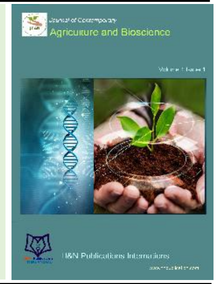
Journal of Contemporary Agriculture and Bioscience (2022), Volume 1, Number 2, Page 24-30

H&N Publications INTERNATIONAL

Journal of Contemporary

Agriculture and Bioscience

Journal Home page: http://www.hnpublication.com/journal/2/JCAB



Research Article

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Integrated management of common cutworm (*Spodoptera litura* Fab.) attacking cabbage in north-eastern part of Bangladesh

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Article info

Received: 30 January, 2022
Accepted: 30 April, 2022
Published: 06 May, 2022
Available in online:
24 May, 2022

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Link to this article:
http://www.hnpublication.com/article/9/details

Abstract

We compared efficacy and profitability of various integrated pest management (IPM) approaches against the common cutworm (*Spodoptera litura* Fab.) of cabbage field in north-eastern Bangladesh. Single and different combinations of IPM practices were evaluated against the control (no treatment). Infestation rates were lowest (<4.3%) and yield was highest (55–60 t/ha) for the treatment consisting of sex-pheromone traps, bio-control insects, and *spodoptera* nuclear *polyhedrosis* virus sprays compared to ca. 90% and 2.4–4.1 t/ha, respectively, for the control. The IPM plots also produced higher financial returns, whereas gross return was negative and benefit cost ratio (BCR) was zero for the control.

Keywords: BCR, biopesticide, NPV, parasitoid, sex pheromone.

Introduction

Cabbage (*Brassica oleracea* L.), is a popular and important winter season vegetable crop in Bangladesh and many other parts of the world. Cabbage is a nutritional leafy green vegetable crop, generally grown for densely leaved heads (Singh et al. 2004). Average yields in Bangladesh during winter of 2010–11 were 13.1 t/ha (Bangladesh Bureau of Statistics 2011), but yield may reach 50–60 t/ha under good management and growing conditions. Higher production can generate economic opportunities and provide better nutrition for small farmers.

About 30–35% of the produced cabbage however is being lost every year in Bangladesh due to the attack of insect pests including common cutworm or prodenia caterpillar (*Spodoptera litura* Fabricius (Lepidoptera: Noctuidae)). It is one of the most destructive pests of agricultural crops worldwide, especially in Asian countries. The common cutworm is a highly polyphagous pest, feeding on about 150 host plant species in India (Rao et al. 1993), and 27 host plant species in Pakistan (Ahmad et al. 2013). In cabbage, the larvae of common cutworm in gregarious form feed inside the cabbage head, tunneling into the soft stem, midribs, and leaf stalks (Awwal 2009). In recent years, devastating outbreaks of common cutworm have been common in Bangladesh (Alam and Dutta 2011). Outbreaks of common cutworm were recorded in mustard at Chalan Bill area of Natore, Sirajgong and Sunamganj districts in Bangladesh during the winter seasons of 2007–08 (Alam et al. 2010). During the same period similar outbreaks were also recorded from some other crops (e.g., okra, aroids, summer tomato, and grass pea).

