on marketable yield and fruit infestation, and (iii) conduct a benefit-cost analysis 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 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 five 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 and integrated pest management packages: Five pest management regimes were evaluated with an untreated control (Table 1). Each IPM package was composed of different combinations of mechanical, biological, and biorational components.

Mechanical control consisted of regular removal and destruction of infested shoots and fruits at weekly intervals. Sex pheromone traps for BSFB were installed at 4-5 weeks after transplanting (WAT) at a density of 80 traps ha^{-1}, maintaining

Table 1. Details of multi-component IPM packages applied in the experiment

Treatments	Description of IPM Packages
T_1	**IPM package 1:** Mechanical control + D-limonene (Bio-clean® 5% SL @ 1 ml L^{-1} water) + Sex pheromone trapping + Spinosad (Success® 2.5 SC @ 1.2 ml L^{-1} water)
T_2	**IPM package 2:** Mechanical control + Sodium lauryl ether sulphate (Fizimite® 10% @ 1 ml L^{-1} water) + Sex pheromone trapping + *Bacillus thuringiensis* var. kurstaki (Bt) + Spinosad (Spinomax® @ 2 ml L^{-1} water)
T_3	**IPM package 3:** Mechanical control + Matrine (Biotrin® 0.5% AS @ 1.5 ml L^{-1} water) + Sex pheromone trapping + *Celastrus angulatus* extract (Bio-Chamak® 1% EW @ 2.5 ml L^{-1} water)
T_4	**IPM package 4:** Mechanical control + Afidopyropen (Sefina® 5 DC @ 2 ml L^{-1} water) + Sex pheromone trapping + Spinosad (Success® 2.5 SC @ 1.2 ml L^{-1} water)
T_5	Farmer's practice: Weekly spraying of Chlorantraniliprole + Thiamethoxam (Voliam Flexi® 300 SC @ 0.5 ml L^{-1} water)
	Untreated control (no pest management interventions)

12.5 m spacing between traps. Traps were positioned just above the crop canopy using bamboo stakes and monitored weekly throughout the cropping period. A total of three 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.

Description of new-generation biorational insecticides: The novel plant-derived bioactive compounds tested in this study included *Celastrus angulatus* extract (Bio-Chamak® 1% EW) and *Matrine* (Biotrin® 0.5% AS). *C. angulatus*, a traditional medicinal shrub native to East Asia, possesses potent insecticidal properties due to its rich content of sesquiterpenes, triterpenes, and flavonoids (Wei *et al*. 2009). The active compounds disrupt pest digestive systems, inhibit feeding, and induce starvation and mortality without causing cross-resistance (Wang *et al*. 2001). *Matrine*, an alkaloid extracted from *Sophora flavescens*, acts as a neuroactive compound that interferes with insect neurotransmission, offering broad-spectrum activity against both sucking and chewing pests. These products were included to evaluate their compatibility and field efficacy within integrated IPM systems.

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.

Shoot and fruit infestation by BSFB: For brinjal shoot and fruit borer, the number of healthy and infested shoots were recorded at 7-day intervals from ten randomly selected plants per plot. During each harvest, the total number of healthy and infested fruits were counted to estimate the percentage of fruit infestation using the formula:

Percent fruit infestation=Number of infested fruits/Total number of fruits×100

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

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

Pheromone trap monitoring: Adult male moths of BSFB captured in pheromone traps were counted weekly throughout the cropping season. The data were used to assess pest abundance and evaluate the trapping efficiency of the IPM packages.

Yield and economic analysis: Healthy fruits were harvested periodically from each plot, and total marketable yield (t ha^{-1}) was calculated. A detailed record of labor, pesticide, biopesticide, and pheromone trap costs was maintained for each treatment. The untreated control served as a reference for gross and net benefit estimation. The marginal benefit-cost ratio (MBCR) was computed following the method of Ali *et al*. (1996): MBCR=Additional benefit over control/Additional cost over control

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). 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 factors play a critical role in pest proliferation in brinjal ecosystems.

Effect of IPM packages on sucking pest suppression: Integrated pest management (IPM) packages 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). 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 IPM regimes. In Rabi 2021-22 season; the mean aphid, jassid, and whitefly populations were the lowest in IPM Package 4 (mechanical control + Sefina® 5 DC + sex pheromone trapping + Success® 2.5 SC ®) recording 1.93, 5.84, and 5.47 individuals per five leaves, respectively. These values were statistically comparable to IPM Package 3 (mechanical control + Biotrin® 0.5% AS + sex pheromone trapping + Bio-Chamak® 1% EW), which recorded 3.40, 6.02, and 5.59 per five leaves, respectively (Table 2). In contrast, the farmer's practice (weekly spray of Voliam Flexi® 300SC) showed moderate suppression, while the untreated control recorded the highest pest densities (9.09, 14.16, and 16.69 per five leaves, respectively). The highest reduction in aphid, jassid, and whitefly populations was achieved by IPM Package 4 (78.78%, 58.75%, and 67.23%, respectively), followed by IPM Package 3 (62.60%, 57.49%, and 66.50%). The farmer's practice resulted in comparatively lower reductions over control (67.77%, 45.34%, and 54.94%, respectively) (Table 3). Similar trend of results was also found in the Rabi 2020-21 season (Tables 2 & 3).

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

Cropping season	Management packages	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	IPM package-1	3.09 b	6.51 c	-	-	6.50 b
	IPM package-2	3.14 b	7.24 b	-	-	6.82 b
	IPM package-3	3.28 b	6.14 c	-	-	6.39 b
	IPM package- 4	1.81 c	5.74 c			5.26 c
	Farmer's practice	2.84 b	7.61 b	-	-	7.31 b
	Untreated Control	8.97 a	14.02 a	-	-	13.47 a
2021-22	IPM package-1	3.21 b	6.63 c	-	-	6.71 b
	IPM package-2	3.26 b	7.36 b	-	-	6.93 b
	IPM package-3	3.40 b	6.02 c	-	-	5.59 c
	IPM package- 4	1.93 c	5.84 c			5.47 c
	Farmer's practice	2.96 b	7.74 b	-	-	7.52 b
	Untreated Control	9.09 a	14.16 a	-	-	16.69 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 IPM packages across two cropping seasons

Management packages	Percent pest population reduction over untreated control					
	2020-21			2021-22		
	Aphid	Jassid	Whitefly	Aphid	Jassid	Whitefly
IPM package-1	65.55	53.57	51.74	65.68	53.17	59.80
IPM package-2	64.99	48.36	49.37	64.14	48.02	58.48
IPM package-3	63.43	56.21	52.56	62.60	57.49	66.50
IPM package-4	79.82	59.06	60.95	78.78	58.75	67.23
Farmer's practice	68.34	45.72	45.73	67.77	45.34	54.94
Untreated Control	-	-	-	-	-	-

Previous studies reported similar trends, 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 biorationals, when combined with pheromone-based and mechanical tactics, can serve as sustainable alternatives to synthetic pesticides in vegetable IPM systems.

Effect of IPM packages on shoot and fruit infestation: The brinjal shoot and fruit borer (BSFB) remained the dominant pest throughout the cropping period, and infestation levels differed significantly among treatments ($p \leq 0.05$) during both cropping seasons (2020-2021 and 2021–2022). The untreated control recorded the highest infestation, with 22.54% of shoots and 30.03% of fruits affected (Table 4). All IPM packages significantly suppressed pest damage. During Rabi 2021-22 season; the lowest shoot (5.34%) and fruit (7.83%) infestations were observed in IPM Package 2 (mechanical control + Fizimite® 10% + sex pheromone trapping + + Spinomax®), which was statistically comparable to IPM Package 3 (mechanical control + Biotrin® 0.5% AS + sex pheromone trapping + Bio-Chamak® 1% EW). These packages achieved 76.31% and 74.06% reduction in shoot infestation and 74.44% and 73.80% reduction over untreated control in fruit infestation, respectively. In Rabi 2020-21 season; the lowest shoot (6.39%) and fruit (8.01%) infestations were observed in IPM Package 3 (mechanical control + Biotrin® 0.5% AS + sex pheromone trapping + Bio-Chamak® 1% EW) which was statistically comparable to IPM Package 4 (mechanical control + Sefina® 5 DC + sex pheromone trapping + Success®). Overall, all four IPM packages reduced shoot and fruit infestation by approximately 70%, whereas the conventional farmer practice achieved only 19.40-22.31% and 24.59-27.34% reduction, respectively in both the cropping season. These results corroborate previous findings by Mamun *et al*. (2014) and Awal (2012), who reported substantial suppression of BSFB infestation through combined pheromone traps and spinosad sprays. Similarly, Noor *et al*. (2017) observed that spinosad-treated plots recorded only 2.45% fruit damage, corresponding to 92.44% reduction over the untreated control. The superior efficacy of the IPM packages in the present study is likely due to a synergistic effect, wherein pheromone traps disrupt mating while bioinsecticides (Spinosad and Bt) induce larval mortality, effectively targeting multiple pest stages.

Pheromone trap catches: Weekly monitoring indicated that the peak capture of BSFB male moths occurred between 60-80 days after transplanting (DAT), coinciding with the peak fruiting period. Treatments integrating both pheromone traps and bio-insecticides (T_1-T_4) captured a considerable number of adult male moths, with an average of 1.7 moths per trap per week (range: 3.0–13.0) in Rabi 2021-22 season whereas 1.3 moths per trap per week (range: 3.0–11.0) in Rabi 2020-21 season (Table 4). Mass trapping of males not only reduces mating success but also contributes to lower shoot and fruit infestation, emphasizing its critical role in multi-tactic IPM strategies.

Effect of IPM packages on yield: Significant differences in marketable fruit yield were observed among treatments ($p \leq 0.05$). All IPM packages produced higher yields compared to the untreated control (8.93- 9.41 t ha^{-1}). The highest yield was recorded in IPM Package 2 (27.0 t ha^{-1}), followed by IPM Package 3 (26.65 t ha^{-1}), IPM Package 4 (25.96 t ha^{-1}), and IPM Package 1 (24.91 t ha^{-1}) in the Rabi 2021-22 cropping season. In contrast, the conventional chemical-based farmer practice yielded only 13.72 t ha^{-1} (Table 4). But in the Rabi 2020-21 cropping season the highest yield was recorded in IPM Package 3 (26.01 t ha^{-1}), followed by IPM Package 4 (25.61 t ha^{-1}), IPM Package 2 (24.53 t ha^{-1}), and IPM Package 1 (23.91 t ha^{-1}). The yield enhancement under IPM treatments can be attributed to reduced pest pressure,

Table 4. Effect of different IPM packages on shoot and fruit infestation by BSFB and marketable yield of brinjal in two cropping seasons

Crop growing season	Treatments	Shoot infestation (%)	Reduction of shoot infestation over control (%)	Fruit infestation (%)	Reduction of fruit infestation over control (%)	Yield (t/ha)	Mean number of moths captured per trap per week (range)
2020-21	IPM package-1	7.73 c	68.08	9.98 c	65.04	23.91 b	1.30 (3-11)
	IPM package-2	7.34 c	69.69	8.31 d	71.81	24.53 b	
	IPM package-3	6.39 d	73.61	8.01 d	72.83	26.01 a	
	IPM package-4	6.74 d	72.17	8.42 d	71.43	25.61 a	
	Farmer's practice	19.40 b	19.90	24.59 b	16.59	12.59 c	-
	Untreated Control	24.22 a	-	29.48 a	-	8.93 d	
2021-22	IPM package-1	6.72 c	70.19	9.52 d	69.32	24.91 b	1.7 (3-13)
	IPM package-2	5.34 d	76.31	7.83 c	74.06	27.01 a	
	IPM package-3	5.76 d	74.44	8.05 c	73.80	26.65 ab	
	IPM package-4	6.29 c	72.09	8.67cd	72.06	25.96 b	
	Farmer's practice	17.51b	22.31	22.55 b	27.34	12.32 c	-
	Untreated Control	22.54 a	-	31.03a	-	9.41 d	

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.

Note: IPM Package 1: Mechanical control + Bio-clean® 5% SL + pheromone trap + Success® 2.5SC; IPM Package 2: Mechanical control + Fizimite® 10% + pheromone trap + Spinomax®; IPM Package 3: Mechanical control + Biotrin® 0.5%AS + pheromone trap + Bio-Chamak® 1% EW; IPM Package 4: Mechanical control + Sefina® 5 DC + pheromone trap + Success® 2.5SC; Farmer practice: weekly Voliam Flexi® 300 SC and untreated control.

improved fruit quality, and effective synchronization of mechanical, biological, and biorational control tactics. These results align with previous reports (Adiroubane and Raghuraman 2008, Awal 2012, Noor *et al*. 2017), which demonstrated that combining Spinosad or Oxymatrine with pheromone-based management enhances fruit marketability and reduces pest-induced losses.

Benefit-cost analysis: Economic assessment indicated that all IPM packages achieved substantially higher marginal benefit-cost ratios (MBCR) compared to the conventional farmer's practice (Table 5). The highest MBCR (7.77) was recorded from IPM Package 3, followed by IPM Package 1 (6.66), IPM Package 2 (6.48), and IPM Package 4 (5.68), whereas the farmer's chemical-based practice yielded a considerably lower MBCR of 1. 05. Although IPM Package 2 produced the higher gross return due to maximum marketable yield, its slightly elevated input costs resulted in a marginally lower MBCR relative to Package 1 (Table 5). These findings align with Awal (2012), who reported an MBCR of 7.15 for an IPM strategy integrating pheromone traps, Spinosad, and mechanical sanitation in brinjal. The results confirm that multi-component IPM approaches not only enhance productivity but also ensure economic sustainability by optimizing input-output efficiency.

Ecological and practical implications: The combination of mechanical control, pheromone trapping, and novel bio insecticides such as Afidopyropen, Matrine, *Celastrus angulatus* extract, Spinosad, and *Bacillus thuringiensis* demonstrates the efficacy of multi component strategies for sustainable brinjal pest management. 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 IPM 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.

Table 5. Economic evaluation of different IPM packages for management of major brinjal pests

Treatment/ packages	Average two years yield (t/ ha)	[1]Gross return (Tk./ha)	[2]Cost of Treatment (Tk./ha)	Net return (Tk./ha)	Adjusted net return (Tk./ha)	Marginal Benefit Cost Ratio (MBCR)
IPM package 1	24.41	366150	29840	336310	198760	6.66
IPM package 2	25.77	385500	33140	352360	214810	6.48
IPM package 3	26.33	394950	29350	365600	228050	7.77
IPM package 4	25.79	386850	37340	349510	211960	5.68
Farmer's practice	12.46	186900	23985	162915	25365	1.05
Untreated control	9.17	137550	0	137550	-	-

Cost of relevant materials/activities are as follows:

[1]Farmgate price of brinjal @ Tk. 15.00 per kg

[2][Cost of Bio-clean 5% SL: Tk. 2400/L; Cost of Success 2.5SC: @ Tk. 3000/L; Cost of Fizimite 10.0%: @ Tk. 4000/L; Cost of Spinomax: @ Tk 3000/L; Cost of Biotrin 0.5% AS @ Tk. 2300/L; Cost of Bio-chamak 1%EW @ Tk. 3000/L; Cost of Sefina 5DC @ Tk. 3500/Kg; Cost of Voliam flexi 300 SC: @ Tk. 5300/L; Cost of BSFB pheromone: @ 100 Tk./trap with installation; Cost of mechanical control: 2 laborers/ha @ Tk 450.00/ labor/day; Cost of spray: Two laborers/spray/ha @ Tk. 450.00/labor/day; Spray volume required: 500L /ha.].

CONCLUSION

The present study demonstrated that the integration of mechanical control, pheromone trapping, and new-generation biorational insecticides provides an effective, eco-friendly, and economically viable approach for the sustainable management of major insect pests of brinjal. All IPM packages significantly reduced the populations of sucking pests (aphid, jassid, and whitefly) and minimized shoot and fruit infestation by *L. orbonalis* compared to the untreated control and farmers' conventional chemical practice. Among the tested combinations, IPM package 3 (mechanical control + Biotrin® 0.5% AS + pheromone trapping + Bio-Chamak®), IPM package 1 (mechanical control + Bio-clean® 5% SL + sex pheromone trapping + Success® 2.5 SC) and IPM package 2 (mechanical control + Fizimite® 10% + pheromone trapping + Spinomax®) exhibited the highest suppression of pest populations and fruit infestation, coupled with superior marketable yields and favorable marginal benefit-cost ratios. 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. 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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FIRST MOLECULAR CONFIRMATION OF *BACTROCERA SCUTELLATA* AND PHYLOGENETIC ASSESSMENT OF MAJOR FRUIT FLY SPECIES IN BANGLADESH

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ABSTRACT

Fruit flies of the genus *Bactrocera* (Diptera: Tephritidae) are among the most destructive insect pests of fruits and vegetables in tropical and subtropical regions, causing significant economic losses in Bangladesh. Accurate identification of these species remains challenging because of their morphological similarity and the presence of cryptic taxa, while molecular data from Bangladesh are still limited. To fill this gap, extensive field surveys and laboratory analyses were conducted to determine the species composition, host associations, and infestation patterns of fruit flies across major agroecological regions of Bangladesh. Adult flies were collected using pheromone traps and reared from infested fruits and vegetables. Morphological identification followed standard taxonomic keys, and molecular confirmation was performed through cytochrome oxidase subunit I (COI) gene sequencing. Morphological observations revealed *Bactrocera cucurbitae* (melon fly) and *B. dorsalis* (oriental fruit fly) as the predominant species in all surveyed sites. COI sequencing of 27 specimens resolved four major clades: *B. dorsalis*, *B. tau* (pumpkin fruit fly), *B. cucurbitae*, and *B. scutellate* (striped fruit fly), with *B. scutellata* representing the first confirmed record in Bangladesh. A sample initially identified morphologically as *Ceratitis capitata* was molecularly confirmed as *B. tau*, highlighting the limitations of morphology-based identification. These results reaffirm the dominance of *B. dorsalis* and *B. cucurbitae* in Bangladeshi fruit and vegetable ecosystems and highlight the value of integrating molecular diagnostics with traditional taxonomy. The findings provide crucial baseline information for species-specific, sustainable fruit fly management and strengthen the molecular framework for future tephritid research in Bangladesh.

