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Population dynamics and management of tobacco caterpillar on cabbage

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The tobacco caterpillar, *Spodoptera litura* Fabricius. (Lepidoptera: Noctuidae) is the most common and damaging insect pest of cabbage worldwide. The cabbage head infestation started in the first week of October when the increase in cabbage heads started. The temperature notably improved during this time, while the rainfall declined. Spraying of voliam flexi 300SC @ 0.5 ml/l water and hand collection and destruction of infested fruits, larvae, pheromone trap and nappy trap (T3) used to be the cure that reduced the infestation of tobacco caterpillars and cabbage head infestation among the treatments (87.99% and 83.67%; 85.92% and 87.76%; 87.19% and 88.30% in the three hill districts over untreated control, respectively). It performed best (54.20, 42.15, and 50.25 tha-1 in three hill districts, respectively). Therefore, in the hilly region of Chattogram, Bangladesh, where the tobacco caterpillar occurs, spraying voliam flexi 300SC @ 0.5 ml/l water and hand collection and destruction of infested fruits, larvae, pheromone trap and nappy trap (T3) to be the most effective method for controlling this pest.

Key words: *tobacco caterpillar, population dynamics, management, nappy trap, hilly areas, cabbage*

INTRODUCTION

Cabbage (*Brassica oleracea* L. var. capitata) is a widely consumed vegetable across the world. Throughout the winter, it is mostly grown in Bangladesh.

Bangladesh produces about 217 thousand tons of cabbage every year (BBS, 2014). Cabbage is rich in nutrients like carotene and vitamin C, with help improve nutrition in Bangladesh (Thompson and Kelly, 1988). According to (FAO, 2005), cabbage production in Bangladesh is lower than in other countries such as South Korea, Germany, Japan, and India. But this low yield is not a sign of the poor quality of Bangladeshi cabbage production. Insect pests have a significant impact on cabbage yield in Bangladesh. A range of insect pests has a significant impact on cabbage output and productivity. Cabbage butterflies, diamondback moths, and tobacco caterpillars are the most destructive pests, causing significant crop losses in cabbage each year (Palande et al., 2004; Rao & Lal, 2005; Mahla et al., 2005; Kumar et al., 2007 & Iqbal et al., 2015). Begum et al., (2021) observed that the Spodolure + Spinosad treatment had the lowest tobacco cutworm (0.33), whereas the T_6 control treatment had the most (5.28). *Spodoptera litura* nuclear polyhedrosis virus @ 2.47/ha at 7 days interval) had the most tobacco cutworm (3.00) in the treated plot, which was statistically equal to Spinosad @ 25 ml/ha at 7 days interval. Reddy et al., (2017) for instance, performed similarly. This is one of the most important cabbage pests, causing a 50% decline in productivity (HA Ei-Tom, 1987).

The caterpillar feeds cabbage by creating holes in its head; larvae carved a small hole in the newly growing head and reached the recently emerging extremely tiny leaf, which they completely consumed. An infestation of saprophytic fungus usually caused degradation within the interior region of the cabbage. The type and severity of the damage varied depending on the caterpillars' age. If the infestation happened during the pinnacle building stage, the juvenile caterpillar on the side of the older caterpillar also did more damage (Tofael, 2004 & Uddin et al., 2007). According to (Ahmad et al., 2008), cabbage caterpillars are responsible for 3.99% to 13.44% of leaves damage and 23.33% to 58.33% of plant damage, depending on the variety. According to (Hemchandra & Singh, 2007), maximum temperatures, minimum RH%, minimum total rainfall, higher daylight hours, and wind speed tend to promote the presence of insects. Low temperatures and rainy days were beneficial to *S. litura* populations, while RH% and rainfall were negatives (Patait et al., 2008). They also observed that morning relative humidity had a positive impact on the population of tobacco caterpillars, but minimum temperature and afternoon RH% had a negative impact. Patait et al., (2008) came to different conclusions from the current study. Many workers from all around India contributed to the data on seasonal abundance (Sharma, 2004; Shukla & Kumar, 2004; Wagle et al., 2005). The efficacy of botanical products against tobacco caterpillars has been investigated extensively (Devaki, K., & Krishnayya, 2004). Pyridalyl is shown to be effective against *S. litura* by many experimenters based on laboratory and field studies (Dhawan et al., 2010). Feeding, deterrents, pesticides, ovicide, egg-laying, and obstacles to growth are just a few of the ways in which pesticides of industrial origin act (Abdullah et al., 2011). Insecticides used before and after emergence has an impact on *S. litura* growth and development (Singh & Bhattacharya, 2004). Indoxacarb was found to be effective against *S. litura*, which is a type of insect *S. litura* (Taggar et al., 2011; Gaur & Chaudhary, 2012). The current results for chlorfenapyr match those of Shashi Bhushan et al., (2010), who found chlorfenapyr effective against *S. litura* Fab. in potatoes. At 72 hours after starting treatment, S. *Litura* larvae were fed baits containing chlorfenpyr, which killed them. Chlorfenpyr was significantly better than the other treatments. Larvae were exposed to the baits, chlorfenapyr 10SC at all four dosages (100, 75, 50, and 25% of recommended doses) recorded 100 percent mortality and was significant to all other treatments (Shankaragouda, et al., 2015). Triazophos and chlorpyriphos were ineffectual as new insecticides; this might be attributed to *S. litura* developing tolerance to existing pesticides. *S. litura* has developed resistance to triazophos and chlorpyriphos, according to (Prasad et al., 2008). The findings of (Raghavendra, 2015 & Nagendra, 2009) on pesticide use in important cabbage cultivating zones of the Belagavi district were consistent with the results of these two studies. Long-term pesticide use, as witnessed in Andhra Pradesh and Karnataka, would surely increase the problem of insecticide resistance (Kranthi, 2001). Chlorpyriphos has already been found to be highly effective against *S. litura* on a number of crops (Sreedhar & Sitaramaiah, 2011; Khan et al., 2011).