The indiscriminate use of pesticides for the control of cabbage pests results in higher costs of control, secondary pest outbreaks, and unacceptable residue levels of concern for human health (Duke et al. 2003; Negahban et al. 2006). Pesticide residue is a great concern for countries exporting many agro-products, especially vegetables and fruits due to adverse effects of pesticide residue on export-oriented production systems (Dissathaporn et al. 2002). In cabbage, the presence of residue may be high because it is often consumed as raw food (e.g., salad) in many developed countries. Therefore, it is of utmost importance to minimize pesticide residue of vegetables for global and domestic markets by using alternative pest control method(s). In response to urgent demand for alternative methods, bio-rational based integrated pest management approaches need to be developed to produce pesticide-free vegetables with minimal production cost and environmental hazards. The outbreaks of secondary pests and adverse effects of pesticides on non-target organisms are becoming increasingly common concern in Bangladesh and many other countries of the world. For example, it has already been reported that common cutworm, *Spodoptera. litura* has developed resistance against the widely used synthetic pyrethroids in Pakistan (Ahmad et al. 2007). Currently the farmers of Bangladesh apply several groups of toxic insecticides (e.g., cypermethrin, lambda cyhalothrin, dimethoate, chlorpyrifos, mixture of thiamethoxam & chlorantraniliprole (Voliam Flexi ® 300SC)) to control common cutworm, *Spodoptera litura* infesting cabbage. However, the pest has already developed resistance against all these groups of insecticides (Rahman et al. 2013). All these factors have made the management of common cutworm, *Spodoptera litura* very difficult. In the recent-past years, sex- pheromone and other bio-rational based management practices (e.g., soaps, oils, botanical extracts, parasitoids and natural enemies, etc.) were reported as effective technologies against the eggplant shoot and fruit borer pest (Alam et al. 2003; Mazumder et al. 2010; Islam 2012). In order to develop alternatives to conventional practices for controlling the common cutworm, researchers in Bangladesh have been evaluating various ecologically suitable pest management methods (Rahman et al. 2013). Trichogrammatid wasps (*Trichogramma* spp.) have been used to control the lepidopteran insect pests worldwide. The members of the genus *Trichogramma* are egg parasitoids which have been extensively used in biological control worldwide for the purpose of inundative release (Miranda et al. 2011). For example, they have been used to parasitize the eggs of cotton bollworm, codling moth, light brown apple moth and European corn borer (Knutson 2005). *Bracon hebetor* is a larval parasitoid of many lepidopteran pests. It is a tiny wasp from the family Braconidae. They paralyze the late instar larvae of Indian meal moth, *Plodia interpunctella*; Mediterranean flour moth, *Ephestia kuehniella* and almond moth, *Cadra cautella* (Alam et al. 2014; Singh et al. 2014).

The present study was undertaken to observe the bio-efficacy and profitability of some ecologically sound pest management approaches for cabbage production in Bangladesh. We evaluated various ecologically suitable pest management options such as hand picking and destruction of the common cutworm larvae, use of egg and larval parasitoids, sex-pheromone lures, and bio-pesticides. The effectiveness and economic viability of these environmentally safe management practices were explored with the hope that cost-effective and sustainable management technologies could be developed and disseminated among the farmers of major cabbage growing areas in Bangladesh and other countries of the world where similar pest problems also exist.

Materials and Methods

Study site and establishment of cabbage

The study was conducted in four commercial cabbage fields in the greater Mymensingh region in the north-eastern part of Bangladesh during three consecutive winter seasons (October - February) of 2012–15. Climate of the study site is subtropical with winters characterized by nighttime and daytime temperatures of 8-10ºC and 15-25ºC. The soil of the experimental sites is characterized by medium lowland to highland (Agro-ecological Zone 9, Fertilizer Recommendation Guide 2012). Each of four commercial fields was considered one replica of the study. Four fields were located at Mucktagacha sub-district (24° 45′ 29.88″ N, 90° 16′ 0.12″ E) in Mymensingh district; Nakla sub-district (24° 58′ 59.88″ N, 90° 10′ 59.88″ E) in Sherpur district; Melandaha sub-district (24° 58′ 0.12″ N, 89° 49′ 59.88″ E) and Jamalpur central sub-district (24° 55′ 0″ N, 89° 57′ 30″ E) in Jamalpur district. Cabbage seedlings were transplanted on the 1st day of October in each cropping year. The optimum planting period of cabbage is from mid-September to mid-November in Bangladesh. Harvesting of cabbage heads was started from mid-November and continued up to mid-February. Irrigation was applied for seven occasions and weeding was done for three occasions. Nitrogen, phosphorus and zinc fertilizers were applied as recommended in Fertilizer Recommendation Guide (2012).