Keywords: Fruit fly, *Bactrocera* spp., molecular identification, DNA barcoding

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INTRODUCTION

Fruit flies (*Bactrocera* spp., Diptera: Tephritidae) are one of the most destructive groups of insect pests affecting fruit and vegetable production in tropical and subtropical regions worldwide. They inflict serious quantitative and qualitative losses in fruit and vegetable production, thereby threatening food security and export potential in many countries, including Bangladesh. The genus *Bactrocera* Macquart is recognized as the most economically important group within Tephritidae, comprising more than 650 described species, of which at least 50 are considered major agricultural pests (White *et al*. 1992, Drew and Romig 2013). These species exhibit wide geographical distribution, broad host ranges, rapid reproductive cycles, and strong adaptability to diverse agroecological conditions across tropical Asia, the Pacific, and Australia. Among the most notorious pest species, *Bactrocera dorsalis* (Hendel) (oriental fruit fly), *B. cucurbitae* (Coquillett) (melon fly), and *B. tryoni* (Froggatt) (Queensland fruit fly) are of major global concern. The *B. dorsalis* complex alone comprises over 85 morphologically similar species (Drew and Romig 2013), including five highly polyphagous pests of commercial importance. The oriental fruit fly, *B. dorsalis*, is native to tropical Asia and infests more than 270 host plants, including mango, guava, citrus, papaya, and other fruit crops (Allwood *et al*. 1999). The melon fly, *B. cucurbitae*, primarily attacks cucurbitaceous vegetables, but also infests papaya and other non-cucurbit hosts, with over 80 known hosts. On the Indian subcontinent, more than 118 fruit fly species have been documented as pests of fruits and vegetables (David and Ramani 2011, Drew and Romig 2013, David *et al*. 2016, and Leblanc *et al*. 2018).

In Bangladesh, *B. cucurbitae* and *B. dorsalis* are the two most widely distributed and economically damaging species, infesting over 16 cucurbit vegetables and a range of fruit crops including mango, guava, citrus, lemon, ber, and mandarin (Alim *et al*. 2012). Recent surveys have demonstrated the remarkable diversity of fruit flies in the country. A comprehensive six-year survey (2013-2018) identified 29 species, including 13 pest and 16 non-pest species, from both cultivated and forest habitats, with *B. dorsalis*, *B. zonata* (peach fruit fly), *Zeugodacus tau* (pumpkin fruit fly), and *Z. cucurbitae* emerging as dominant species (Leblanc *et al*. 2019). Earlier studies also recorded *B. nigrofemoralis*, *B. scutellata*, and several *Dacus* species, including eight new country records (Leblanc *et al*. 2013 & 2014), indicating expanding species diversity and possible species invasions. However, these findings were based primarily on morphological identification, which can be unreliable due to phenotypic variability and overlapping morphological traits within the *Bactrocera* species complex.

Traditional morphology-based taxonomy, though foundational in insect systematics, requires expert knowledge and specialized skills that are increasingly scarce. Morphological identification becomes particularly challenging in cryptic species complexes, immature life stages (larvae and pupae), and specimens with damaged diagnostic characters. These limitations can result in misidentification, misinterpretation of pest status, and ultimately, ineffective management interventions. Such taxonomic uncertainty has serious implications for species-specific pest management strategies, especially pheromone-based and baiting systems, since their efficacy depends on correct species identification. The introduction or emergence of new or cryptic fruit fly species could undermine existing Integrated Pest Management (IPM) programs developed for *B. cucurbitae* or *B. dorsalis* and lead to control failures.

Molecular techniques, particularly DNA barcoding, have revolutionized insect taxonomy by providing a rapid, reliable, and universal method for species identification. The mitochondrial cytochrome c oxidase I (COI) gene has proven to be an efficient and standardized marker for DNA barcoding in fruit flies (Hebert *et al*. 2003 and Blaxter 2003). Several molecular diagnostic techniques such as PCR-RFLP (Restriction Fragment Length Polymorphism), real-time PCR, and loop-mediated isothermal amplification (LAMP) have been successfully applied to discriminate closely related *Bactrocera* species (Sultana *et al*. 2022). These molecular tools overcome the limitations of traditional taxonomy and facilitate early detection of invasive species, monitoring of species complexes, and accurate pest diagnosis for biosecurity and quarantine purposes.

Despite the global advancement in molecular diagnostics, molecular-level studies on fruit fly taxonomy and population composition remain very limited in Bangladesh. Most existing information relies solely on morphological identification, and comprehensive molecular evidence on species diversity, distribution, and host association are lacking. Consequently, the understanding of *Bactrocera* species complexes and their ecological significance in the country remains incomplete. Therefore, the present study was undertaken to document the species composition, host association, and damage intensity of fruit flies infesting major fruits and vegetables across different agro-ecological zones of Bangladesh. Importantly, the study applied molecular characterization using mitochondrial COI gene-based DNA barcoding to identify economically important *Bactrocera* species. This research provides the first integrated morphological and molecular assessment of fruit fly species diversity in Bangladesh, offering novel insights into their taxonomy, ecology, and distribution. The findings will contribute to the refinement of species-specific IPM strategies, strengthen national fruit fly surveillance, and support sustainable pest management and biosecurity initiatives.

MATERIALS AND METHODS

Study sites and sampling design: Field surveys were conducted across eight agro-ecological regions of Bangladesh, encompassing diverse fruit and vegetable production systems. Sampling locations included BARI regional research stations and Multi-Location Testing Sites (MLTS) situated in Gazipur, Jamalpur, Ishwardi, Bogura, Rangpur, Jashore, Barishal, and Khagrachari (Table 1). Each site was selected to represent distinct agro-ecological conditions, cropping patterns, and host diversity.

Trapping and collection of fruit flies: The monitoring program employed ten pheromone lures specific to different fruit fly species, all of which were procured from Russell IPM Ltd., UK (Plate 1). BARI-designed water traps were placed in bottle gourd, bitter gourd, pumpkin, guava, mango, papaya, and citrus fields. Traps were installed depend upon the crops and maintained throughout the fruiting period. Traps were inspected every three days, and captured adult fruit flies were collected using fine forceps, washed, and preserved in 100% ethanol for laboratory examination. Specimens were labeled with location, date, host crop, and lure type and stored at -20°C for molecular analysis.

Morphological characterization and laboratory rearing: Infested fruits and vegetables were collected from the field and transported to the IPM Laboratory, Entomology Division, BARI, Gazipur, for rearing and identification. Infested samples were placed in plastic trays containing a 5-cm layer of sterilized sand to

Table 1. Sampling locations of fruit fly species with corresponding latitude and longitude

Sl.	Species	Location	Latitude	Longitude
1.	*Bactrocera cucurbitae*	Entomology Research Field, BARI, Gazipur	23.99941	90.42027
2.	*B. tau*	Regional Agricultural Research Station, BARI, Jamalpur	24.92302	89.95011
3.	*B. triyoni*	Regional Agricultural Research Station, BARI, Ishwardi, Pabna	24.12011	89.07770
4.	*B. zonata*	Multi Location Test Site (MLTS), OFRD, Sherpur, Bogura	24.85104	89.36972
5.	*B. papayae*	Regional Agricultural Research Station, BARI, Rangpur	25.92660	89.23426
6.	*B. dorsalis*	Regional Agricultural Research Station, BARI, Jashore	23.18535	89.18720
7.	*B. nigrofema*	Regional Agricultural Research Station, BARI, Barishal	22.78736	89.29257
8.	*Ceratitis capitata*	Hill Agricultural Research Station, BARI, Khagrachari	23.14167	92.00229
9.	*C. rosa*	Do		
10.	*C. cosyra*	Do		

facilitate pupation. Emerging pupae were collected daily and maintained in rearing cages (30 × 30 × 30 cm) under controlled laboratory conditions (25 ± 2°C, 60 ± 5% RH, and 12:12 h light: dark photoperiod). Adults emerging from pupae were morphologically identified based on diagnostic features including coloration and patterns of the head, thorax, abdomen, scutum, and wing venation. Identification was followed as *Bactrocera* based features following the descriptions given by Leblanc *et al*. 2013, 2014 & 2019, Hossain *et al*. 2019, Drew and Hancock (1994) and White and Elson-Harris (1992). Morphometric variations among species were also documented and compared.

DNA extraction, PCR amplification and phylogenetic analysis: Molecular confirmation of morphologically identified fruit fly species was conducted through DNA barcoding of the mitochondrial cytochrome oxidase I (COI) gene. Total genomic DNA was extracted from the thoracic tissue of individual adult flies using a commercial extraction kit (Promega USA) following the manufacturer's protocol with minor modifications to optimize yield and purity.

Plate 1. Ten pheromone lure types from Russell IPM, UK, were used for monitoring fruit fly species in the study

A total of 32 specimens from eight locations were subjected to PCR amplification using the universal COI primers LCO1490 (5′-GGTCAACAAATCATAAAGATATTG-3′) and HCO2198 (5′-TAAACTTCAGGGTGACCAAAAAATCA-3′). PCR reactions were performed in 25 µL volumes containing 12.5 µL of 2× PCR Master Mix, 1 µL of each primer (10 µM), 2 µL of template DNA, and 8.5 µL of nuclease-free water. Thermal cycling conditions were: initial denaturation at 94°C for 3 min; 39 cycles of 94°C for 1 min, 50°C for 1 min, and 72°C for 1 min; followed by a final extension at 72°C for 10 min. PCR products were visualized on 1% agarose gel electrophoresis in 0.5× Tris-borate-EDTA (TBE) buffer and stained with ethidium bromide. Amplicons showing clear and specific bands (~650 bp) were purified using a commercial PCR purification kit and sent to 1st BASE Laboratory (Malaysia) for Sanger sequencing. Obtained sequences were edited and aligned using BioEdit software, and homology searches were conducted using BLASTn (NCBI database) to confirm species identity. Phylogenetic analyses were performed in MEGA 7 software using the neighbor-joining (NJ) method with the Kimura 2-parameter (K2P) model. Confidence levels of tree nodes were assessed by 1,000 bootstrap replications. Reference COI sequences of closely related *Bactrocera* and *Ceratitis* species were retrieved from GenBank for comparative analysis.

RESULTS AND DISCUSSION

Morphological identification and variation: Morphological differentiation among adult *Bactrocera* species remains challenging due to high intraspecific variability, cryptic species complexes, and overlapping diagnostic characters (White *et al*. 1997, Drew and Romig 2013). In the present study, adult fruit flies reared from infested fruits and vegetables at the laboratory, revealed that the species *Bactrocera cucurbitae* (melon fly) and *B. dorsalis* (oriental fruit fly) were the most prevalent across the eight surveyed locations. Quantitative assessment indicated that *B. cucurbitae* was most abundant, followed by *B. dorsalis* and *B. zonata* (peach fruit fly).

Pheromone trap data confirmed these findings, showing that *B. cucurbitae* and *B. dorsalis* were widely distributed across all study sites. *Bactrocera cucurbitae* predominated in cucurbit vegetables, whereas *B. dorsalis* primarily infested fruit crops including guava (*Psidium guajava*), mango (*Mangifera indica*), and citrus (*Citrus* spp.). *Bactrocera zonata* was detected in traps but at lower abundance. Other species including *B. tau* (pumpkin fruit fly), *B. papayae* (papaya fruit fly), *B. tryoni* (Queensland fruit fly), and *B. nigrofemoralis* were occasionally captured, but their adult emergence from infested fruits was inconsistent, likely due to subtle morphological differences complicating species identification (Leblanc *et al*. 2013, Hossain *et al*. 2019). The Mediterranean fruit fly *Ceratitis capitata* was recorded once from Barishal; however, molecular analysis identified this specimen as *B. tau*, demonstrating the limitations of morphology-based identification within closely related tephritid species. No adults were captured in *Ceratitis rosa* and *Ceratitis cosyra (Walker)* traps during the survey works.

These results align with previous surveys in Bangladesh where *Bactrocera dorsalis*, *Zeugodacus cucurbitae* (*B. cucurbitae*), *Zeugodacus tau*, and *B. zonata* were consistently dominant (Leblanc *et al*. 2013, 2014 & 2019, and Sultana *et al*. 2022). Similarly, Rahman (2021) reported five major pest species including *B. dorsalis*, *Z. cucurbitae*, *Z. tau*, *B. zonata*, and *Dacus longicornis*, with *B. dorsalis* showing the highest abundance in Bandarban and Chapainawabganj district. These findings confirm the persistent dominance of *B. dorsalis* and *B. cucurbitae (Z. cucurbitae)* in fruit and vegetable agro-ecosystems in Bangladesh.

Molecular identification: Molecular characterization using mitochondrial cytochrome oxidase I (COI) gene sequencing validated the morphological identifications and provided additional insight into species diversity. Out of 32 samples, 27 produced high-quality COI sequences suitable for phylogenetic analysis. Neighbor-joining analysis grouped the sequences into four major *Bactrocera* clades: *B. dorsalis* (13 samples), *B. tau* (8 samples), *B. cucurbitae* (4 samples), and *B. scutellata* (2 samples) (Figs. 1-3). The *B. dorsalis* clade was clearly distinct from *B. tau* and *B. cucurbitae*, confirming the genetic separation reported in previous phylogenetic studies (Drew and Romig 2013, Schutze *et al*. 2015). Interestingly, two samples identified as *B. scutellate* (striped fruit fly) represent the first confirmed molecular records of this species in the agro-ecological regions of Bangladesh. This detection suggests a possible range expansion or introduction event, warranting continued monitoring. One specimen (LCO11) initially presumed to be *C. capitata* through morphological observation was later identified as *B. tau* based on COI sequence similarity (>99%) with GenBank accessions. Similar misidentifications have been reported in other studies, where *B. tau* was frequently confused with *B. cucurbitae* or *B. dorsalis* due to subtle morphological differences (San Jose *et al*. 2018, Hossain *et al*. 2019).

Earlier records from Bangladesh reported 10-15 tephritid fruit fly species (Alam 1967, Kapoor *et al*. 1980). More recent studies have expanded the known diversity to 29 species, including both pest and non-pest taxa (Leblanc *et al*. 2019). The present molecular results are consistent with these findings and further confirm that *B. dorsalis*, *B. tau*, and *B. cucurbitae* remain the predominant pest species affecting major fruits and vegetables across the country.

The integration of molecular methods alongside morphological identification proved essential for resolving cryptic species and confirming pest status. COI barcoding provides a rapid, reliable, and universally applicable tool, overcoming the limitations of traditional taxonomic approaches and supporting accurate species-level identification for effective pest management (Hebert *et al*. 2003a, b, Greenstone 2006). Overall, the findings confirm that the fruit fly fauna of Bangladesh is dominated by *B. dorsalis*, *Z. tau*, and *Z. cucurbitae*, with emerging records of *B. scutellata*. Accurate identification of these species using DNA barcoding is crucial for updating species distribution maps, refining pheromone lure deployment, and developing sustainable fruit fly management strategies suited to local agro-ecological conditions.

Fig. 1. Phylogenetic tree (traditional) based on mitochondrial Cytochrome Oxidase I (COI) gene sequences illustrating genetic relationships among *Bactrocera* species. The 27 isolates from this study are indicated by black diamonds. Bootstrap values from 1000 replicates are shown at the nodes.