Faruq et al., (2022) reported that the treatment voliam flexi 300SC @ 0.5 ml Liter^{-1} water with hand collection and destruction of infested fruits and larvae+pheromone trap+nappy trap was found to be the best for controlling the pest population of cabbage in the Chattogram hill districts in Bangladesh. According to Faruq et al., (2021) voliam flexi 300SC @ 0.5 ml Liter^{-1} water with hand collection and destruction of infested fruits and larvae+nappy trap reduced the maximum infestation of bean pods by 90.07% in Bandarban, 89.29% in Rangamati, and 89.80% in Khagrachari. The same treatment generated the most pods throughout the season (17.64 tha^{-1}, 15.14 tha^{-1} and 15.93 tha^{-1} in three hill districts, respectively). Spraying voliam flexi 300SC @ 0.5 ml Liter^{-1} water with hand collection and destruction of infested fruits and larvae+pheromone trap+nappy trap resulted in the highest brinjal yield (31.56 ton/ha) (Faruq et al., 2021). Another severe pest of the cabbage crop is the tobacco caterpillar (*S. litura* Fab.), which helps to reduce productivity by up to 50% (Bhat et al., 1994). Khan (2007) claims that the cultivar Atlas-70 is more susceptible to cutworm in terms of head infection and yield. Treatment Spodolure + Spinosad treatment generated the most marketable cabbage head plot^{-1} (19.48 kg), according to (Begum et al., 2021). Undertreated plants, the lowest commercial cabbage head plot^{-1} (8.30 kg) was identified in control treatment, whereas the lowest marketable cabbage head plot^{-1} (12.34 kg) was detected in SNPV @ 2.47/ha at 7-day interval. So, a study was carried out to determine the population dynamics and management for controlling cabbage tobacco caterpillars in the Chattogram hill districts in Bangladesh.

MATERIALS AND METHODS

Description of the field experiment site

Experiments on the populations of the tobacco caterpillar of cabbage were conducted in the hills and valleys of Chattogram, Bangladesh, from 2015-2016 to 2016-2017. Farmers in these locations have long cultivated cabbage, and studies have covered a vast area of vegetable cultivation in the regions. The research site was chosen because of strong road connectivity, farmer attitudes on collaboration, and cabbage insect pest management tactics. The test site was in the hill districts of Sadar, Bandarban (Latitude 21°49'51"N, longitude 92°22'70"E); Dewanpara, Ghagra in Rangamati (Latitude 22°37'59"N, longitude 92°11'60"E); and Pathachara, Guimara in Khagrachari (Latitude 23°06'28"N, longitude 91°58'12"E).

Soil

The soil of the areas is a mixture of fine sand with a hard clay-like color and texture and contains high levels of sesquioxide. Soils vary from weakly acidic to strongly acidic. The natural fertility of the soil is significantly reduced. Hills are usually located between natural and forests. On the other hand, the soil of the research plot was sandy loam soil with a pH of 6.8. The soil of the experimental plot is the Chattogram hill tracts in (AEZ-28 and 29). The experimental plot was located on a high hill (Source: Soil Resources Development Institute (SRDI), Bandarban, Chattogram).

Weather conditions

The climate of the site is subtropical. It has three growing seasons: the dry season (October-March) and the wet season (May-October) (Edris et al., 1979). Table 1 shows the characteristics of the field data on temperature, RH (%), and rainfall collected by the Bangladesh Meteorological Department in Dhaka during the study period.

Table 1. Weather data for the experimental locations were collected monthly from October to March.