Study design and treatment application

The experiment was laid out in a randomized complete block (RCB) design with four dispersed replications. Commercial field located in each sub-district was considered one dispersed replication. In one commercial field of each sub-district, seven experimental plots (6 treatment plots + 1 control plot) were prepared where each plot size was 50 × 50 m. A distance of 200 m was maintained among the treatment and control plots. The seven treatments were: sex-pheromone trap (T_1); one spraying of spodoptera nuclear polyhedrosis virus) (SNPV×1) (T_2); bio-control (T_3); sex-pheromone trap + SNPV×2 (two sprayings) (T_4); sex-pheromone trap + bio-control insects (T_5); sex-pheromone trap + bio-control insects + SNPV×1 (T_6); and control (no treatment). One sex-pheromone trap was placed in central part of each plot, i.e., 25 m inside from four edges of the plot. It is to be noted that hand removal (weekly hand picking of infested leaves and destruction of cutworm larvae) was done in six treatment plots except control plot. Hand removal was done only up to two-month old cabbage during October-November of 2012-15.

Sex-pheromone traps were placed in the middle of T_1, T_4, T_5 and T6 plots, keeping 25 m distance from all edges of the plot. Two sex-pheromone traps require to be placed at least 20-25 m distance. In this study, sex-pheromone traps were placed keeping at 250 m distance between two traps (200 m distance between two plots + 25 m distance from edge of the plot to the middle of T_1, T_4, T_5 & T_6 plots where sex-pheromone traps were used). In some locations, sex-pheromone traps were placed keeping more than 250 m distance between two traps when T_1, T_4, T_5 and T_6 treatment plots were separated by T_2, T_3 and control).

The sex-pheromone trapping consisted of mass-trapping of male common cutworm moths with *Spodoptera litura* lure, which contained two compounds: Z,E,9,11-14:AC and Z,E,9,12-14:AC. The lure for the common cutworm species *Spodoptera litura* and *S. littoralis* contains the same two compounds, but the compounds need to be loaded into the lure dispensers in different amounts depending on the species to be attracted. Mixing ratio of the two compounds was not disclosed. The sex-pheromone bait trap (Figure 1a) consisted of a pheromone lure and locally fabricated water trough. The water trough was a 22-cm-tall clear plastic container with 5L capacity. Several triangular openings were cut out on all four sides at 3–4 cm intervals. Approximately 2.5–3 cm of soapy water was maintained inside the trap throughout the season. The sex-pheromone tube was hung through the center of the lid of the plastic container using thin wire so that the bait was 3–4 cm above the soapy water. The trap was then placed just above the crop canopy using bamboo stakes for support. Sex-pheromone traps were placed in the experimental plots at 20 days after transplanting (DAT) of seedlings on the 1st day of October during 2012-15.

In case of T_2 treatment, SNPV (0.2g per liter of water) was sprayed once at 60 days after transplanting (DAT) of seedlings on 30 November during three study years. In case of T_4 treatment, SNPV (0.2g per liter of water) was sprayed twice, first on 30 November at 60 DAT of seedlings and second on 20 December at 80 DAT of seedlings during three study years. The nuclear polyhedrosis virus belongs to the sub-group Baculoviruses, which is a natural pathogen that affects the establishment of moths and butterflies. Bio-control consisted of weekly release of egg parasitoid, *Trichogramma chilonis* @ 1g parasitized rice meal moth eggs/ha/week (40,000-50,000 adults emerged from 1g parasitized eggs) and larval parasitoid, *Bracon hebetor* @ 1 bunker adults/ha/week (800-1000 braconid adults).