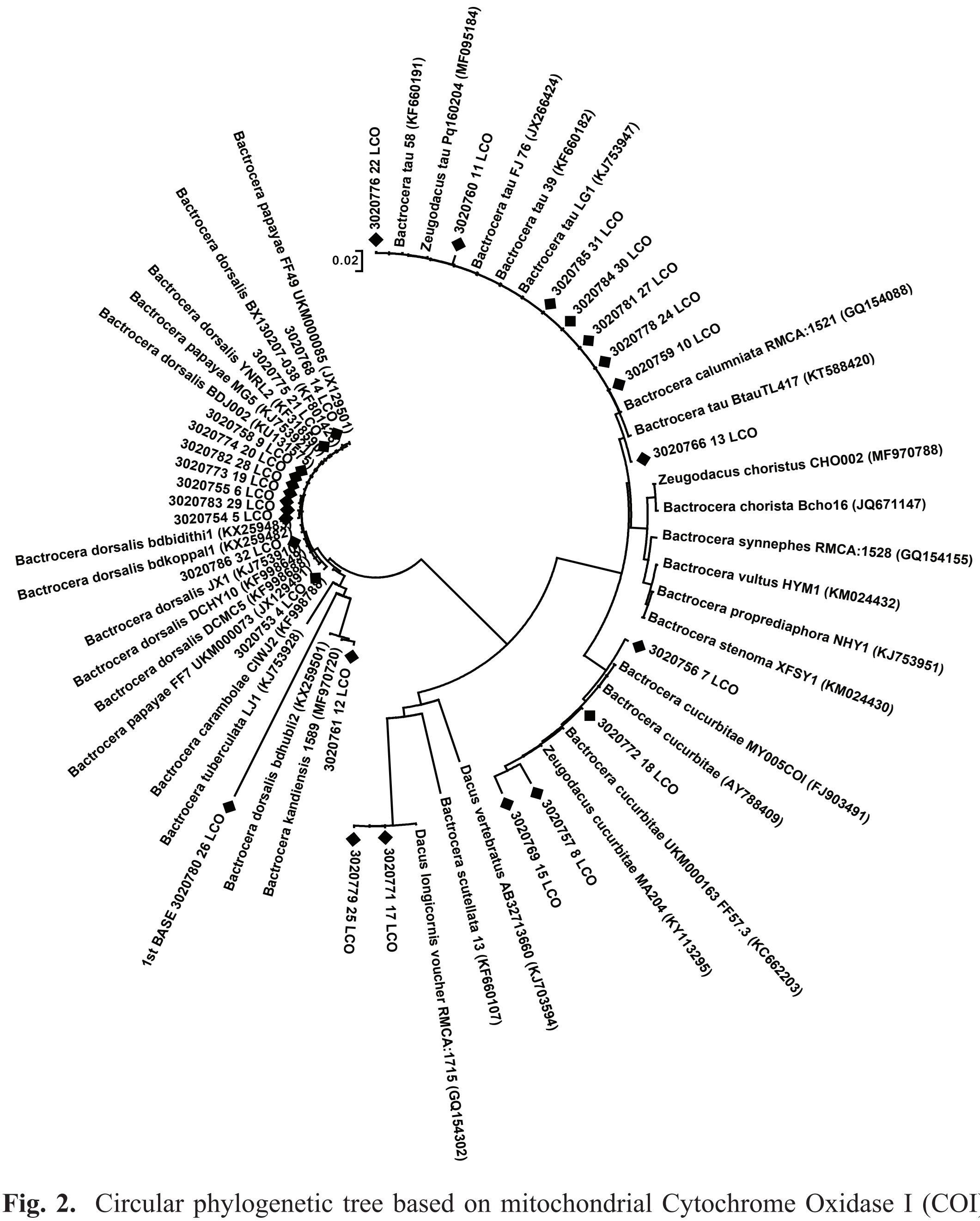

Fig. 2. Circular phylogenetic tree based on mitochondrial Cytochrome Oxidase I (COI) gene sequences showing the evolutionary relationships among *Bactrocera* species. The 27 isolates analyzed in this study are marked with black diamonds. Node support is indicated by bootstrap values from 1000 replicates.

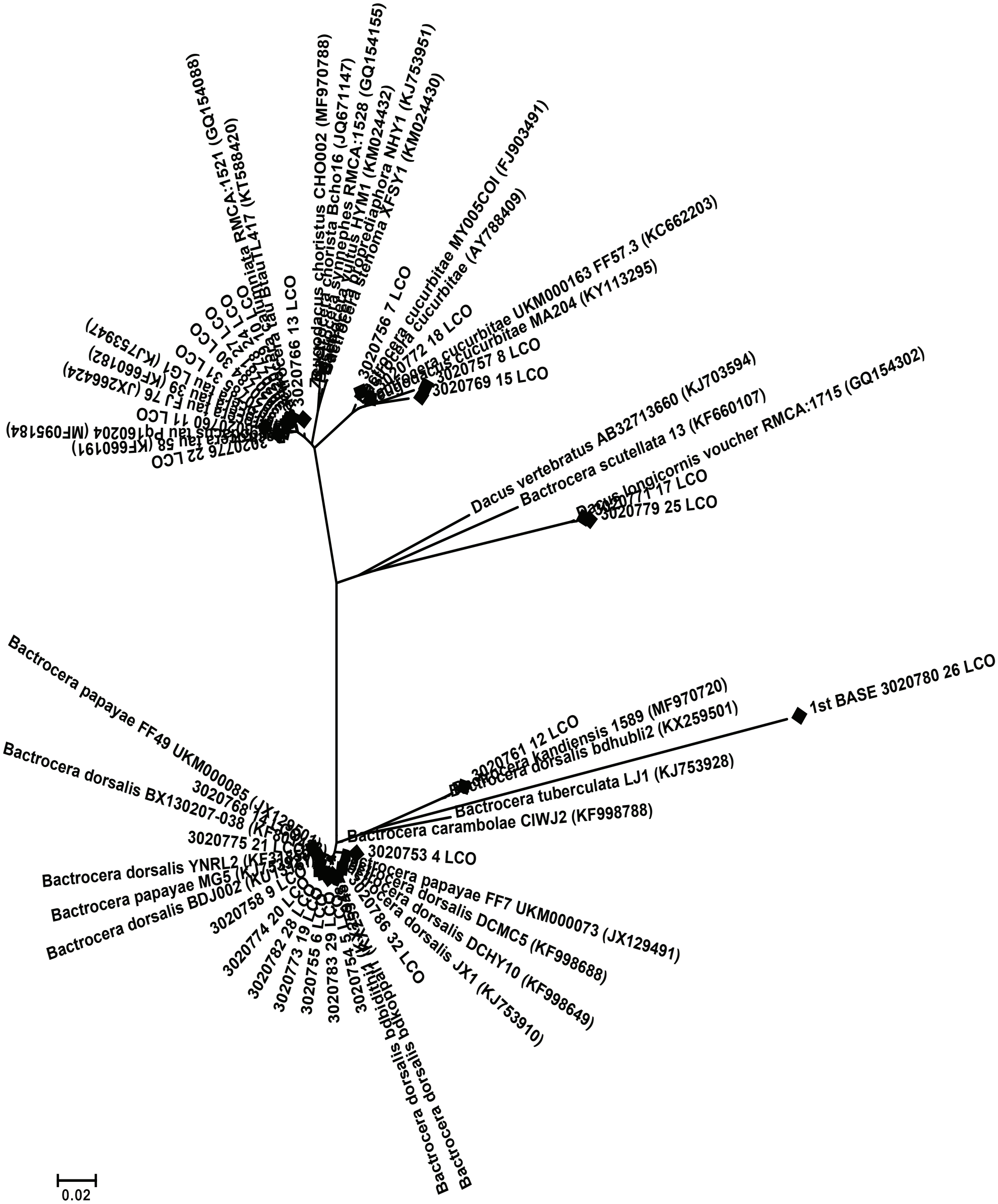

Fig. 3. Radial phylogenetic tree based on mitochondrial Cytochrome Oxidase I (COI) gene sequences depicting the phylogenetic relationships among *Bactrocera* species. The 27 isolates from this study are highlighted with black diamonds. Bootstrap support values from 1000 replicates are provided at each node.

CONCLUSION

This study provides a comprehensive assessment of fruit fly diversity, distribution, and host associations in Bangladesh. Morphological and molecular analyses confirmed that *Bactrocera dorsalis* and *B. cucurbitae (Zeugodacus cucurbitae)* remain the dominant pests in fruit and vegetable crops. The detection of *Bactrocera scutellata* represents the first confirmed record of this species in the country, indicating potential changes in fruit fly fauna and the need for ongoing monitoring. Misidentifications based on morphology underscore the importance of molecular identification methods for precise species determination. These findings offer essential insights for designing targeted and effective pest management strategies, including species specific interventions, and provide a foundation for future research on fruit fly ecology, host range, and integrated pest management in Bangladesh.

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EFFICACY OF THREE INDIGENOUS PLANT EXTRACTS AGAINST *MYZUS PERSICAE* SULZER IN LABORATORY CONDITION

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ABSTRACT

The experiments were conducted to study the efficacy of three indigenous plant extracts namely, ata (*Annona reticulata*), marigold (*Tagetus patula*) and chilli (*C. frutescens*) in n-hexane solvent for their residual toxicity and repellency effect against aphid, *M. persicae* in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur during the period from December 2024 to April 2025. The n-hexane solvent extracts of ata, marigold and chilli at three concentrations (1.0, 1.5 and 2.0 mg/ml) were maintained in each extract along with a control. The results showed that all tested plant extracts had toxic and repellent effects against aphid. Among the tested plant extracts, chilli extract showed the highest toxic effect (mortality, 58.98%) whereas marigold extract showed the lowest toxic effect (mortality, 44.29%). The order of the toxicity of the plant extracts were found as chilli>ata> marigold. Mortality percentage was also found directly proportional to the level of concentrations of plant extracts and to the exposure periods. Chilli extract showed the highest repellency **(**60.44%) but marigold showed the lowest repellency (43.56%).

Keywords: *M. persicae*, botanical extracts, toxicity, repellency, B:C ratio.

INTRODUCTION

Tomato (*Solanum lycopersicum*) is one of the most important vegetables in the world. It is the third most economically important vegetable crop after potato and onion. Major tomato producing countries in descending order include China, USA, India, Turkey and Egypt, respectively. Africa contributes 15% of the world's tomato production (FAOSTAT 2008). It is ranked second important vegetable crop after potato. Its fruits are eaten as raw or cooked. It is used in salad in homes and

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hotels. Large quantities are used to produce soup, juice, ketchup, paste and powder. The average yield of tomato was found 32.78 t/ha (Agong *et al*. 2003). It contains many compounds that play a pivotal role in the prevention of cancer, heart disease, and many other common health problems. It is a good source of vitamins A, B, and C and contains fat of 3.5%, mineral 1%, vitamin 0.5% glucose 32.1% soybean meal 29.8%.

Myzus persicae become a major pest of tomato and has a wide host range in beans, citrus, cucurbits, potato, tomato, sugar beet, and sugarcane in tropical and sub- tropical areas. Market price of tomato is high but the production is low due to the insect's infestation. Both nymphs and adults of *M. persicae* damage different crops from vegetative to fruiting stages and may cause yield loss up to 100% (Attia *et al.* 1986). When plants are heavily infested, leaf distortion and stunted growth commonly occur, and the end result is poor quality of fruits (York 1992). Moreover, it transmits about 20 non-persistent plant viruses (Kaiser 1979, Thottappilly and Rossel 1985).

Many preventive and effective chemical control measures have been reported to minimize the loss of fruits and vegetables due to insect attack. Among these, many researchers suggested that chemical insecticides are effective for their control. But chemical control of insects has been used with serious drawbacks. The synthetic insecticides are expensive and create many undesirable side effects such as (i) development of pesticides resistance in insect pests (ii) toxic residues in food and the environment (Rajappan *et al.* 2000) (iii) pests' resurgence and outbreak of secondary pests, (iv) destruction of natural enemies of pests and non-target organisms, (v) health hazards, (vi) environmental pollutions (Metcalf and Luckmann 1975). The development of cross and multi-resistant strains in many important insect species; resulting from the continuous use of chemical insecticides have been reported from all over the world (Dyte 1970, Dyte and Hallday 1985, Irshad and Jilani 1990, Zettler and Cuperus 1990, Zettler 1991). Botanical insecticide is an effective alternative pest management method because of its eco-friendly nature (Wang *et al.* 2012).

Plant based botanical insecticides can be effective and safe, which are locally available, cheap and less hazardous. Plants are a rich source of bioactive compounds having insecticidal activities (Arnason *et al.* 1989). The main advantages of botanicals are that these can be easily produced by farmers, less expensive, biodegradable, safe to apply and unique in action. Most of the botanical insecticides are non-hazardous and non-toxic to human. The earlier studies by different authors also established the successful actions of different plant parts and extracts against different major insect pests of Bangladesh (Talukder and Howse 1993, 1994a, 1994b, 1995a, 1995b, Haque and Husain 1993).

In spite of the above facts, few scientific research works were conducted to explore locally available plant materials for the management of harmful insect pest in vegetables. Therefore, the present study was undertaken with the following objectives:

- To determine the efficacy of three plant extracts against *M. Persicae*.
- To evaluate the repellency of three plant extracts against *M. Persicae*.

MATERIALS AND METHODS

The present study on the evaluation of toxicity and repellency effect of three indigenous plant extracts against aphid *Myzus persicae* was conducted in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during December 2016 to April 2017. The tested plants were ata (*Annona reticulata*), marigold (*Tagetes patula*) and chilli (*Capsicum frutescens*). Both the leaves and fruits were used for this experiment. The english name, scientific name, family name and the three botanical plants which, used in the research are given in the following Table 1.

Collection and preparation of botanical powders: The fresh plant leaves of ata marigold were collected around the HSTU campus and fruits of chilli were collected from basherhat, Dinajpur. After collection, they were kept in the laboratory for 7 days for air drying followed by one day sun drying before making powder. After dried they were made powder separately by an electric grinder in the laboratory. Later, the powder was stored separately at room temperature in air tight plastic pot for experimental use.

Collection and rearing of insects: The aphid, *Myzus persicae* was collected from the infested tomato field in HSTU campus and the stock insects were built

Table 1. List of plants and their parts used in the bioassay

English name	Scientific name	Family name	Plant parts used
Sweet soap	*Annona reticulata*	Annonaceae	Leaf
Marigold	*Tagetes patula*	Compositae	Leaf
Chilli	*Capsicum frutescens*	Solanaceae	Fruit

up in the laboratory of Department of Entomology. Then, the stock insects were reared in rectangular jars, setting in a growth chamber with ventilation at ambient temperature, RH and photoperiod in the laboratory. Fresh leaves were given time to time. The jars were covered with pieces of cloth and fastened with rubber bands to prevent insect escape.

Preparation of plant extracts: The prepared powdered materials were extracted in n-hexane solvent. Fifty grams of each category of powder were taken in a 600 ml beaker and mixed separately with 150 ml of n-hexane. Then the mixture was stirred for 30 minutes in a magnetic stirrer (600 rpm). The mixture was then allowed to stand for 72 hours in an electric shaker. Then, the mixture was filtered through a filter paper (Whatman no. 4) and allowed to evaporate the solvents. Finally, hard different coloured extracts were obtained. Then extracts were preserved in tightly corked vials separately and stored in a refrigerator for experimental use.

Preparation of doses: The crude extracts were weighed by electronic balance and dissolved in n-hexane solvent for making different concentrations. Different concentrations (2.0, 1.5, and 1.0 mg/ml) of each category of plant extracts were prepared by dissolving the stock solution in the n-hexane solvent. Prior to conducting study, pilot experiments were done to obtain the appropriate dose.

Insect bioassays: Insect bioassay were performed in laboratory conditions with ambient temperature of 28 ± 2°C and 75 ± 5% relative humidity to determine the direct toxicity and repellent effects on aphid.

Direct toxicity test: Residual film method was used for toxicity test of different plant extracts against *M. persicae* (Busvine 1971). Extracts collected from the different leaf and fruit were weighed and dissolved in the n–hexane solvent according to the proportion of the concentration of 2.0, 1.5 and 1.0 mg/ml. For insect bioassay 5 cm diameter Petri dishes were used. Then 1 ml plant extract of each dose was dropped separately on Petri dishes (5 cm) with the help of pipette, covering uniformly the whole area of the Petri dish internally. The Petri dishes were then kept open for sometimes to evaporate the solvents fully. When solvents were fully evaporated, 10 aphids (7 days old), *M. persicae* were released in each Petri dish. Three replications were made for each dose of all the 4 treatments. Only distilled water was used for the untreated control. The Petri dishes were then kept without food at 25°C ± 0.5°C in the laboratory and insect mortality were recorded at 12, 24, 36, 48, 60 and 72 hours after treatment. The percentage of mortality was corrected using Abbott's formula (Abbott 1987). P = [(P' -C)/100-C) × 100] Where, P= Corrected mortality (%); P'= Observed mortality (%); C= Mortality (%) in untreated control. The observed data then subjected to probit analysis according to Finney (1947) and (Busvine 1971) using software MSTAT-C. This data entered into a linear regression program, which first a regression linear into a probit log dose concentration graph. Mortality percentage and doses can be determined from this graph using the probit transformation table (Busvine 1980).

Repellency test: The repellent activities of the three indigenous plant extracts were evaluated using the filter paper impregnation method (Talukder and Howse 1993). The filter paper (Whatman no. 4) was cut into two halves, treated and untreated filter paper attached with cello tap and 1 ml solution of each concentration was applied to half of the filter paper by the help of micro pipette. The treated and untreated control papers then air dried for 20 minutes to evaporate the solvent. The treated half of the paper was attached with the untreated half one in the way that attachment did not interfere with the free movement of aphid from one half to another. After attachment, the treated and untreated control paper were placed in a Petri dish (5 cm diameter) and then 5 pairs of adult wingless aphid (7 days old) from lab culture were released at the centre of the filter paper. The Petri dish was covered with its lid and kept in undisturbed condition in the laboratory. Each treatment was replicated thrice and the number of insects on each portion was counted at hourly intervals up to the 5th hours. The data was expressed as percentage of repulsion (PR) using the following formula: PR= (Nc-50) × 2 where, Nc = Percentage of insects present in the untreated control half. Positive (+) values expressed repellency and negative (-) values attractancy. The average values were categorized according to the following scale (McDonald *et al.* 1970) shown in Table 2.

Table 2. Scale and rates of average values of repellency

Class	Repellency (%)	Class	Repellency (%)
0	0 > 0.01 to 0.1	III	40.1 to 60
I	0.1 to 20	IV	60.1 to 80
II	20.1 to 40	V	80.1 to 100

Statistical analysis: The data obtained from the experiments were statistically analyzed by MSTAT-C computer program and the treatment mean values were compared by New Duncans Multiple Range Test (Duncan 1951). The original insect mortality data were corrected by Abbott's formula before analysis. The observed mortality was also subjected to probit analysis. All other graphical works were done by using Microsoft Excel.