Data collection and analyses

The numbers of healthy and infested cabbage heads were counted at 7-day intervals. These data were collected from randomly selected 2.0 m^2 areas; keeping approx. 15 m distance from edge of the plot and 10 m distance from the middle part of each plot. The infestation rate was calculated from the mean data of four

Table 1. Effect of various combined IPM treatments* on head infestation (mean % ± SE) of cabbage by *Spodotera litura* in north eastern Bangladesh

	Season					
Treatments	**2012-13**	**Relative reduction over control (%)**	**2013-14**	**Relative reduction over control (%)**	**2014-15**	**Relative reduction over control (%)**
T_1	42.53±3.53 (3.60) b	52.46	32.37±3.30 (3.14) c	65.12	34.45±3.71 (3.25) c	63.36
T_2	19.61±3.21 (2.44) c	78.08	17.19±3.37 (2.29) d	81.48	19.76±3.63 (2.46) d	78.98
T_3	79.49±3.78 (4.93) a	11.14	70.11±3.91 (4.63) b	24.45	71.16±3.97 (4.67) b	24.31
T_4	9.15±3.12 (1.67) d	89.77	7.31±3.87 (1.49) e	92.1	6.49±4.01 (1.40) e	93.10
T_5	31.26±3.42 (3.09) b	65.06	28.87±3.76 (2.97) c	68.89	30.42±3.59 (3.05) c	67.65
T_6	4.32±2.89 (1.14) d	95.17	2.44±2.71 (0.86) f	97.37	1.08±2.46 (0.57) f	98.87
C	89.46±2.31 (5.23) a	-	92.80±2.62 (5.33) a	-	94.02±2.54 (5.36) a	-

***Footnote:**

- T_1 = Sex-pheromone trap, T_2 = one spraying of spodoptera nuclear polyhedrosis virus (SNPV×1), T_3 = Bio-control insects, T_4 = Sex-pheromone trap + SNPV×2 (two sprayings), T_5 = Sex-pheromone trap + bio-control insects, T_6 = Sex-pheromone trap + bio-control insects + SNPV×1, C = Control (no treatment). Hand removal was done up to two-month old cabbage during October-November of 2012-15.
- Means followed by the same letter are not significantly different (P>0.05) based on ANOVA and Tukey's HSD. Transformation values are shown in parenthesis.

replicates (four commercial fields) for each treatment and control plot for each year. Data on head infestation (%) was transformed following Arcsine transformation (Table 1). To quantify pest abundance, the number of adult males of the common cutworm were counted and recorded twice per week at the time of sex-pheromone trap maintenance and summed for each week.

At the end of the season, we quantified the amount of harvested marketable healthy cabbage heads (head yield, t/ha) produced in each treatment plot and that of the control plot. The costs incurred due to labour, insecticide, bio-pesticide, application of pesticides, sex-pheromone, parasitoids, and other materials were recorded during the study period. The untreated control did not require any pest management cost. The cost for each treatment and that of control were calculated based on the local market price. The results of benefit-cost analyses were expressed in terms of benefit:cost ratios (BCRs). Three components viz., gross return, total cost of cultivation and gross margin were considered to calculate the benefit-cost ratios. The head infestation, head yield, gross return and BCRs were compared among treatment and control plots using ANOVA and Tukey's HSD test.

Table 2. Effect of various combined IPM treatments* on head yield (t/ha) of cabbage in north eastern Bangladesh.

	Season					
Treatments	**2012-13**	**Relative increase over control (%)**	**2013-14**	**Relative increase over control (%)**	**2014-15**	**Relative increase over control (%)**
T_1	36.52±3.64 c	784	37.09±3.71 c	892	38.39±3.38 bc	1252
T_2	45.12±3.79 b	992	46.82±3.69 b	1152	43.46±3.52 b	1420
T_3	10.18±3.21 d	146	13.17±3.37 d	252	12.14±3.25 d	324
T_4	53.43±3.82 a	1194	54.29±3.84 a	1352	56.88±3.75 a	1889
T_5	31.82±3.47 c	670	33.17±3.52 c	787	33.89±3.63 c	1085
T_6	55.80±2.42 a	1251	57.31±2.64 a	1432	60.18±2.88 a	2005
C	4.13±2.17 e	-	3.74±2.32 e	-	2.86±2.08 e	-

***Footnote:**

- Treatment abbreviations as in Table 1.
- Means followed by the same letter are not significantly different (P>0.05) based on ANOVA and Tukey's HSD.

Results

Head infestation and pest abundance

Head infestation and pest abundance differed significantly among the treatments (Table 1). Among the combination treatments, head infestation rates were lowest for the T_4 (sex-pheromone trap + SNPV×2) and T_6 (sex-pheromone trap + bio-control insects + SNPV×1), which ranged from 1.08 to 9.15% during three study years. Correspondingly relative infestation reduction over control was highest for the T_4 and T_6 treatments which ranged from 89.77

Table 3. Gross return (mean±SE), total cost of cultivation, gross margin (USD/ha), and benefit–cost ratios (BCR, mean±SE) for the different management approaches against the common cutworm of cabbage during the three consecutive winter seasons (2010-13).

	2012-2013				2013-2014				2014-2015			
	Gross return	Total cost of cultivation	Gross margin	BCR	Gross return	Total cost of cultivation	Gross margin	BCR	Gross return	Total cost of cultivation	Gross margin	BCR
T1	4017.2±252.00 d	1574.3	2442.9	1.55±0.07 b	2781.75±240.05 d	1580.75	1201.00	0.76±0.02 c	4222.9±263.00 d	1804.1	2418.8	1.34±0.06 b
T2	4963.2±285.31 c	1963.2	3000.0	1.53±0.05 b	3511.5±262.18 c	2010.5	1501.0	0.75±0.02 c	5432.5±299.08 c	2261.2	3171.3	1.40±0.06 b
T3	1119.8±212.34 f	1097.6	22.2	0.02±0.01 d	987.75±198.24 e	947.26	40.49	0.04±.01 d	1517.5±207.86 f	1252.4	265.1	0.21±0.01 d
T4	5877.3±305.26 b	2286.7	3590.6	1.57±0.07 b	5971.9±305.00 b	2302.7	3669.2	1.59±0.07 a	6256.8±324.52 b	2370.6	3886.2	1.63±0.09 a
T5	3500.2±232.00 e	1726.5	1773.7	1.02±0.03 c	3648.7±279.54 c	1762.8	1885.9	1.06±0.04 b	2727.9±231.26 e	1802.5	1925.4	1.06±0.05 c
T6	6138.0±328.00 a	2426.5	3711.5	1.65±0.08 a	6304.1±292.38 a	2452.3	3851.8	1.63±0.06 a	6619.8±295.88 a	2566.3	4053.5	1.63±0.07 a
C	454.3±178.72 g	680.3	0	0	411.4±142.00 f	695.3	0	0	314.6±125.68 g	709.2	0	0

Footnote:
- Treatment abbreviations as in Table 1.
- Market price of cabbage = 0.110 USD/kg
- Means followed by the same letter are not significantly different (P>0.01) based on ANOVA and Tukey's HSD.

to 98.87% during three study years. Among the individual treatments, head infestation rates were low to intermediate level for the T_1 (sex-pheromone trap) and T_2 (SNPV×1), which ranged from 17.19 to 42.53% during three study years. Corresponding to head infestation, relative infestation reduction over control was intermediate to high level for the T_1 and T_2 treatments which ranged from 52.46 to 81.48% during three study years. In individual treatment, T_3 (Bio-control insects) had little impact on relative head infestation reduction over control with few exceptions during three study years. The highest head infestation rate was recorded in the control plot (C) in all the three study years (89.46 – 94.02%, Figure 1b). The trends in head infestation rates among treatments were more or less similar for all three study years (F = 312.716, 628.174, 1457.196 for 2010–11, 2011–12, 2012–13, respectively, P < 0.01, df = 18).

Pest abundance (average number of adult males caught per trap per week) ranged from 7.73 to 17.83 among the different treatments (Figure 2). In every study year, the highest pest abundance was recorded in T_1 treatment (sex-pheromone traps). While the lowest pest abundance was recorded in T_6 (F = 2.48, 2.76, 2.93 for 2010–11, 2011–12, 2012–13, respectively; P < 0.05, df = 18). The trends of pest abundance were similar among the three study years 2010–13.