RESULTS AND DISCUSSION

The effects of three indigenous plant extracts (ata, marigold and chilli) were evaluated against aphid, *M. persicae*. The results of various experiments were conducted during the study period are presented and discussed under the following subheadings.

Direct toxicity effects of different plant extracts against aphid: The results of the direct toxicity effects of ata, marigold and chilli extracts on aphid are presented in Tables 3, 4 & 5. Average mortality percentage at 24, 48 and 72 hours after treatment (HAT) indicated that chilli extract possessed the highest toxic effect (mortality, 58.98%) whereas marigold extract possessed the lowest toxic effect (mortality, 44.29%) on aphid (Table 3). Mortality percentages were directly proportional to the time after treatment. The orders of the toxicity of three plant extracts on aphid was: chilli > ata > marigold. The average mortality percentage of aphid was differed significantly ($P<0.05$) among all the plant extracts.

Mortality percentage of aphid was also differed significantly ($P<0.05$) among all the concentrations level at different time intervals (Table 4). The highest average mortality (75.34%) was observed at the highest concentration (2%) of plant extract. On the other hand, the lowest average mortality (62.9%) was found at the lower

Table 3. Direct toxic effect of different plant extracts against *Myzus persicae* at different hours after treatment (HATs) (Interaction of plant extracts and times)

Plant extracts used	Insect mean mortality (%); ± SE at different time intervals			Average mortality (%)
	24 HAT	48 HAT	72 HAT	
Ata	45.00 ± 8.11 a	53.33 ± 9.48 b	65.37 ± 10.39 a	54.37 ± 9.24 a
Marigold	29.17 ± 6.13 b	46.67 ± 8.20 c	57.12 ± 9.33 b	44.29 ± 7.63 b
Chilli	50.83 ± 9.16 a	60.28 ± 10.25 a	65.83 ± 10.42 a	58.98 ± 9.90 a
Control	0.00 c	0.00 d	0.00 c	0.00 c
LSD	9.101	5.667	6.067	6.228
CV (%)	25.92	12.59	11.47	14.07
$S\bar{x}$	3.118	1.942	2.079	2.134
p-value	0.0002	0.0002	0.0104	0.0002

Within column values followed by different letter(s) are significantly different at 5 % level of probability by DMRT.

concentration (1.0%) and it was also found that the average mortality percentage directly proportional to the level of concentration of different plant extracts.

The interaction effects of plant, dose and time is presented in Table 5. Mortality percentage of aphid treated with different plant extracts of different dose level at different hours were found statistically significant ($P<0.05$). Overall average value indicated that the highest percent mortality (84.07%) was found in chilli extract at highest dose (2.0%) whereas marigold plant extract showed the lowest mortality (53.08%) at lowest dose (1.0%), which was statistically different from all other plant extracts at different concentration level.

From the above finding it was observed that the tested three plant extracts possessed toxicity effect on aphid but chilli can be most effective against aphid and marigold plant extracts can be less effective. This might be due to the major active constituent of chilli is Capsaicin and its analogues; collectively called Capsaicinoids. The present results coincided with the findings of Das *et al.* (2008) who evaluated aphidicidal activity of hot and cold-water extracts of some indigenous plants, *Azadirachta indica*, *Calotropis procera, Polygonum hydropiper* and *Ipomoea sepiaria* were tested against the tomato aphid, *M. persicae*. Hot water extract of *Polygonum hydropiper* and *Azadirachta indica* was found to be the most effective (87.6-94.5%) and (80.47-89.6%) mortality, respectively).

Table 4. Direct toxic effect of different doses of plant extracts against *Myzus persicae* at different HATs (Interaction of doses and times)

Dose (mg/ml)	Insect mean mortality (%); ± SE at different time intervals			Average mortality (%)
	24 HAT	48 HAT	72 HAT	
2.0	62.22 ± 6.40 a	77.65 ± 3.18 a	86.04 ± 2.25 a	75.34 ± 3.80 a
1.5	55.56 ± 5.29 ab	71.97 ± 3.95 a	82.59 ± 2.90 ab	69.71 ± 3.75 ab
1.0	48.89 ± 5.12 b	62.96 ± 2.80 b	76.91 ± 3.13 a	62.92 ± 3.54 b
Control	0.00 ± 0.00 c	1.11 ± 1.11 c	5.556 ± 1.75 c	2.21 ± 0.78 c
LSD	10.51	6.544	7.005	7.191
CV (%)	25.92	12.59	11.47	14.07
$S\bar{x}$	3.600	2.242	2.400	2.464
p-value	0.000	0.000	0.000	0.000

Within column values followed by different letter(s) are significantly different at 5 % level of probability by DMRT.

Table 5. Direct toxic effect of different plant extracts of different doses against *Myzus persicae* at HATs (Interaction of plant extracts, doses and times)

Plant extracts used	Doses (mg/ml)	Insect mean mortality (%); ± SE at different time intervals			Average mortality (%)
		24 HAT	48 HAT	72 HAT	
Ata	2.0	66.67 ± 3.33 ab	76.67 ± 3.33 abc	89.25 ± 0.37 a	77.65 ± 2.16 ab
	1.5	60.00 ± 5.77 abc	73.33 ± 3.33 bcd	85.92± 4.07 a	72.22 ± 2.93abc
	1.0	53.33 ± 3.33 abcd	63.33 ± 3.33 def	79.63 ± 5.45 ab	65.43 ± 3.88 bcd
	Control	0.00 ± 0.000 e	0.00 ± 0.000 g	6.67± 3.33 c	2.20 ± 1.10 e
Marigold	2.0	43.33 ± 13.33 bcd	70.00 ± 5.77 cde	79.60 ± 5.43 ab	64.32 ± 7.89 bcd
	1.5	40.00 ± 10.00 cd	60.00 ± 5.77 ef	76.29 ± 6.29 ab	58.65 ± 7.05 cd
	1.0	33.33 ± 8.81 d	56.67 ± 3.33 f	69.26 ± 5.14 b	53.08 ± 5.56 d
	Control	0.00 ± 0.00 e	0.000 ± 0.00 g	3.33 ± 3.33 c	1.10 ± 1.100 e
Chilli	2.0	76.67 ± 3.33 a	86.29 ± 3.16 a	89.25±0.37 a	84.07 ± 2.23 a
	1.5	66.67 ± 3.33 ab	82.59 ± 3.76 ab	85.55 ± 3.90 a	78.27 ± 3.11 ab
	1.0	60.00 ± 5.77 abc	68.89 ± 5.87 cdef	81.85 ± 4.07 ab	70.24 ± 5.13 bc
	Control	0.000 ± 0.00 e	3.33 ± 3.33 g	6.67 ± 3.33 c	3.33 ±1.93 e
	LSD	21.76	11.33	12.13	12.46
	CV (%)	25.92	12.59	11.47	14.07
	$S\bar{x}$	7.454	11.33	4.157	4.268
	P-value	0.0022	0.0036	0.000	0.000

Within column values followed by different letter(s) are significantly different by DMRT at 5 % level of probability.

Probit analysis for direct toxic effect of plant extracts: The results of the probit analysis for the estimation of LD_{50} values, chi-square values and their 95% fiducial limits at 24, 48 and 72 hours after treatment (HAT) for the mortality of tomato aphid are presented in Table 6. The LD_{50} values of three plant extracts showed that at 24 HAT chilli (0.67) extract was the most toxic followed by ata (0.86) and marigold (2.86) extracts. The LD_{50} values of ata (0.54 mg), marigold (0.75 mg) and chilli (0.57 mg) at 48 HAT indicated that ata extract showed the highest toxic effect. Among the three indigenous plant extracts chilli plant extract also performed the highest toxicity as compared by LD_{50} values at 24, 48 and 72 HAT. The chi-square values were insignificant at 5% level of probability of different plant extracts at different HAT and mortality data did not show any heterogeneity.

From the above probit results it is clear that all the tested three plants extract would be more or less effective for controlling aphid but chilli and ata was found the most effective. These results are comparable with the findings of Das *et al.* (2008) who evaluated aphidicidal activity of hot and cold-water extracts of some indigenous plants i.e., *Azadirachta indica, Calotropi procera* (Aiton), W.T. Aiton (akanda), *Polygonum hydropiper* L. (biskatali) and *Ipomoea sepiaria* J. koenig ex Roxb. (bankalmi) were tested against aphid. Hot water extract of *P. hydroper* and *A. indica* was found to be the most effective (87.6-94.5 and 80.5-89.6% mortality, respectively, $P<0.01$) among all the extracts. Other hot and cold water extracts also appeared to be useful (59.5-87.5% mortality) as pesticides against aphid. Finally, from the above result it is concluded that chilli would be effective for controlling the tomato aphid, *M. persicae.*

Probit regression lines: The probit regression lines for the bioefficacy of three indigenous plant extracts (ata, marigold and chilli) against *M. persicae* at 24, 48 and 72 HAT are presented in Fig. 1 (A, B, C). The calculated probit regression equation lines for the Bioefficacy of different plant extracts on tomato aphid at 24 HAT were $Y= 0.18x + 5.616$, $Y= 0.13x + 4.97$, $Y= 0.245x + 5.966$ for ata, marigold and chilli plant extracts, respectively (Fig. 1A). Among the three lines, the regression line for chilli extract showed the highest probit mortality but marigold extract showed the lowest probit mortality. The probit regression lines for three plant extracts on aphid at 48 HAT are given in Fig. 1B. From the probit analysis, the regression equations were $Y= 0.205x + 6.013$, $Y= 0.17x + 5.656$, $Y=0.305x + 6.476$ for ata, marigold and

Table 6. Relative toxicity (by probit analysis) of different plant extracts treated against *Myzus persicae* after 24, 48 and 72 hours after treatment

Extracts used	No. of insect used	LD_{50} mg/cm^2	95% fiducial limits		χ^2 values with 1 df
			Lower	Upper	
			24 HAT		
Ata	90	0.86	0.30	2.46	2.67
Marigold	90	2.86	0.58	14.27	7.27
Chilli	90	0.67	0.20	2.27	0.19
			48 HAT		
Ata	90	0.54	0.18	2.73	0.39
Marigold	90	0.76	0.19	2.95	0.20
Chilli	90	0.57	0.20	1.58	0.12
			72 HAT		
Ata	90	0.41	6.97	2.36	5.23
Marigold	90	0.32	1.15	9.41	3.41
Chilli	90	0.005	8.78	3623.26	0.01

Values were based on three concentrations, three replications of 10 insects each. χ^2 = Goodness of fit, the tabulated value of χ^2 is 3.84 (d.f = 1 at 5% level)

chilli plant extracts, respectively. Comparing among the three plant extracts at 48 HAT for probit mortality, chilli extract showed the highest probit mortality whereas marigold extract showed the lowest. Chilli was also maintained its highest probit mortality when the probit regression lines were compared at 72 HAT (Fig. 1C). The insect mortality rate showed positive correlation with the doses in all treatments. The probit regression lines of three plant extracts showed a clear linear relationship between probit mortality and their log doses and the regression lines become sleeper as doses increased, because the adult insects were treated with more toxins for the same period at higher doses.

The repellent effect: The repellency rate of three plant extracts at different HAT are presented in Table 7. Ata, marigold and chilli plant extracts showed different repellent effect against tomato aphid. Among the three plant extracts tested, chilli extract showed the highest **(**60.44**)** mean repellent effect followed by ata (50.44%) and marigold (43.56%). On the basis of mean repellency rate, it was found that ata and marigold plant extracts were in the same repellency class i.e., class III and other plant extracts chilli were in class IV.

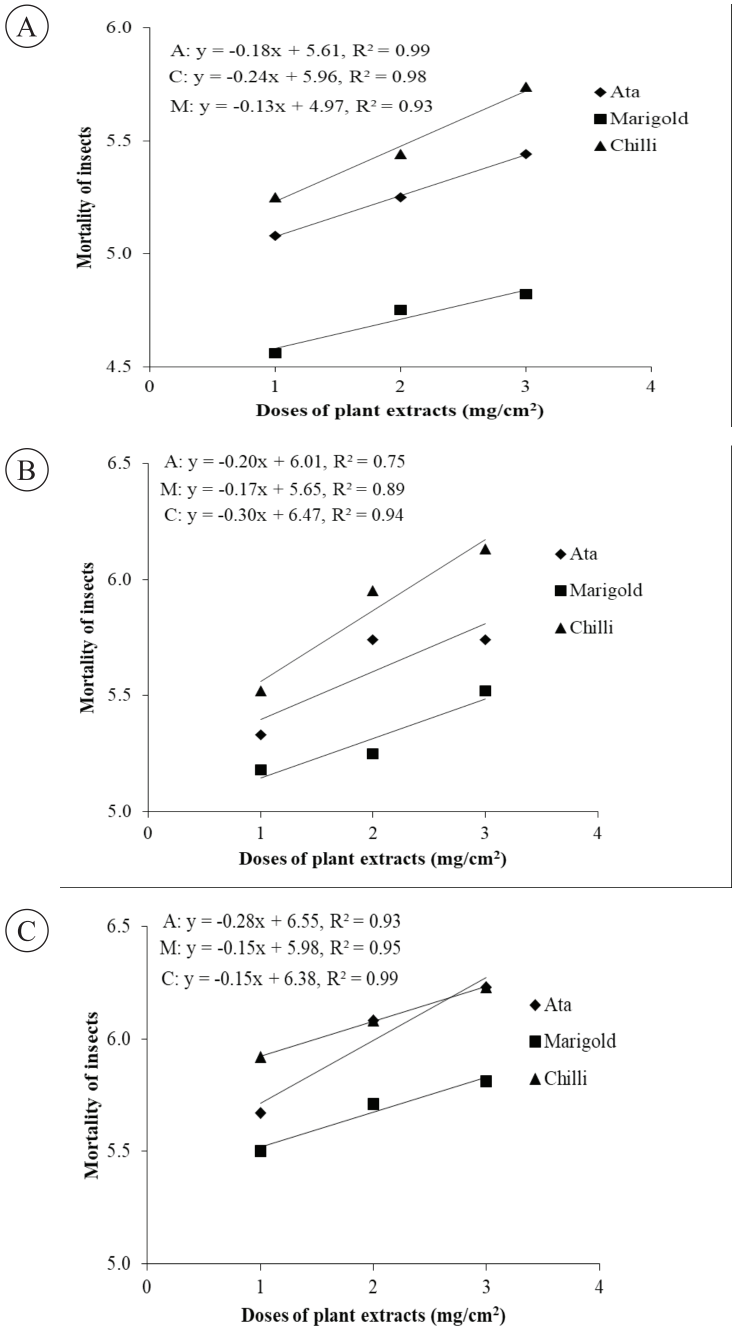

Fig. 1. Relationship between probit mortality and log doses of different plant extracts against *Myzus persicae* at 24 HAT (A), 48 HAT (B) and 72 HAT (C).

Table 7. Repellent effect of different plant extracts against *Myzus persicae* using treated filter paper at different HAT (Interactions of plant extracts and times)

Extracts used	Repellency rate (%); mean ± SE					Mean repellency (%)	Repellency classes
	1 HAT	2 HAT	3 HAT	4 HAT	5 HAT		
Ata	52.22 ± 7.41 a	75.56 ± 6.47 a	62.22 ± 7.77	68.89 ± 5.87a	60.00 ± 8.16	63.78 ± 3.86	IV
Marigold	43.33 ± 6.23 a	46.67 ± 8.81 b	51.11 ± 9.49	53.33 ± 11.05 a	46.67 ± 9.42	48.22 ± 5.85	III
Chilli	40.00 ± 6.66 a	41.11 ± 10.06 b	46.67 ± 6.66	40.00 ± 12.90 a	44.44 ± 10.42	42.44 ± 5.11	III
LSD	15.48	22.79	26.95	29.77	29.28	14.49	
CV (%)	34.60	42.27	51.03	55.59	58.69	28.42	
$S_{\bar{x}}$	5.212	7.671	9.072	10.02	9.855	4.877	
p-value	0.256	0.011	NS	0.153	NS	0.017	

Mean followed by the same letter(s) are not significantly different at 5% level by DMRT.

The repellency effect of different plant extracts in different doses level against tomato aphid are presented in Table 8. The repellency rates of insects were influenced by the concentration of extracts. The highest mean repellency (63.78%) was found in 2% level of concentration and its bear repellency class IV and the lowest repellency (42.44%) was found in 1% level of concentration and its bear repellency class III.

Table 9 shows the interaction repellent effect of plant, dose and time. The repellent effect influenced by different level of concentrations at different HAT and had significant difference. Among different plant extracts chilli extract showed the highest mean repellency rate (73.33%) in highest concentration level. The repellency class of different plant extracts at different concentration level varied between I to IV. Chilli is the most toxic and also serves as a repellent against *M. persicae*. From the above result it was found that chilli extract showed strong repellent effect against tomato aphid than other plant extracts.

Table 8. Repellent effect of different plant extracts against *Myzus persicae* using treated filter paper at different HAT (Interactions of doses and times)

Dose (mg/ml)	Repellency rate (%); mean ± SE					Mean repellency (%)	Repellency classes
	1 HAT	2 HAT	3 HAT	4 HAT	5 HAT		
2.0	30.00 ± 5.27 b	45.56 ± 13.65 a	48.89 ± 8.24	51.11 ±12.95	42.22 ± 8.46 a	43.56 ± 5.46	III
1.5	43.33 ± 6.23 b	53.33 ± 8.16 a	55.56 ± 8.01	53.33 ± 7.45	46.67 ± 9.42 a	50.44 ± 5.96	III
1.0	62.22 ± 4.00 a	64.44 ± 5.55 a	55.56 ± 8.67	57.78 ± 222	62.22 ± 9.68 a	60.44 ± 4.73	IV
LSD	15.48	22.79	26.95	29.77	29.28	14.49	
CV (%)	34.60	42.27	51.03	55.59	58.69	28.42	
$S\bar{x}$	5.212	7.671	9.072	10.02	9.855	4.877	
p-value	0.001	0.243	NS	NS	0.343	0.073	

Mean followed by the same letter(s) are not significantly different at 5% level by DMRT.

Table 9. Repellent effect of different plant extracts against *Myzus persicae* using treated filter paper at different HAT (Interactions of plant extracts, doses and times)

Extracts used	Doses (mg/ml)	Repellency rate (%); mean ± SE					Mean repellency (%).	Repellency classes
		1 HAT	2 HAT	3 HAT	4 HAT	5 HAT		
Ata	2.0	46.67 ± 13.33abc	80.00 ± 11.54 a	66.67 ± 6.66	66.67 ± 6.66 a	60.00 ± 11.54	64.00 ± 4.61 ab	IV
	1.5	50.00 ± 5.77 ab	40.00 ±0.00 a	53.33 ± 17.63	66.67 ± 6.66 a	40.00 ± 20.00	50.00 ± 7.02 ab	III
	1.0	33.33 ± 13.33bc	40.00 ± 11.54 a	46.67 ± 17.63	26.67 ± 6.66 a	40.00 ± 20.00	37.33 ± 13.33 b	II
Marigold	2.0	36.67 ± 8.81bc	73.33 ± 17.63 a	60.00 ± 11.54	60.00 ± 11.54 a	40.00 ± 11.54	54.00 ± 3.05 ab	III
	1.5	20.00 ± 0.00c	53.33 ± 29.05 a	40.00 ± 23.09	26.67 ± 17.63 a	40.00 ± 11.54	36.00 ± 14.42 b	II
	1.0	33.33 ± 13.33bc	10.00 ± 5.77 b	46.67 ± 6.66	66.67 ± 33.33 a	46.67 ± 24.03	40.67 ± 7.33 b	III
Chilli	2.0	73.33 ± 6.66a	73.33 ± 6.66 a	60.00 ± 23.09	80.00 ± 11.54 a	80.00 ± 11.54	73.33 ± 7.42 a	IV
	1.5	60.00 ± 0.000ab	46.67 ± 6.66 a	60.00 ± 11.54	66.67 ± 24.03 a	60.00 ± 20.00	58.67 ± 4.80 ab	III
	1.0	53.33 ± 6.66ab	73.33 ± 6.66 a	46.67 ± 13.33	26.67 ± 17.63 a	46.67 ± 17.63	49.33 ± 6.66 ab	III
LSD		26.82	39.48	46.69	51.57	50.72	25.10	
CV (%)		34.60	42.27	51.03	55.59	58.69	28.42	
$S\bar{x}$		9.027	13.29	15.71	17.36	17.07	8.447	
p-value		0.000	0.104	0.000	0.156	0.000	0.000	

Means followed by the same letter(s) are not significantly different by DMRT at 5% level of probability.

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EVALUATION OF BIO-RATIONAL INSECTICIDES FOR ECO-FRIENDLY MANAGEMENT OF LOOPER AND POD BORER OF SOYBEAN

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ABSTRACT

Soybean (*Glycin max*) is high in protein and vegetable oil grown widely globally and nationally. About 15-20% of the total soybean production is lost directly or indirectly by the attack of insect pests every year. The study was conducted during October 2024 to April 2025 in the field and laboratory of the Department of Entomology of Gazipur Agricultural University (GAU), Gazipur to assess some selected bio-rational insecticides against looper and pod borer of Soybean with 6 treatments and 3 replications following randomized complete block design. Biomax 1.2 EC (Abamectin) @ 1 ml/L, Success 2.5 SC (Spinosad) @ 1 ml/L, Biotrin (Matrine 0.5% AS) @ 1.5 ml/L, Bio BTK (*Bacillus thuringiensis kurstaki*) @ 1 g/L, Neem Seed Kernel Extract (NSKE) @ 50 g/L were the key elements of the treatment and an untreated control plot was maintained for comparison. Looper and pod borer were found in the soybean field and those pests were effectively controlled by two sprays of Biomax 1.2 EC (Abamectin), Success 2.5 EC (Spinosad), Biotrin (Matrine 0.5% AS), Bio BTK (*Bacillus thuringiensis kurstaki*) and Neem Seed kernel Extract (NSKE). Among the treatments, the highest percent of pod infestation reduction over untreated control plot was found in Success 2.5 SC (91.6% by n/n) treated plot as well as the highest yield (4.4±1.1 MT/ha) and MBCR (4.6) was recorded with management approach comprising 2 sprays of Success 2.5 SC (Spinosad)@ 1.5 g/L of water. This management approach might be an effective, suitable and viable approach for suppressing looper and pod borer in soybean field.

Keywords: Soybean pests, *Helicoverpa armigera*, Looper, Bio-rational insecticides

INTRODUCTION

Soybean (*Glycine max* L.) is one of the most important leguminous crops (family Fabaceae) which is mainly grown for oil and protein in both the Rabi and Kharif

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seasons of Bangladesh. Soybean is also recognized as golden bean or miracle bean grows in tropical, subtropical and temperate climates (Yadav *et al*. 2013). Seeds of soybean contain about 42% protein and 20% oil and considerable amounts of dietary fibers, minerals and vitamins which provide 60% of the world supply of vegetable protein and 30% of the edible oil (Das *et al*. 2022). In Bangladesh, total quantity of soybean production was 0.064 million tones and occupied 0.041 million ha of land (BBS 2020).

In Bangladesh, one of the key factors limiting soybean yield is insect pest infestation, which causes an estimated 15–20% loss in production annually (Biswas 2008). Soybean plants are attacked by various pests, including aphids, looper pod borer, stem flies, bugs, whiteflies, leaf miners, jassids, and hairy caterpillars. Among them, the hairy caterpillar (*Spilarctia oblique*), leaf roller (*Lamprosema indicata*), cutworm (*Spodoptera litura*), pod borer (*Helicoverpa armigera*), stem fly (*Ophiomyia phaseoli*), and whitefly (*Bemisia tabaci*) are considered major pests due to their high population density and significant yield impact (Biswas 2013). Developing effective, eco-friendly, and economically viable pest management strategies requires detailed knowledge of pest species, their status, seasonal occurrence, and the nature of damage (Jayanthi *et al*. 1993). Although insecticides are widely used in crop production for their quick action, ease of use, and availability. The reliance on synthetic insecticides has led to several problems, including pest resistance, residue accumulation, resurgence of pest populations due to the loss of natural enemies, and harm to pollinators. Moreover, they pose serious risks to human health, the environment, and biodiversity (Rahaman and Prodhan 2007).

In that case, eco-friendly approaches such as Integrated Pest Management Tools can be a solution to minimize the effect of synthetic insecticides on non-target organisms as IPM tools are a combination of biological, cultural, mechanical, and chemical methods used in a coordinated way to control pests sustainably by minimizing harm to humans, beneficial organisms, and the environment.(Horowitz and Ishaaya 2004). Therefore, the present research work was undertaken to evaluate the effectiveness of some selected IPM tools for developing packages against the major insect pests of soybean and disseminate sustainable insect pest management technologies for optimizing the yield of soybean.

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 October 2024 to April 2025. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. A total of 18 plots was made and the unit plot size was 3 m × 2 m. The BU Soybean 2 was collected from the Department of Agronomy, GAU, Gazipur. Before planting the seeds were treated with Vitavex-200 @ 0.25% to prevent seeds from the attack of soil borne disease. The seeds were sown in continuous line placed at about 5 cm depth from the soil surface by maintaining a 30 cm distance from row to row. After the germination of seedling, thinning of seedling was done keeping the seedling at 6 cm distance from each plant to plant in a row. Intercultural operations were done as necessary**.**

Treatments and methods of application: Five treatments viz., Biomax 1.2 EC (Abamectin) @ 1.0 ml/L of water, Success 2.5% SC (Spinosad) @ 1.5 g/L of water, Biotrin (Matrine 0.5% AS) @ 1.5 ml/L of water, Bio BTK (*Bacillus thuringiensis kurstaki*) @ 1.0 g/L of water, Neem seed kernel extract (NSKE) @ 50 g/L of water and an untreated control (spray of tap water only) were evaluated on the basis of reduction in looper and pod borer infestation in soybean.

Mature seeds of neem were collected and grounded into powder. The powder was soaked in water @ 50 g/300 ml of water overnight. The mixture was filtered through nylon net and maintained the volume at 1000ml. 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 2 spray of insecticides was done, one was applied at 30 days after sowing during seedling stage and another was applied at 45 days after sowing during pod developing stage. 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 number of pests and natural enemy with crop growing season, rate of plant infestation by different pests, healthy and infested pods per plot by number and weight and yield of soybean. The cumulative yield per plot from total harvests was calculated and it was then expressed in MT/ha. The observations on the incidence of insect pests and their natural enemies were counted visually with the help of magnifying glass at 15 days interval recorded from their appearance on plants till harvest. The insect pests and natural enemies were identified through comparing specimens in museum as well as by relevant literature and photographs. Sample was taken from 2 rows randomly and then converted to 6 rows per plot (3 × 2 m^2) for expressing rate of plant infestation and number of arthropod pests per plot. For obtaining pod yield (MT/ha), the weights of healthy, infested, and total pods of all harvests were taken plot-wise. The yield of healthy, infested, and total pods obtained were transformed into pods yield in ton per hectare. The weight of infested pods was recorded from the total weight of the harvested pods 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 made by F variance test (Gomez and Gomez 1984) and the mean comparisons were performed by Tukey HSD posthoc statistics.

RESULTS AND DISCUSSION

The abundance and infestation rates of soybean looper: The abundance and infestation rates of soybean looper varied significantly across the tested IPM tools (Table 1). At 3 DAT, the lowest number of larvae was recorded in Success 2.5 SC (8.0±0.5) treated plot with 9.3±3.7% infestation rate, followed by Biotrin (abundance 10.1±2.0/plot and 17.8±5.0% infestation rate) treated plot. In contrast, the highest was observed in untreated control plot (abundance 21.8±1.3/plot and 33.6±4.2% infestation rate) followed by Biomax 1.2 EC (16.6±3.6%), NSKE (18.5±4.4%) and Bio BTK (18.5±4.3%) treated plots. Similarly at 7 DAT, Success 2.5 SC (7.5±1.1%) treated plot performed better, followed by Biotrin (16.0±0.7%) treated plots and the highest infestation rate was found in untreated control plots (33.8±1.8%) with abundance 21.5±1.1/plot. In align with the present study Swami *et al*. (2019) observed that Spinosad 45 SC at different concentrations had been found to reduce the larval population of soybean loopers significantly, resulted a larval reduction of 67.29%.

Table 1. Effect of different bio-rational insecticides against looper of soybean (BU soybean 2) grown during *Rabi* season 2024-25

Treatment	Number of looper/plot		Rate of plant infestation (%)	
	3 DAT	7 DAT	3 DAT	7 DAT
Biomax 1.2 EC	14.3±0.8 b	13.3±0.5 b	16.6±3.6 b	16.8±0.6 b
Success 2.5 SC	8.0±0.5 c	7.3±0.9 c	9.3±3.7 c	7.5±1.1 c
Biotrin	10.1±2.0 bc	10.5±0.3 bc	17.8±5.0 b	16.0±0.7 b
Bio BTK	13.1±0.6 b	13.2±1.3 b	18.5±4.3 b	17.6±1.0 b
NSKE	13.6±1.4 b	13.2±1.5 b	18.5±4.4 b	14.5±0.2 b
Untreated control	21.8±1.3 a	21.5±1.1 a	33.6±4.2 a	33.8±1.8 a

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.

Rate of pod infestation (n/n): The rate of pod infestation differed significantly as impacted by the tested IPM tools (Table 2). Significantly the highest number of healthy pods per plot (34.0±4.1) was obtained from Success 2.5 SC treated plot, followed by Biomax 1.2 EC (27.3±3.3), whereas the lowest was from untreated control plot (13.6±5.6). The highest number of infested pods per plot was recorded from untreated control (10.5±2.0) and the lowest was achieved from Success 2.5 SC (1.3±0.0) treated plot. Total number of pods per plant was maximum in Success 2.5 SC (35.3±4.1) treated plot and minimum in untreated control (24.0±5.6) plot. In similar manner, pod infestation rate resulted lowest in Success 2.5 SC and considerably high in control (43.8±1.5) and Bio BTK (26.5±1.3) treated plots (Table 2). In a study conducted by Mohanty *et al*. (2022) on chickpea, spinosad 45% SC was one of the most effective treatments, resulting in a reduction of 65.03% in larval population.

The highest percent of pod infestation reduction over untreated control plot was found in Success 2.5 SC (91.6% by n/n) treated plot followed by Biomax 1.2 EC (64.4% by n/n) treated plot. The lowest percent of pod infestation reduction over untreated control plot was found in NSKE treated plot (32.0% by n/n) followed by Bio BTK (39.5% by n/n) and Biotrin treated plots (53.4% by n/n) (Fig. 1). In a similar study, Tanzum *et al*. (2023) found that the highest percent of pod infestation reduction over untreated control was found in Tracer 45 SC (90.8% by n/n and w/w)

Table 2. Effect of different different bio-rational insecticides on rate of pod infestation (n/n) of soybean per plot (3 × 2 m^2) grown during *Rabi* season 2024-25

Treatments	No. of healthy pods/plant	No. of infested pods/plant	No. of total pods/ plant	Pod infestation%
Biomax 1.2 EC	27.3±3.3 b	5.0±1.1 b	32.0±3.3 a	15.6±0.9 c
Success 2.5 SC	34.0±4.1 a	1.3±0.0 b	35.3±4.1 a	3.7±0.3 d
Biotrin	25.6±4.9 b	6.6±0.6 b	32.3±4.9 a	20.4±1.2 bc
Bio BTK	20.3±2.4 bc	7.3±1.2 b	27.5±2.4 ab	26.5±1.3 b
NSKE	17.6±7.0 c	7.6±1.3 b	25.5±7.0 b	29.8±1.3 b
Untreated control	13.6±5.6 d	10.5±2.0 a	24.0±5.6 b	43.8±1.5 a

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.

treated plot followed by Biomax 1.2 EC (71.7% by n/n and 72.0% by w/w) treated plot. The lowest percent of pod infestation reduction over untreated control plot was found in NSKE treated plot (58.0% by n/n and 58.5% by w/w) followed by Bio BTK (64.8% by n/n and 65.2% by w/w) and Biotrin (65.8% by n/n and 66.2% by w/w) treated plots. The untreated control in another study by Sreekanth *et al*. (2015) showed a mean pod damage of 35.7% and a weight loss of 21.9%, whereas treated plots significantly lowed the damage and obtained higher yields.

Effect of bio-rational insecticides to non-target arthropods: Data in Table 3 represents the effect of different eco-friendly management approaches on the abundance of beneficial/non-target arthropods at the studied soybean fields. The highest number of ladybird beetle per plot was found in Biomax 1.2 EC treated plot (14.2±0.5) followed by untreated control (13.2±1.5). In case of abundance of syrphid fly per plot, the findings showed that the abundance of syrphid fly was ranging from 3.2±1.2 to 7.9±1.1 per plot. Regarding black ant, the highest abundance of black ant was found in untreated control plots (47.2±1.8) followed by Biotrin (46.0±0.8). The abundance of spider showed no variation among the treatments including untreated control plots which ranged from 3.42±1.1 to 4.86±1.3 per plot. The highest number of bees per plot was observed in Biomax 1.2 EC treated plot (2.2±0.2) which was statistically similar to NSKE treated plot (1.8±0.5), Biotrin (1.7±0.2), Success (1.6±0.8), untreated control (1.6±0.2) and Bio BTK (1.5±0.1) treated plot. According to Efad *et al*. (2021) Azadirachtin, Spinosad, and Abamectin

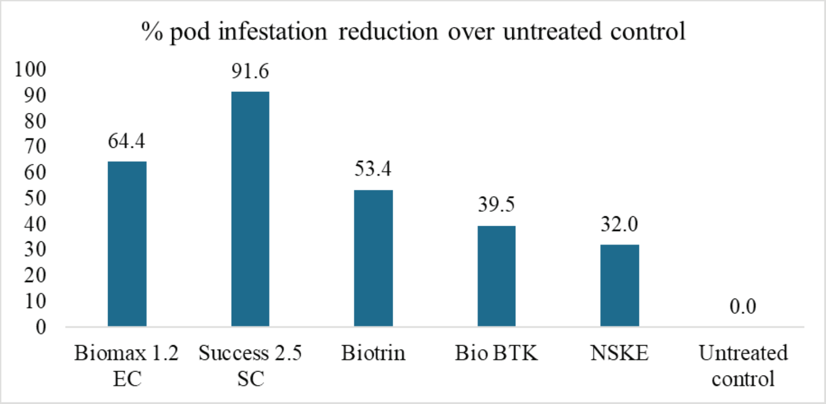

Fig. 1. Effect of different bio-rational insecticides on the rate of % pod infestation reduction over untreated control (n/n) by pod borers of soybean per plot (3 × 2 m^2) during *Rabi* season 2024-25.

were found to be bio-rational when beneficial arthropods such as ladybird beetles, syrphid flies, black ants, and spiders were present on the field over the whole brinjal season. In their investigation, the number of black ant and ladybird beetles showed the least statistical variation in the Spinosad and Abamectin treated plots compared to the untreated control plot, but no statistical variation was observed in the syrphid fly and spider populations among the treatments, including the untreated control.