Cabbage yield

Corresponding to the infestation rate, head yields were highest for the T_4 and T_6 treatments (Table 2) which ranged from 53.43 to 60.18 t/ha during three study years. The lowest head yield was recorded in the control which ranged from 2.86 to 4.13 t/ha during three study years. Among the combination treatments, head yield was highest for the T_4 (sex-pheromone trap + SNPV×2) and T_6 (sex-pheromone trap + bio-control insects + SNPV×1), which ranged from 53.43 to 60.18 t/ha during three study years. Correspondingly relative yield increase over control was highest fo the T_4 and T_6 treatments which ranged from 1194 to 2005% during three study years.

Among the individual treatments, head yields were low to intermediate level for the T_1 (sex-pheromone trap) and T_2 (SNPV×1), which ranged from 36.52 to 46.82% during three study years. Correspondingly relative yield increase over control was intermediate to high level for the T_1 and T_2 treatments which ranged from 784 to 1420% during three study years. In individual treatment, T_3 (Bio-control insects) had little impact on relative yield increase over control during three study years. The trends in cabbage yield among treatments were more or less similar for all three study years (F = 512.379, 331.979, 380.972 for 2010–11, 2011–12, 2012–13, respectively; P < 0.01, df = 18).

Benefit-cost analyses

The highest gross returns and benefit-cost ratios (BCRs) were also obtained from the T_4 and T_6 treatments (Table 3). Gross return was negative and thus BCR was zero for the control (**Gross return**: F = 1230.96, 1142.72, 1097.81 for 2010–11, 2011–12, 2012–13, respectively; **BCR**: F = 317.681, 268.427, 226.829 for 2010–11, 2011–12, 2012–13, respectively; P < 0.01, df = 18).

Discussions

Mass trapping of male moths consists of deploying traps baited with sex pheromone to attract and catch males before they locate and mate with females, while mating disruption consists of deploying sex pheromones to prevent male insects from finding and mating with female (Welter et al. 2005). Sex-pheromone traps have been used to control insect pests in three ways: 'mass trapping', 'mating disruption', 'lure and kill' (Klein and Lacey 1999). Mass trapping, mating disruption and attracticide methods have been used for the management of stored product insect pests (Savoldelli and Trematerra 2011). Population monitoring, mass trapping and mating disruption with insect sex-pheromone have been successfully employed for the management of several other insect pests (Talekar and Shelton 1993; Grzywacz et al. 2010). Mass trapping has been used in long-term management of many