Table 3. Effect of different bio-rational insecticides on abundance of beneficial arthropods per plot (3×2 m^2) during entire cropping season of soybean (Mean of 5 observations)

Treatments	No. of ladybird beetle/plot	No. of syrphid fly/plot	No. of black ant/plot	No. of spiders/plot	No. of bees/ plot
Biomax 1.2 EC	14.2±0.5 a	3.2±1.2 a	45.8±1.2 a	3.42±1.1 a	2.2±0.2 a
Success 2.5 SC	12.4±1.1 a	3.9±1.5 a	44.3±0.6 a	4.12±0.3 a	1.6±0.8 a
Biotrin	12.3±0.5 a	5.8±0.8 a	46.0±0.8 a	4.86±0.9 a	1.7±0.2 a
Bio BTK	11.6±0.7 a	4.1±0.8 a	43.0±1.4 a	4.86±1.4 a	1.5±0.1 a
NSKE	11.6±0.2 a	4.9±1.3 a	43.5±2.2 a	4.86±0.3 a	1.8±0.5 a
Untreated control	13.2±1.5 a	7.9±1.1 a	47.2±1.8 a	4.86±1.3 a	1.6±0.2 a

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 bio-rational insecticides on yield of soybean: Tested treatment effects caused variation in yield and yield contributing parameters (Table 4). The highest 100-seed weight was obtained in Success 2.5 SC treated plot (24.5±1.4 g) which was statistically similar with Biomax 1.2 EC (22.7±1.1 g), Biotrin (22.4±1.7 g) and Bio BTK (20.3±1.3 g) treated plots. Significantly the lowest 100-seed weight was obtained in untreated control plot (16.8±1.8 g) which showed statistical similarity with NSKE treated plot (17.5±1.3 g). The highest yield (2.6±0.2 kg/plot) was obtained from Success 2.5 SC treated plot which was statistically similar to that of Biotrin (2.4±0.6 kg/plot) treated plot, Biomax 1.2 EC (2.4±0.1 kg/plot), Bio BTK (2.3±0.4 kg/plot), NSKE (2.0±0.4 kg/plot) and untreated control plot (1.4±0.2 kg/plot). The highest yield (4.4±1.1 MT/ha) was obtained from Success 2.5 SC treated plot which was statistically similar to that of Biotrin (4.0±1.1 MT/ha), Biomax 1.2 EC (4.0±1.3 MT/ha) and Bio BTK (3.8±1.1 MT/ha) treated plot. The lowest yield (3.3±0.8 MT/ha) was obtained from untreated control plot (3.0±0.8 MT/ha) which was statistically similar to that of NSKE treated plot (3.2±0.9 MT/ha) (Table 4). Spinosad 45 SC at a concentration of 0.01% was found to be highly effective in suppressing the larval populations of *Spodoptera litura* on soybean, resulting in a significant increase in grain yield of 13.46 q/ha compared to untreated control (Raut *et al*. 2019).

The highest percent increase of yield over untreated control (47.7%) was recorded in plot treated with Success 2.5 SC followed by 34.5% in Biotrin and 33.3% in Biomax 1.2 EC treated plots. The lowest percent increase of marketable

Table 4. Effect of different bio-rational insecticides on yield of soybean (MT/ha) grown during *Rabi* season 2024-25

Treatment	100-seed weight (g)	Yield (kg/plot)	Yield (MT/ha)
Biomax 1.2 EC	22.7±1.1 ab	2.4±0.1 a	4.0±1.3 a
Success 2.5 SC	24.5±1.4 a	2.6±0.2 a	4.4±1.1 a
Biotrin	22.4±1.7 ab	2.4±0.6 a	4.0±1.1 a
Bio BTK	20.3±1.3 ab	2.3±0.4 a	3.8±1.1 ab
NSKE	17.5±1.3 bc	2.0±0.4 a	3.3±0.9 b
Untreated control	16.8±1.8 c	1.4±0.2 a	3.0±0.8 b

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.

yield over untreated control was found from NSKE treated plot (10.0%) followed by Bio BTK (26.7%) treated plots (Fig. 2).

Economic analysis of different IPM tools: The details of the cost of pest management (Tk./ha) under tested IPM tools against insect pests in soybean grown during *Rabi* season 2024-25 are presented in Table 5. Management cost was the highest (Tk. 12910.0) with Success 2.5 SC followed by Biomax 1.2 EC (Tk. 9920.0) and Biotrin (Tk. 9408.0). The lowest management cost (Tk. 2320.0) was found in untreated control plot followed by Tk. 5500.0 with NSKE and Tk. 8212.0 with Bio BTK (Table 5). The highest gross return (Tk. 220000.0) was found with Success 2.5 SC followed by Tk.200000.0 in Biomax 1.2 EC and Biotrin. The lowest gross return (Tk. 150000.0) was found in untreated control, followed by NSKE (Tk. 165000.0) and Bio BTK (Tk. 190000.0) treated plot. The highest net return (Tk. 207090.0) was recorded from Success 2.5 SC followed by Tk. 190592.0 in Biotrin, Tk. 190080.0 in Biomax 1.2 EC, Tk. 177090.0 with Bio BTK, Tk. 156788.0 with NSKE and the lowest Tk. of 147680.0 in untreated control. The highest adjusted net return (Tk. 59410.0) was recorded in Success 2.5 SC followed by Tk. 42912.0 from Biotrin and Tk. 42400.0 from Biomax 1.2 EC treated plot. The lowest adjusted net return was calculated from NSKE (Tk. 9108.0) followed by Bio BTK (Tk. 29410.0) whereas untreated control had no adjusted net return (Table 5).

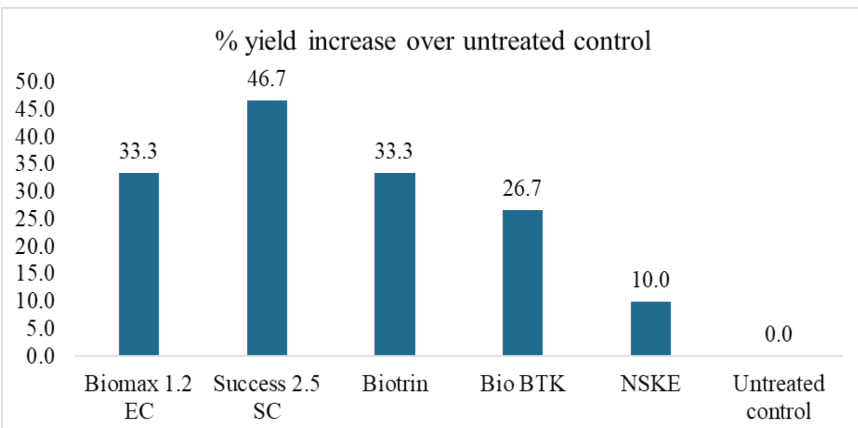

Fig. 2. Effect of different bio-rational insecticides on % yield increase over untreated control of soybean during *Rabi* season 2024-25.

Table 5. Marginal benefit cost ratio (MBCR) analysis of selected IPM tools against arthropod pests in soybean (MT/ha) grown during *Rabi* season 2024-25

Treatments	Management cost (Tk)	Gross return (Tk)	Net return (Tk)	Adjusted net return (Tk)	MBCR
Biomax 1.2 EC	9920.0	200000.0	190080.0	42400.0	4.2
Success 2.5 SC	12910.0	220000.0	207090.0	59410.0	4.6
Biotrin	9408.0	200000.0	190592.0	42912.0	4.5
Bio BTK	12910.0	190000.0	177090.0	29410.0	2.2
NSKE	8212.0	165000.0	156788.0	9108.0	1.1
Untreated control	2320.0	150000.0	147680.0	0.0	-

Market value of soybean= 50.0 Tk./kg, cost of Biomax 1.2 EC per spray= 3800.0 Tk/ha, Success 2.5 SC per spray= 5295.0 Tk/ha, Biotrin per spray= 3544.0 Tk/ha, Bio BTK per spray = 5295.0 Tk/ha, Neem seed kernel extract per spray = 2946.0 Tk/ha, Labor cost= 550 Tk/day, No. of spray=2, sprayer rent= 30 Tk/day.

The highest MBCR of 4.6 was obtained from the plot treated with Success 2.5 SC followed by 4.5 in Biotrin, 4.2 in Biomax 1.2 EC and 2.2 in Bio BTK sprayed plots. The lowest marginal benefit cost ratio (1.1) was found from the NSKE treated plot (Table 5).

Alam *et al*. (2021) found that the highest benefit cost ratio (12.81) estimated for Voliam Flexi (Thiamethoxam + Chlorantraniliprole) @ 0.25ml/L of water at 10 days interval and the lowest (4.16) for Allion 2.5 EC (Lamda-Cyhalothrin) @ 2.0 ml/L of water at 10 days interval. The highest BCR found in the treatment with Voliam Flexi, which may be due to the minimum pest infestation compared to the other treatment components and resulted the better yield. In a similar study, Tanzum *et al*. (2023) found the highest MBCR of 3.02 from the plot treated with Tracer 45 SC followed by 2.37 with Biomax 1.2 EC, 1.99 with Bio BTK and 1.88 with Fytomax PM sprayed plots. The lowest marginal benefit cost ratio (1.60) was obtained from the NSKE treated plot.

CONCLUSION

Management approach comprising of two sprays of Success 2.5 SC @ 0.4 g/L of water at 15 days interval might be an effective, suitable and viable approach for suppressing looper and pod borer in soybean field.

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EVALUATION OF FOUR BIO-PESTICIDES AGAINST JASSID, *AMRASCA BIGUTTULA* (HEMIPTERA: JASSIDAE) FOR THE SAFE PRODUCTION OF YARDLONG BEAN

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ABSTRACT

Yardlong bean (*Vigna unguiculata* subsp. *sesquipedalis*) is a highly nutritious vegetable widely cultivated in Bangladesh, serving as an important source of protein, particularly for rural populations. However, its production is often constrained by sap-sucking pests, especially jassids, which can cause considerable yield losses. To evaluate effective pest management strategies, a field experiment was conducted at the Entomology Research Field of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, using RCBD. The study assessed the efficacy of four bio-pesticides against jassid infestation in yardlong bean variety BGL-1205. Four treatments were tested: T_1 Azadirachtin 1% EC, T_2 *Celastrus angulatus* 1% EW, T_3 Buprofezin 40% SC, T_4 Lufenuron 5% EC, and an untreated control. The results showed that buprofezin 40% SC @ 0.4 ml L^{-1} was the most effective treatment (T_3), recording the lowest mean jassid populations of 8.77, 6.00, and 8.39 per three leaves per plant after the first, second, and third sprays, respectively. In contrast, the untreated control consistently exhibited the highest infestations. Buprofezin reduced jassid populations by 58.67%, 68.42%, and 57.92% after 1st, 2nd and 3rd sprays, respectively and produced the highest yield per pit (318.07 g), the largest yield increase (68.70%) over control and the maximum benefit-cost ratio (2.26). These findings indicate that buprofezin 40% SC @ 0.4 ml L^{-1} is an effective, economical, and bio-safe option for jassid management, enhancing plant growth and significantly increasing yardlong bean productivity.

Keywords: Evaluation, bio-pesticides, yardlong bean, jassid, safe food

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INTRODUCTION

Yardlong bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Walp) is a key legume crop extensively cultivated in Southeast Asia and southern China (Suma *et al*. 2021, Mia *et al*. 2024). The crop is rich in essential amino acids such as lysine and tryptophan, vitamins, and minerals (Pandey *et al*. 2020), earning it the nickname "meat of the poor" and has importance in rural diets (Jat *et al*. 2013, Khatun *et al*. 2020). Despite its significance, the average yield in Bangladesh remains low at 4.65 t ha^{1} (BBS 2021), far below the standards in other Asian countries (Sarada and Rao 2020). Low productivity is largely due to abiotic stresses and biotic challenges, with insect pests and diseases being major limiting factors (Khan *et al*. 2018, Khatun *et al*. 2020, and Mia *et al*. 2024). Over 55 insect pest species attack yardlong bean (Chopkar *et al*. 2020, Chowdhury *et al*. 2019, Rahman *et al*. 2022). Among them, the jassid *Amrasca biguttula* (Cicadellidae: Hemiptera) is a significant seasonal pest (Tamang *et al*. 2025). This polyphagous pest feeds on plant sap using piercing-sucking mouthparts, reducing photosynthesis, resulting stunting growth, and lowering yields (Afzal *et al*. 2025). It also produces honeydew-like exudates, which accumulate more on younger leaves, which affect plant health and productivity (Bhandari *et al*. 2022).

At present, farmers rely almost exclusively on synthetic chemical insecticides to combat various insect pests to protect the crops from the pest damage. However, extensive usage of chemical insecticides leads to pest resistance, pest resurgence and serious health hazards due to their bio-magnification and persistent nature (Sharma *et al.* 2019, and Goff & Giraudo 2019). Hence, globally, researchers are increasingly adopting alternatives to detrimental chemical pesticides, with a strong focus on new-generation bio-rational pesticides and bio-pesticides. This shift is driven by the need to reduce environmental harm, protect beneficial organisms, and address consumer concerns about food safety and ecological sustainability (Khanal *et al.* 2021). So, keeping in view the importance of yardlong bean jassid, a field trial was conducted to evaluate the effectiveness of four selected bio-pesticides viz., Azadiractin, *Celastrus angulatus*, Buprofezin, Lufenuron in controlling jassid.

MATERIALAS AND METHODS

Experimental site: The experiment was carried out in the research field of the Department of Entomology of Hajee Mohammad Danesh Science and Technology University, Dinajpur during March to July 2024. The site is categorized as medium high land within AEZ-1 of the Old Himalayan Piedmont Plain. The soil is characterized by medium to high elevation and featured sandy loam and sandy clay loam textures with a pH of 5.52, an electrical conductivity of 2.0 mS m^{-1}, and a medium organic matter content (Shil *et al*. 2016).

Plant culture: The seeds of yardlong bean (*Vigna unguiculata* subsp. *sesquipedalis*) variety BGL-1205 were obtained from the Bangladesh Agricultural Development Corporation (BADC), Sadar Upazila, Dinajpur. The experimental field was thoroughly prepared by ploughing and cross-ploughing using a power tiller to achieve a fine tilth, followed by laddering and spading. Stubbles and uprooted weeds were removed, and the field was leveled prior to sowing. Three seeds were placed in each prepared pit and lightly irrigated to maintain adequate soil moisture for germination. At 15 days after sowing, thinning was performed to retain a single healthy seedling per pit. Each plant was provided with a bamboo stake to prevent lodging. Routine intercultural operations, including irrigation, weeding, and other necessary field management practices were carried out as required. Fertilizers were applied according to the recommended doses to ensure optimum growth and yield (Mia *et al*. 2024).

Treatments and data collection: Four bio-pesticides evaluated as the treatments were T_1 = Azadiractin 1 EC @ 1 mlL^{-1} of water; T_2 = *Celastrus angulatus* 1 EW @1.5 mlL^{-1} water, T_3 = Buprofezin 40 SC @ 0.4 mlL^{-1} water, and T_4 = Lufenuron 5 EC @ 0.5 mlL^{-1} water. An untreated control was maintained by applying water only. Sprayings were done three times at 15-days intervals using a knapsack sprayer, at 4:00 pm to minimize risk to pollinators. Number of jassids were counted at 1, 5 and 10 days atter treatments on three leaves per plant. Also, number and weight of healthy pods, along with percent infestation increase and decrease over control were recorded and calculated after the 1^{st}, 2^{nd}, and 3^{rd} sprays. Pods were harvested at 5-day intervals after each spray during the fruiting stage, and weighed separately.

$$\text{Infestation decrease (\%) over control} = \frac{\text{Control mean - Treatment data}}{\text{Control data}} \times 100$$

$$\text{Infestation increase (\%) over control} = \frac{\text{Treatment mean - Control mean}}{\text{Treatment mean}} \times 100$$

Yield estimation: Fruits were harvested from each picking event and were weighed using a digital scale and recorded for each pit at 5 days intervals. The total yield per pit was calculated by summing the weights from all harvested within that specific pit, providing a cumulative measure of productivity across the growing period. To standardize the results and enable comparisons with other studies, the yield per pit measured in grams and was converted to kilogram per hectare using the following formula:

$$\text{Yield (Kg/ha)} = (\text{Yield (kg) plot}^{-1} / \text{Plot size m}^2) \times 10000$$

Benefit cost ratio (BCR): To determine the Benefit Cost Ratio (BCR), current market prices of fruits were obtained from local markets. Gross income for each plot was calculated by multiplying the weight of marketable fruits by the prevailing market price. Net income was derived by subtracting the total cost of cultivation including land preparation, planting material, fertilizers, labor, irrigation, pest management, and other inputs from the gross income. The BCR was then calculated as the ratio of gross income to total cost of cultivation using the following equation:

BCR = Gross return / Total cost of production (treatment costs + common cost)

Statistical analysis: Statistical analysis of the experimental data was carried out to determine significant differences among treatments. The data were analyzed using STATISTIX-10 software, and analysis of variance (ANOVA) was performed. Mean comparisons among treatments were conducted using the Least Significant Difference (LSD) test at the 5% level of significance.

RESULTS AND DISCUSSION

Effect of four bio-pesticides against jassid after 1st spray: The tested biopesticides showed statistically promising effects against the jassid after the first (3DAS: $p< 0.01$, $F = 33.04$, $df = 14$; 5DAS: $p< 0.01$, $F = 16.90$, $df = 14$; 10DAS: $p< 0.01$, $F = 40.49$, $df = 14$), spray as compared to the untreated control (Tables 1-3). Significantly

(3 DAS: $p < 0.01$, F =33.04, *df* =14; 5 DAS: $p < 0.01$, F =16.90, *df* =14; 10 DAS: $p < 0.01$, F = 40.49, *df* =14) the lowest number of jassids were found as 8, 9 and 9.33, respectively from the T_3 (buprofezin 40 SC at 0.4 mlL^{-1} water treated plant) after the 1st spray while the highest jassid recorded were 19, 21 and 23.67 at 1, 5 and 10 days, from the untreated control. Buprofezin 40 SC @ 0.4 ml L^{-1} showed the highest percentage decrease (58.67%) over untreated control. The results clearly indicate that buprofezin based treatments were found as the most effective in controlling jassid populations in yardlong bean after first spray. Ahmed *et al.* (2020) reported that buprofezin @ 0.75 mLL^{-1} water achieved the highest infestation reduction over untreated control of jassid population in flower (64.16%) and pod (70.60%) of yardlong bean. Similarly, Kavita *et al.* (2014) found that buprofezin 25% SC significantly reduced jassid population (1.10 jassids/leaf) compared to the control, demonstrating its efficacy against jassids in mungbean.

Efficacy of bio-pesticides against jassid after second spray: Similarly, significantly (3DAS: $p < 0.01$, F =25.70, *df* =14; 5DAS: $p < 0.01$, F =23.19, *df* =14; 10DAS: $p < 0.01$, F =24.88, *df* =14) the lowest number of jassids were counted as 6, 5.33 and 6.67, respectively from the T_3 (buprofezin 40 SC at 0.4 mlL^{-1} water) treated plant while the highest 17.67, 18.67 and 20.67 were recorded at 1, 5 and 10 days, from the untreated control after 2nd spray. Buprofezin 40 SC @ 0.4 ml L^{-1} also showed

Table 1. Effectiveness of four bio-pesticides against jassid on yardlong bean after first spray

Treatments	Doses (ml L^{-1})	Number of jassid after 2nd spray			Mean	Decrease (%) over control
		1 DAS	5 DAS	10 DAS		
T_1	1	12.67 c	12.67 c	12.67 c	12.67 c	40.29
T_2	1.5	16.33 b	16.33 b	16.33 b	16.11 b	24.08
T_3	0.4	8.00 d	8.00 d	8.00 d	8.77 d	58.67
T_4	0.5	15.00 bc	15.00 bc	15.00 bc	15.22 bc	28.27
Untreated control	-	19.00 a	19.00 a	19.00 a	21.22 a	-
CV (%)	-	13.72	15.83	13.90	8.53	-

Means in a column with different letters differ significantly at 0.05% (LSD test). DAS = Days after spray, T_1 = Azadirachtin, T_2= *Celastrus angulatus*, T_3 = Buprofezin, T_4 = Lufeneuron, and Untreated control the highest percentage decrease (68.42%) over untreated control. Choudhary *et al.* (2022) reported that buprofezin 25 SC (0.04%) resulted effectively against jassid count after the second spray, achieving a high population reduction of 85.52% at 3 days after treatment, indicating strong and timely suppression. Likewise, Barot and Patel (2022) observed that buprofezin + acephate 0.075% significantly effective against jassid, reducing the population to 1.27 jassids per leaf after the second spray.

Efficacy bio-pesticides against jassid after third spray: Again, significantly (3DAS: $p< 0.01$, $F =28.37$, $df =14$; 5DAS: $p< 0.01$, $F =29.43$, $df =14$; 10DAS: $p< 0.01$, $F =37.84$, $df =14$) the highest number of jassids were counted as 18, 19.67 and 22.17 after 1, 5 and 10 days, respectively from the untreated control. Conversely, the lowest number of jassids were found as 8.83, 8.33 and 8.0 after 1, 5 and 10 days, respectively from the T_3 (buprofezin 40 SC @ 0.4 mlL^{-1}) treatment. The highest reduction (57.92%) over the untreated control was observed from buprofezin 40 SC @ 0.4 ml L^{-1} followed by T_2 treatment (*Celastrus angulatus* 1% EW @ 1.5 ml L^{-1}). These findings are consistent with Kumar *et al.* (2019) who observed that buprofezin 25 SC (800 mlha^{-1}) significantly reduced jassid populations to 7.00-10.67 jassids per three leaves after sprays. Also, Chaudhary *et al.* (2018) found similar result of buprofezin which reduced jassid populations to1.97-2.04 jassids per three leaves after sprays. In short, buprofezin 40% SC @0.4 mlL^{-1} worked as the best in

Table 2. Effectiveness of four bio-pesticides against jassids on yardlong bean after the second spray

Treatments	Doses (ml L^{-1})	Number of jassid after 2nd spray			Mean	Decrease (%) over control
		1DAS	5DAS	10DAS		
T_1	1	14.00 b	11.00 b	13.33 b	12.78 b	32.74
T_2	1.5	13.67 b	10.67 b	13.33 b	12.56 b	33.98
T_3	0.4	6.00 c	5.33 c	6.67 c	6.00 d	68.42
T_4	0.5	8.00 c	9.33 b	10.33 b	9.22 c	51.47
Untreated control	-	17.67 a	18.67 a	20.67 a	19.00 a	-
CV (%)	-	13.72	15.83	13.90	8.53	-

Means in a column with different letters differ significantly at 0.05% (LSD test). DAS = Days after spray, T_1 = Azadirachtin, T_2= *Celastrus angulatus*, T_3 = Buprofezin, T_4 = Lufeneuron, and Untreated control

Table 3. Effectiveness of four bio-pesticides against jassids on yardlong bean after the third spray

Treatments	Doses (ml L^{-1})	Number of jassid after 3rd spray				Decrease (%) over control
		1 DAS	5 DAS	10 DAS	Mean	
T_1	1	15.33 b	14.67 b	15.83 b	15.28 b	23.37
T_2	1.5	12.17 c	11.17 c	13.00 c	12.11 c	39.27
T_3	0.4	8.83 d	8.33 d	8.00 d	8.39 d	57.92
T_4	0.5	14.83 b	12.50 bc	15.83 b	14.39 b	27.83
Untreated control	-	18.00 a	19.67 a	22.17 a	19.94 a	-
CV (%)	-	8.18	10.23	9.67	8.17	-

Means in a column with different letters differ significantly at 0.05% (LSD test). DAS = Days after spray, T_1 = Azadirachtin, T_2= *Celastrus angulatus*, T_3 = Buprofezin, T_4 = Lufeneuron, and Untreated control

managing jassid populations on yardlong bean compared to the other treatments.

Efficacy of tested bio-pesticides on the yields: The effectiveness of selected bio-pesticides on the yield of yard-long bean was evaluated, and significant variations were observed among treatments at each harvest (Table 4). The highest cumulative yield (318.07 g $plant^{-1}$) was recorded with buprofezin 40% SC @ 0.4 ml L^{-1} water, while the lowest yield (99.54 g pit^{-1}) harvested from the untreated control. Yield increase over the untreated control was the most distinct with buprofezin 40% SC @ 0.4 ml L^{-1}, showing a substantial increase of 68.70%. These findings align well with Ahmed *et al.* (2020a) reported that, buprofezin at 0.75 ml L^{-1}achieved the highest yardlong bean yield (15.14 t ha^{-1}), which was 40.34% increase over untreated control treatment. Likewise, Badariprasad *et al.* (2020) observed that buprofezin @175 g a.i./ha produced the highest yield of 65.50 qha^{-1}, which marked a 40.6% increase over untreated control.

Efficacy of bio-pesticides on Benefit Cost Ratio (BCR): Table 5 presents the economic analysis and Benefit Cost Ratio (BCR) of yard-long bean cultivation under different treatments. Among them, buprofezin 40% SC @ 0.4 ml L^{-1} proved to be the most economically viable, recording the highest BCR (2.26) and emphasizing the importance of effective pest management in improving yield and profitability. However, differences in treatment costs indicate that although several bio-pesticides

Table 4. Effectiveness of four bio-pesticides on the yield of yardlong bean at different harvesting stage

Treatments	Doses (ml L^{-1})	Cumulative yield	Yield increase (%) over control
T_1	1	178.76 b	44.32
T_2	1.5	182.66 b	45.49
$_{T}3$	0.4	318.07 a	68.70
T_4	0.5	159.84 c	37.72
$_{T}5$	-	99.54 d	-
CV (%)	-	2.10	-

Means in a column with different letters differ significantly at 0.05% (LSD test). DAS = Days after spray, T_1 = Azadirachtin, T_2= *Celastrus angulatus*, T_3 = Buprofezin, T_4 = Lufeneuron, and Untreated control

offer economic benefits, buprofezin provides the highest return on investment in this specific context.

These results align with previous studies demonstrating the economic benefits of buprofezin. Ahmed *et al*. (2020a) reported the highest BCR (1.48) with buprofezin @ 0.5 ml L^{-1} in yard-long bean. Similarly, Alam *et al*. (2022) recorded a BCR of 1:1.44 using buprofezin (Award 40 SC). Chakraborty *et al*. (2017) also observed a superior BCR (1:5.79) with a buprofezin–fipronil combination, confirming its economic viability.

Table 5. Effectiveness of four bio-pesticides on the economic analysis and benefit cost ratio (BCR) infesting yardlong bean

Treatments	Yield (Kg/ha)	Gross return (Tk/ha)	Total cost of production (Tk/ha)			Net return (Tk/ha)	Benefit Cost ratio
			Common	Treatments	Total		
T_1	3575.2	178760	135000	3265	138265	40495	1.29
T_2	3653.2	182660	135000	4120	139120	43540	1.31
T_3	6361.4	318070	135000	5626	140626	177444	2.26
T_4	3196.8	159840	135000	3858	138858	20982	1.15
Untreated control	1990.8	99540	135000	-	135000	-35460	0.74

T_1 = Azadirachtin, T_2= *Celastrus angulatus*, T_3 = Buprofezin, T_4 = Lufeneuron and Untreated control

All the tested chemicals e.g., Azadirachtin, *Celastrus angulatus*, Buprofezin and Lufeneuron yielded significant results over untreated control. However, among the treatments, buprofezin 40% SC @ 0.4 ml L^{-1} of water was observed more effective against the jassids in yardlong bean.

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BIO-RATIONAL MANAGEMENT APPROACHES OF MAJOR INSECT PESTS ATTACKING YARDLONG BEAN

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ABSTRACT

Yardlong bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Walp.) is an important leguminous vegetable crop in Bangladesh, and its productivity is severely constrained by major insect pests, including aphids, jassids, whiteflies, and the legume pod borer (*Maruca testulalis*). Excessive reliance on synthetic insecticides has resulted in resistance development and ecological disruption, highlighting the need for safer alternatives. The experiment was conducted at Gazipur Agricultural University (GAU), Gazipur using a randomized complete block design with eight treatments and three replications. The treatments included Biotrin 0.5 AS (Matrine) @ 1ml/L of water, Bio-Clean 5 SL (De- limonin) @ 1ml/L of water, Biomax M 1.2 EC (Abamectine) 1ml/L of water, mahogany Oil @ 5ml/L of water, Bio-Action 1.5 SL (Matrine) @ 1ml/L of water, Spinomax 44.3 SC (Spinosad) 1ml/L of water, neem oil @ 5ml/L of water, and untreated control. Results showed that Biomax 1.2 EC, Spinomax 44.3 SC, neem oil, and mahogany oil significantly reduced populations of aphids, jassids, whiteflies, and pod borer larvae compared with the untreated control. Spinomax 44.3 SC consistently resulted in the lowest pod infestation (9.5±0.5%) and pod borer larval density (10.3±0.4). Among all treatments, Spinomax 44.3 SC and Biomax 1.2 EC produced the highest yield (20.2±0.8 and 18.6±1.4, respectively) and marginal benefit-cost ratio (3.97 and 3.43, respectively). Botanical treatments exhibited comparatively lower adverse effects on beneficial arthropods. The findings suggest that selected bio-rational insecticides, particularly Spinomax 44.3 SC and Biomax 1.2 EC, can be effectively integrated into sustainable pest management programs for yardlong bean cultivation.

Keywords: *Maruca testulalis*, Aphid, Jassid, Whitefly, IPM, Eco-friendly pest management.

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INTRODUCTION

Yardlong bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Walp.) is an important leguminous vegetable cultivated worldwide and is particularly popular as a summer vegetable in Bangladesh due to its high market demand and profitability. In Bangladesh, the crop covered an area of 17,307 ha with a total production of 28,469 MT during the 2018–2019 growing season (BBS 2019). Yardlong bean is a rich source of essential nutrients, including vitamins, proteins, minerals, and fats. Despite its nutritional and economic importance, high incidences of insect pests significantly affect the yield and quality, limiting the crop's overall productivity. According to Mrong *et al*. (2023), 12-30% of yield loss is recorded to be occurred in yardlong bean due to insect pests. The crop is attacked by several economically important pests, including aphids (*Aphis craccivora*), jassids (*Amrasca devastans*), whiteflies (*Bemisia tabaci*), epilachna beetle (*Epilachna dodecastiga*), green stink bug (*Nezara viridula*), jute hairy caterpillar (*Spilosoma obliqua*), and red spider mite (*Tetranychus* spp.). Among these, the legume pod borer (*Maruca testulalis*) is considered the most destructive pest in Bangladesh, causing yield losses of up to 80% across various host plants (Malacrinò *et al*. 2020). The larvae bore into flowers and pods, remaining concealed within plant tissues, which makes difficult for effective control using conventional chemical insecticides.

To manage these pests, farmers predominantly rely on synthetic insecticides. However, the indiscriminate and repeated use of systemic insecticides has led to the development of insecticide resistance, pest resurgence, secondary pest outbreaks, and disruption of agro-ecosystems by adversely affecting non-target organisms (Dittrich *et al*. 1990). In contrast, bio-rational pest management approaches involve the use of pesticides that are target-specific, environmentally benign, and rapidly degradable, thereby reducing environmental persistence and exposure risks. Bio-rational products, including botanical extracts and plant-based oils, have been widely incorporated into integrated pest management (IPM) programs due to their proven efficacy against insect pests (Soares *et al*. 2019). These botanicals exert toxic, antifeedant, and growth-inhibitory effects on insect pests, ultimately suppressing their development and reproduction (Ahad *et al*. 2016; Mazumder *et al*. 2016). Considering these aspects, the present study was undertaken to evaluate the efficacy of selected bio-rational insecticides for managing major insect pests of yardlong bean, assessing their impact on natural enemy populations, and determining the marginal benefit-cost ratio (MBCR) of the tested bio-rational insecticides under field conditions.

MATERIALS AND METHODS

Design of experiment and crop production: The experiment was conducted under the Department of Entomology, Gazipur Agricultural University (GAU), Gazipur during February to May, 2022. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 3 replications. A total of 24 plots were made and the unit plot size was 3 m × 2 m. There were 10 plants planted in each plot. In total 240 plants were planted for this study. The spacing between row to row and plant to plant was 1.0 m and 0.50 m, respectively. The seed of BARI Borbati-1 variety was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Three-week-old seedlings were transplanted to the field on March 4, 2022, maintaining row to row distance 1 m and pit to pit distance 50 cm.

Treatments and methods of application: Seven treatments along with an untreated control were evaluated on the basis of pest's infestation in yardlong bean. During the entire cropping season, insecticide was sprayed on experimental field for six times maintaining 7 days interval. The treatments, namely, Biotrin 0.5 AS (Matrine) @ 1ml/L of water, Bio-Clean 5 SL (De- limonin) @ 1ml/L of water, Biomax M 1.2 EC (Abamectine) 1ml/L of water, mahogany Oil @ 5ml/L of water, Bio-Action 1.5 SL (Matrine) @ 1ml/L of water, Spinomax 44.3 SC (Spinosad) 1ml/L of water, neem oil @ 5ml/L of water, and untreated control (spraying of only water at the same time of other treatments application). A particular insecticide was mixed with water in the Knapsack sprayer, was shaken well and sprayed well covering the whole plant. Before spraying, the spray machine was calibrated to find out the required quantity of spray materials for three plots. The spraying was done early in the afternoon to avoid bright sunlight and drift caused by the strong wind and adverse effect on pollinating bees.

Data collection and analysis: The observation on the incident of insect pests and their natural enemies was counted from their appearance on plants till harvest. Data were collected from some pre-selected parameters such as abundance and infestation of insect pests and natural enemies with crop growing season. Sample was taken from 5 plants respectively and then converted to 10 plants (3m × 2m) for expressing the rate of plant infestation and number of pests per plot. Rate of infestation by different pest, healthy and infested pods per plot by number and weight and yield of fruit were recorded at 3 days after the spraying of selected insecticides. The weight of infested and total leaves and pods for each treated plot and untreated control plot were recorded and the percent reduction over control of leaf and infestation by weight was calculated. The cumulative yield of per plot from total harvest was calculated and it was then expressed as ton per hectare. The natural enemies found in the experimental field were lady bird beetle, black ant, bees, syrphid fly and spider. 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). One-way analysis of variance followed by Tukey HSD Posthoc test (at 5% level of significance) for determining the effects of insecticides on number of pests, number of natural enemies, larval number of pod borer and yield. All the analyses were performed using IBM SPSS 20.0.