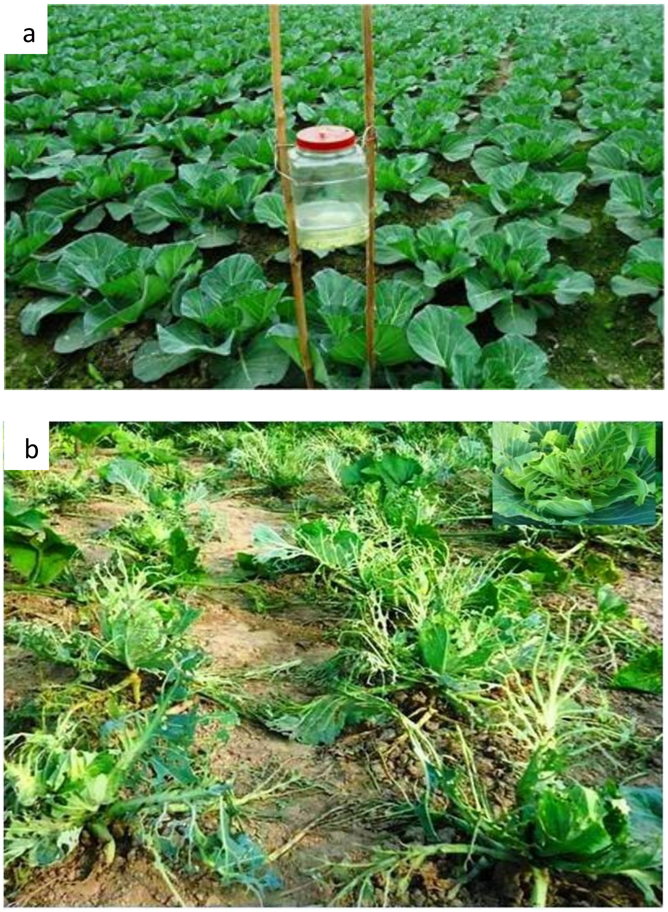

Figure 1. (a) Sex-pheromone traps with Spodoptera litura lures and (b) Severely infested cabbage crop with common cutworm in the control plot.

insect pest species *viz.,* codling moth, *Cydia pomonella* (L.); pink bollworm, *Pectinophora gossypiella* (Saunders); bark beetles, etc. and in eradication of invasive insect pest species *viz.,* gypsy moth, *Lymantria* dispar (L.) and boll weevil, *Anthonomus grandis grandis* Boheman (El-Sayed et al. 2006). In this study, individual treatments *viz.*, mass trapping of *Spodoptea litura* male moths with sex-pheromone traps (T_1) and spraying of spodoptera nuclear polyhedrosis virus (SNPV) (T_2) markedly reduced head infestation and considerably increased cabbage yield (Table 1). In agreement with our results, Song et al. (2009) found that the application of sex pheromone trapping significantly reduced the infestation of adults, decreased larvae or egg mass density as well as the damage rate of *Spodoptera litura* in Chinese cabbage field. They also found that the sex pheromone trapping had helped the farmers to obtain higher financial benefits by lowering costs and increasing yield compared to the sole use of chemical control. Sex-pheromone traps alone caught highest number of male moths (Figure 2), suggesting that there may have association between number of male moths caught with traps and relative head infestation reduction and relative increase in yield of cabbage (Table 1 and Table 2).

As of sex-pheromone traps, some researchers have also found that spodoptera nuclear polyhedrosis virus has proven effective in controlling common cutworm, *Spodoptera litura* (Jayanthi and Padmavathamma 2001). Other authors also reported that the effect of spodoptera nuclear polyhedrosis virus alone was found to be effective in controlling common cutworm, *Spodoptera litura* but it was more effective when applied in combination with endosulfan and neem seed kernel extract) the pest infesting cabbage (Kumari and Singh 2009). Entomopathogenic viruses of the family Baculoviridae have been used as biopesticides as they are narrowly pest specific and safe to wildlife (Szewczyk et al. 2009). Biopesticides can also provide ecologically sound solutions to pest problems and are known to be effective in controlling pests that have already developed resistance to chemical pesticides. They leave little or no toxic residues and are commonly harmless to beneficial insects and other non-target organisms. The application of Baculovirus biopesticides may have limitations due to their slow pest killing action. The killing activity of baculoviruses may be improved in future through modifying genome of the baculovirus.

Both sex-pheromone traps and spodoptera nuclear polyhedrosis visrus treaments gave maximum protection to cabbage crop from the attack of common cutworm and produced maximum head yield when they were applied in combination (T_4) and (T_6) (Table 1 and Table 2). These results agree with the previous study where *Bacillus thuringiensis* (Bt) and spodoptera nuclear polyhedrosis virus were applied in combination to control *Spodoptera litura* in cabbage (Annon. 2015). A number of researchers have reported ‘Granulovirus’ as a significant mortality factor of diamondback moth around the world (Talekar and Shelton 1993; Dezianian et al. 2010; Subramanian et al. 2010). Some previous researchers reported that biological control methods using natural enemies such as predators, parasitoids and entomopathogenic microorganisms were effective alternatives to overcome the problems of chemical control (Silva-Torres et al. 2010a,b; Miranda et al. 2011). Some researchers found that many braconid *Cotesia* species (parasitoid wasp) were effective natural enemies of agricultural and forestry pests and several natural enemies were found to be successful biological control agents of lepidopterans in temperate and tropical regions of the world (Rattan et al. 2006; Silva-Torres et al. 2010b). In contrast, bio-control insects (T_2) alone in the present study had no considerable effect on reducing head infestation or on increasing yield of cabbage, but in earlier study weekly release of larval parasitoid (*Bracon hebetor*) and application of botanical insecticide (neem products) was found to be effective against common cutworm in cabbage (Awwal 2009). Host finding ability of egg parasitoid, *Trichogramma platneri* Nagarkatti may depend on

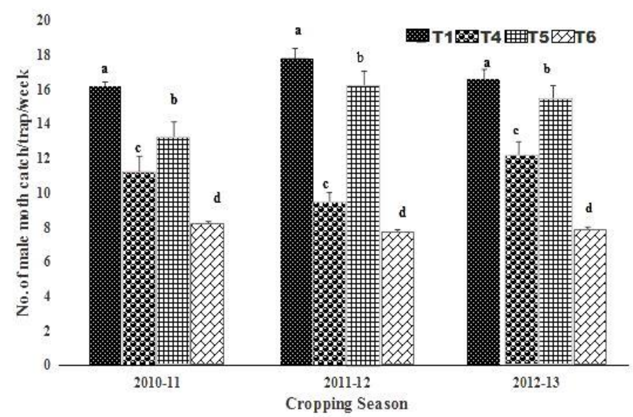

Figure 2. The number of adult males of common cutworm caught per trap per week from the plots treated with sex-pheromone trap (T_1), sex-pheromone trap + SNPV×2 (two sprayings) (T_4), sex-pheromone trap + bio-control insects (T_5), and sex-pheromone trap + bio-control insects + SNPV×1 (one spraying) (T_6). Error bars indicate one SE.

the suitability and availability of host insects as well as physiological conditions of the female moths (Hohmann and Luck 2004). In the present study, the availability of cutworm host and head infestation was very high, but physiological states of egg and larval parasitoids used in the present study could be weak or the microclimatic conditions of the cabbage field were not suitable for good parasitism. Although biocontrol insects had negligible influence on pest reduction and yield increase, combining parasitoid insects and SNPV with sex-pheromone traps proved more effective in pest reduction, yield increase and thereby proved to be cost-effective (Table 3).

Because our study was conducted using commercial sites, the number of replications were limited and we could not control for infestation levels among the sites. However, it can be inferred from our results suggest that to produce pesticide residue-free safe vegetables, especially cabbage, we need to adopt IPM approaches consisting of a combination of different methods to overcome the shortcomings of conventional practices and for the efficient management of insect pests. To minimize the quantitative and qualitative losses by common cutworm infestation in cabbage, the combined use of sex-pheromone trap, bio-control insects, and microbial pesticides could be the best practice in all respects at cabbage growing areas in greater Mymensingh region of Bangladesh as well as other countries of the world where similar socio-economic conditions and pest problems also occur. Further studies could be undertaken for motivating the vegetable growers to widely adopt IPM practices in Bangladesh to ensure a steady supply of safe vegetables for both the domestic and overseas consumers.

Acknowledgment

We would like to thank Dr. Syed Nurul Alam, Chief Scientific Officer and Head, Entomology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh for his assistance and advice during the study. We gratefully acknowledge the financial support for the study through SPGR sub-project (ID: 303) under the National Agricultural Technology Project (NATP): Phase 1, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka 1215, Bangladesh. Sex-pheromone lure, traps, SNPV and bio-control parasitoid insects were supplied by Ispahani Biotech Limited.

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How to cite: Noman, M.S., Afroz, S., & Maleque, M.A. 2022. Integrated management of common cutworm (*Spodoptera litura* Fab.) attacking cabbage in north-eastern part of Bangladesh. Journal of Contemporary Agriculture and Bioscience, *1(2)*, 24-30.