RESULTS AND DISCUSSION

Efficacy of biorational insecticides against aphid and whitefly attacking yardlong bean: The effects of tested biorational insecticides on aphid and whitefly populations and their infestation rates in yardlong bean are presented in Table 1. Significant variation was observed among the treatments for both pest density and infestation rate. The untreated control plot recorded the highest aphid population (36.8±1.7 per plot) and infestation rate (32.1±6.4%), as well as the highest whitefly population (28.7±1.7 per plot) and infestation rate (28.5±3.0%). Among the treated plots, Biomax 1.2 EC and mahogany oil resulted in comparatively lower aphid populations (13.4±0.9 and 15.4±1.2 per plot, respectively) and reduced infestation rates. For whitefly, the lowest population was recorded in mahogany oil (8.8±0.3 per plot), followed by Biomax 1.2 EC (9.9±0.5 per plot). All biorational insecticide treatments significantly reduced aphid and whitefly populations and infestation rates compared to the untreated control. In align with the present study Mollah and Khatun (2024) referred Biomax M as a non-toxic alternative to suppress aphid population in brinjal ecosystem. Similarly, Choudhury (2020) found neem and mahogany as a potential bio-rational means for suppressing whitefly population.

Table 1. Effect of different biorational insecticides on aphid and whitefly population density and infestation rate (%) in yardlong bean

Treatments	Aphid/plot	Infestation rate%	Whitefly/plot	Infestation rate%
Biotrin 0.5 AS	25.6±1.1b	21.6±6.3ab	14.8±0.4c	13.3±1.7b
Bio-Clean 5 SL	22.3±1.1c	18.3±3.5b	19.0±0.3b	12.1±1.5b
Biomax 1.2 EC	13.4±0.9d	15.8±1.9b	9.9±0.5de	11.2±2.7b
Mahogany oil	15.4±1.2d	18.3±1.3b	8.8±0.3e	13.6±1.8b
Bio-Action 1.5 SL	24.2±0.7bc	18.7±3.6b	15.7±0.6c	11.5±2.2b
Spinomax 44.3 SC	22.5±0.9c	16.1±4b	11±0.4d	10.7±1.7b
Neem oil	15.5±0.4d	18.5±3.6b	11±0.1d	10.4±2.4b
Untreated control	36.8±1.7a	32.1±6.4a	28.7±1.7a	28.5±3a

Data expressed as mean± S.E. Means within a column followed by no common letter(s) are significantly different by Tukey Post hoc statistics at $P \leq 0.05$.

Efficacy of biorational insecticides against jassid and pod borer attacking yardlong bean: Data of Table 2 show the effect of different biorational insecticides on jassid and pod borer abundance and infestation rate in yardlong bean. Significant variation was observed among treatments for both pests. The highest jassid population and infestation rate were recorded in the untreated control plot (65.2±0.7 per plot and 37.2±5.4%, respectively). Among the treated plots, Spinomax 44.3 SC resulted in the lowest jassid population (16.4±1.7 per plot), which was statistically similar to neem oil (18.0±1.1) and mahogany oil (19.8±1.6). The lowest jassid infestation rate was observed in Biomax 1.2 EC (14.2±1.3%), followed by mahogany oil (15.3±1.2%), both of which differed significantly from the untreated control. In the case of pod borer, the untreated control plot recorded the highest larval population (25.8±1.7 per plot) and infestation rate (36.6±2.1%). Spinomax 44.3 SC exhibited the lowest pod borer population (10.3±0.4 per plot) and infestation rate (9.5±0.5%), which was statistically similar to Biomax 1.2 EC (16.5±0.5 larvae per plot and 10.3±1.1% infestation). Other biorational treatments showed moderate suppression of pod borer compared to the untreated control. Therefore, the results indicate that Spinomax 44.3 SC and Biomax 1.2 EC were the most effective treatments in reducing both jassid and pod borer populations and infestation rates under field conditions. Similarly, Choudhury (2020) found neem and mahogany as a potential bio-rational means for controlling whitefly population. Ahmed *et al*. (2019) observed that BioNeem plus

Table 2. Effect of different biorational insecticides on jassid and pod borer population density and infestation rate (%) in yardlong bean

Treatments	Jassid/plot	Infestation rate%	Pod borer/plot	Infestation rate
Biotrin 0.5 AS	49.3±2.4b	26.3±2.3b	23.7±0.4a	17.3±1bc
Bio-Clean 5 SL	49.4±1.9b	23.5±2.1b	22±0.3ab	18±0.5b
Biomax 1.2 EC	22.2±2.0d	14.2±1.3cd	16.5±0.5b	10.3±1.1d
Mahogany oil	19.8±1.6de	15.3±1.2cd	15.6±0.3b	12.8±0.6cd
Bio-Action 1.5 SL	38.8±3c	19.3±3.6c	21±0.6ab	15.5±3.2bc
Spinomax 44.3 SC	16.4±1.7e	18.3±0.3c	10.3±0.4c	9.5±0.5d
Neem oil	18±1.1de	17.6±0.7c	13.3±0.1bc	15.5±1.5bc
Untreated control	65.2±0.7a	37.2±5.4a	25.8±1.7a	36.6±2.1a

Data expressed as mean± S.E. Means within a column followed by no common letter(s) are significantly different by Tukey Posthoc statistics at P≤ 0.05

and mahogany oil performed better against pod borer. Mrong *et al*. (2024) similarly recorded lowest pod infestation from Tracer 45 SC (Spinosad). Choudhury (2020) and Ahmed *et al*. (2020) reported neem and mahogany oil effective for reducing pod infestation.

Bio-rational management approaches on number of natural enemies: Data presented in Table 3 illustrate the effects of different eco-friendly management approaches on the abundance of beneficial and non-target arthropods in yardlong bean fields. Significant variation was observed in the population of lady bird beetles among treatments. The highest number of lady bird beetles per plot was recorded in the untreated control (20.6±4.6), which was statistically similar to Biotrin 0.5 AS (18.0±5.2). In contrast, the lowest lady bird beetle population was observed in plots treated with Spinomax 44.3 SC (10.0±0.0). These findings indicate that chemical insecticides adversely affect natural enemy populations. Similar observations were reported by FAO (2003), who documented a substantial reduction in beneficial insects, particularly spiders and lady bird beetles, following insecticide application in brinjal agroecosystems. Additionally, Tohnishi *et al*. (2005) reported that neem-based products are comparatively less toxic to predators such as lady bird beetles, spiders, and other natural enemies than synthetic insecticides.

In the case of syrphid flies, no significant variation was detected among treatments, including the untreated control. The population ranged from 1.3±0.9 to 5.7±2.9 individuals per plot. Similarly, black ant populations did not differ significantly among treatments. The highest number of black ants was recorded in the untreated control (30.3±5.1), followed by Biotrin 0.5 AS (28.6±1.3) and Bio-Clean 5 SL (28.6±0.3), while the lowest population occurred in Spinomax 44.3 SC (20.0±2.3) and Biomax 1.2 EC (20.6±0.6). Comparable trends were also reported by Roy *et al*. (2016), who observed that chemical insecticides negatively affect both pest and beneficial arthropod populations, whereas biopesticides are comparatively safer and environmentally benign.

Regarding spider populations, the highest abundance was found in the untreated control (6.0±0.6), which was statistically similar to Bio-Clean 5 SL (4.3±0.3). The lowest spider population was recorded in Spinomax 44.3 SC (1.0±0.6), which was statistically comparable to neem oil (2.0±0.6) and Biomax 1.2 EC (2.0±0.6). Supporting these findings, Efad *et al*. (2021) reported that Spinomax 44.3 SC, being a bio-rational insecticide, maintained the presence of beneficial arthropods such as lady bird beetles, syrphid flies, black ants, and spiders throughout the cropping season in brinjal. Their study showed minimal statistical variation in lady bird beetle and black ant populations between Spinomax-treated and untreated plots, while no significant differences were observed for syrphid flies and spiders across the treatments.

Table 3. Effect of different bio-rational management approaches on number of natural enemies per plot during entire cropping season

Treatments	No. of lady bird beetle	No. of black ant	No. of syrphid fly	No. of spiders
Biotrin 0.5 AS	18.0±5.2a	28.6±1.3a	2.3±1.2a	3.0±0.6bc
Bio -Clean 5 SL	16.0±2.3a	28.6±0.3a	2.3±1.2a	4.3±0.3ab
Biomax 1.2 EC	11.3±1.1a	20.6±0.6a	1.7±0.9a	2.0±0.6bc
Mahogany oil	14.6±2.9a	24.0±3.0a	2.7±0.3a	4.0±0.6ab
Bio -Action 1.5 SL	15.3±2.4a	26.6±1.6a	3.3±0.3a	3.0±0.6ab
Spinomax 44.3 SC	10.0±0.0a	20.0±2.3a	1.3±0.9b	1.0±0.6c
Neem oil	14.0±0.6a	22.6±0.6a	2.0±0.6a	2.0±0.6b
Untreated control	20.6±4.6a	30.3±5.1a	5.7±2.9a	6.0±0.6a

Data expressed as mean± S.E. Means within a column followed by no common letter(s) are significantly different by Tukey Posthoc statistics at $P \leq 0.05$

Effect of bio-rational approaches on yield of yardlong bean: The obtained yields of yardlong bean from plots treated with different insecticides are presented Table 4. The effects of different insecticides on yield differed significantly. Total yield of yardlong bean ranged from 10.4 to 20.2 MT/ha. The highest yield (20.2±1.2 MT / ha) was obtained in plot treated with Spinomax 44.3 SC followed by Biomax1.2 EC (18.6±1.4 MT/ha). The lowest yield (10.4±1.2 MT/ha) was obtained from untreated control plot. The highest marketable yield was obtained in Spinomax 44.3 SC (17.6±0.6) and lowest in untreated control plot (6.5±1.0). Lowest infested yield found in Bio-Action (1.0±0.6) and highest infested yield found in untreated control plot (4.9±0.6). The highest percent yield loss was observed in Bio-Action 1.5 SL treated plot and lowest percent yield loss was observed in untreated control plot. Mrong *et al*. (2024) obtained the highest yield from the plots treated with Tracer 45 SC (Spinosad).

Figure 1 illustrates the highest percent reduction in yield loss was recorded in Bio-Action 1.5 SL (84.99%) treated plot, followed by Biotrin 0.5 AS (81.85%), whereas the lowest percent reduction in yield loss was obtained in untreated control plot (15.62%). Spinomax 44.3 (72.3), neem oil (68.21%), and Biomax 1.2 EC (64.3%) showed moderate yield reduction.

Economic analysis of different bio-rational approaches: The details of the cost of pest management (Tk ha^{-1}) under tested bio-rational management approaches

Table 4. Effect of different treatments on yield per hectare of yardlong bean and yield increase over untreated control

Treatments	Total yield (MT/ha)	Marketable yield (MT/ha)	Infested yield (MT/ha)	% Yield loss
Biotrin 0.5 AS	14.6±0.3b	13.3±0.6bc	1.3±0.3a	81.85
Bio-Clean 5 SL	14.6±1.0b	12.0±0.8abc	2.6±0.2a	63.71
Biomax1.2 EC	18.6±1.4ab	15.3±1.6abc	3.3±0.6a	64.30
Mahogany Oil	13.3±0.8ab	10.0±0.3ab	3.3±0.6a	50.03
Bio-Action 1.5 SL	13.3±1.3b	12.3±1.1bc	1.0±0.6a	84.99
Spinomax 44.3 %	20.2±0.8b	17.6±0.6bc	3.0±0.3a	72.35
Neem oil	14.6±1.2a	12.3±0.8a	2.3±0.4a	68.21
Untreated control	10.4±1.2b	6.5±1.0c	4.9±0.6a	15.62

Data expressed as mean± S.E. Means within a column followed by no common letter(s) are significantly different by Tukey Posthoc statistics at P≤ 0.05

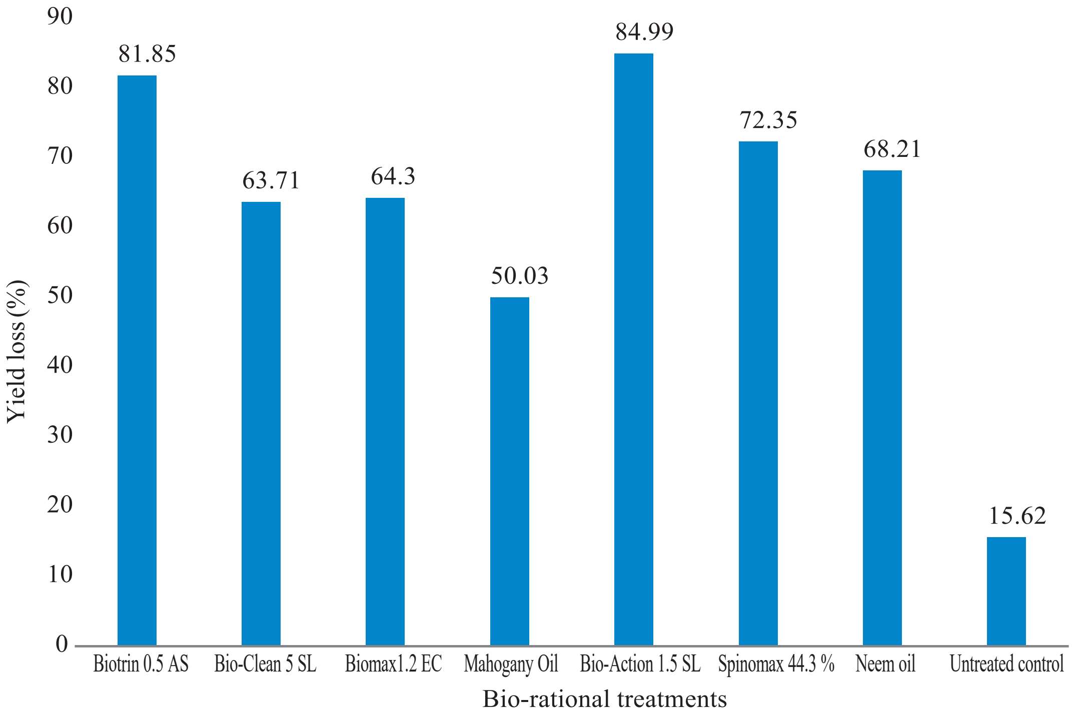

Fig. 1. Yield loss (%) assessment of yardlong bean as affected by tested bio-rational treatments.

Table 5. Marginal benefit cost ratio (MBCR) analysis of selected bio-rational management approaches against pests attacking yardlong bean (MT/ha)

Treatments	Management cost (tk)	Gross return (tk)	Net return (tk)	Adjusted net return (tk)	MBCR
Biotrin 0.5 AS	69550.0	325000.0	255450.0	99500.0	1.43
Bio-Clean 5 SL	53550.0	300000.0	246450.0	90500.0	1.69
Biomax1.2 EC	49350.0	375000.0	325650.0	169700.0	3.43
Mahogany Oil	45550.0	250000.0	204450.0	48500.0	1.06
Bio-Action 1.5 SL	56700.0	308250.0	251550.0	95600.0	1.68
Spinomax 44.3 SC	52320.0	416500.0	364180.0	208230.0	3.97
Neem oil	45550.0	308250.0	262700.0	106750.0	2.34
Untreated control	20550.0	200000.0	155950.0	0.0	

Market value of yardlong bean=25 tk/kg

against insect pests in yardlong bean was presented in Table 5. Management cost was the highest (Tk. 69550.0) with Biotrin 0.5 AS followed by Bio-Action (Tk. 56700.0). The lowest management cost (Tk. 20550.0) was found with untreated control followed by Tk. 45550.0 with neem and mahogany oil. The highest gross return (Tk. 416500.0) was found with Spinomax 44.3 SC followed by Tk. 375000.0 with Biomax 1.2 EC. The lowest gross return (Tk. 200000.0) was found with untreated control followed by Bio-Clean 5 SL (Tk. 86400.0). The highest net return (Tk.364180.0) was recorded with Spinomax 44.3 SC followed by Tk. 325650.0 with Biomax 1.2 EC, Tk. 255450.0 with Biotrin 0.5 AS, Tk. 251550.0 with Bio-Action, Tk. 246450.0 with Bio-Clean 5 SL and the lowest Tk. 155950.0 in untreated control plot. The highest adjusted net return (Tk. 208230.0) was recorded with Spinomax 44.3 SC followed by Tk. 169700.0 with Biomax 1.2 EC. The lowest adjusted net return was calculated from Mahogany oil (Tk. 48500.0) followed by Bio-Clean 5 SL (Tk. 90500.0) whereas untreated control plot had no adjusted net return. The highest MBCR of 3.97 was obtained from the plot treated with Spinomax 44.3 SC followed by 3.43 with Biomax 1.2 EC. The lowest marginal benefit cost ratio (MBCR) was found 1.06 from the Mahogany oil followed by Biotrin 0.5 AS (1.43). Our findings are supported by Mrong *et al*. (2024) who also obtained maximum marginal benefit cost ratio from the plots treated with Tracer 45 SC (Spinosad).

CONCLUSION

The findings of the present study indicate that Spinomax 44.3 SC and Biomax 1.2 EC were the most effective insecticides among the treatments evaluated for managing insect pests under field conditions. Consequently, plots treated with Spinomax 44.3 SC and Biomax 1.2 EC recorded the highest yield and marginal benefit–cost ratio (MBCR). Therefore, the application of these bio-rational insecticides is recommended for the effective management of aphids, jassids, whiteflies, and pod borers attacking yardlong bean cultivation. Future research should focus on the combination or rotation of active ingredients derived from different biological sources to enhance pest control efficiency while ensuring minimal adverse effects on non-target organisms and the environment.

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