Month	Weather parameter (location wise)											
	Bandarban				Rangamati				Khagrachari			
	Temperature (°C)		RH (%)	Rainfall (mm)	Temperature (°C)		RH (%)	Rainfall (mm)	Temperature (°C)		RH (%)	Rainfall (mm)
	Max	Min			Max	Min			Max	Min		
October	30.5	22.5	75	3.60	30.2	23.0	72	5.03	31.0	22.8	74	4.07
November	28.5	18.0	68	0.75	27.5	17.5	67	0.53	29.0	20.5	65	0.96
December	27.2	17.3	70	0.58	28.2	18.1	69	0.49	28.2	18.1	69	0.69
January	24.1	18.7	68	0.33	25.1	19.5	70	0.40	25.1	19.5	68	0.40
February	31.5	23.0	70	0.45	32.5	24.5	69	0.03	32.5	25.5	72	0.36
March	33.2	24.0	69	0.00	33.5	25.2	72	0.24	33.2	24.8	74	0.00

*Monthly average, Source: Bangladesh Meterological Department, Agargaon, Dhaka

Tillage operation

After thorough plowing, cross harrowing was done to prepare the soil. Before transplanting, well-decomposed manure was thoroughly mixed. The soil was carefully prepared for growing seedlings. In the planter, rows were laid with a sickle every 10 cm.

Intercultural operation

The test plot was tilled several times before the ladder for planting was done to get good soil. It started growing in October, opened in the sun for a week, ploughing several times, and then planting in the seeds on the seedbed. For the aim of growing vegetables, the soil has been adequately prepared and cultivated. The target land was divided into 21 equal lots with 1 m spacing, 1 m block spacing, and 60 cm x 60 cm planting spacing, and 10 tons of decomposed cow manure per acre was added to the soil along with the listed fertilizers during site preparation. Rashid et al. (2006) reported that Urea, TSP, and MP have applied fertilizers at the rates of Urea: 150 kg/ha, TSP: 100 kg/ha, and MP: 125 kg/ha respectively at 10, 25, and 50 days after transplanting (DAT). Weeding is usually done in nursery beds to keep them weed-free so that healthy seedlings can grow. In the field, weeding and hoeing are carried out gradually so that the planting plot does not get weeds and ensures aeration for the soil. The first watering is carried out at the time of transplanting, the following waterings are carried out every 15 days. In the plots, weeding and mulching are done as needed.

Planting materials

The study material selected for the cabbage variety was Atlas-70, and the seeds were brought to a local market. To ensure pest control, all accepted cultural practices include the use of pesticides.

Seedling establishment

Cabbage seedlings grew in three different locations in farmer fields in beds in an experimental area. The seeds of this variety are sown in a carefully prepared seedbed. All weeds, crop residue, and dead roots were removed before sowing. To avoid moisture, the seedbed is dried in the sun. Beds were sown on 30 October of year 2016-2017 with 5g of seeds. Before sowing the seeds, a germination test is performed to confirm a germination rate of about 90%. Leave the soaked seeds in the seedbed for 24 hours to ensure germination. After sowing, cover with a thin layer of light soil. All seeds germinated perfectly 7 days after sowing. To protect young seedlings from light and moisture, a polyethylene coating is applied to the planter. Weeding, mulching, and watering are performed regularly to ensure that the environment is conducive to healthy growth and excellent seedlings.

Transplanting of seedlings

On November 29, healthy seedlings and even more than 30 days are transplanted into 60 cm × 60 cm distance test plots. The transplant has been completed in the afternoon and the seedlings are irrigated immediately afterward. The dust land at the root of each tree is crushed after the sowing frame and damaged trees are replaced with seedlings of a comparison merchant. Banana leaves are used to provide shade during the day for young plants. They're open to absorbing the dews at night. After 57 days, removed the banana leaves from the main field and plant them elsewhere.

Experimental design

In the RCBD experiment, three replicates were performed. The size of the lot is 5m×5m = $25m^2$. This experiment consisted of seven (07) separate treatment combinations with three (03) replications. The experiment used a total of 21-unit plots. The distance between the two plots was maintained at 1.0 m, while the distance between the two plots was maintained at 1.0 m.

Treatments

The management methods used in the experiment are as follows:
T_1= Spraying of voliam Flexi 300SC @ 0.5 ml $Liter^{-1}$ water
T_2= Spraying of voliam Flexi 300SC @ 0.5 ml $Liter^{-1}$ water+nappy trap
T_3= Spraying of voliam Flexi 300SC @ 0.5 ml $Liter^{-1}$ water+hand collection & destruction of infested fruits and larvae+pheromone trap+nappy trap
T_4= Spraying of ripcord 10EC @ 1.0 ml $Liter^{-1}$ water
T_5= Spraying of ripcord 10EC @ 1.0 ml $Liter^{-1}$ water+pheromone trap
T_6= Farmer's practices
T_7= Control

Treatment materials

Nappies are usually purchased from local markets in the hilly regions. There are also Voliam Flexi 300SC, Ripcord 10EC, and other handling products available for sale, including pheromones and surfxcels, among others.

Application of the treatments

The plots were sprayed with Voliam Flexi 300 SC and Ripcord 10 EC at a predetermined rate using a knapsack sprayer. Then they were watered down. Spray always in the afternoon, avoiding direct sunlight. Spray products are used regularly to ensure that the plants grown in the specified plots are completely covered. When spraying, make sure that the sprayed liquid does not spread to adjacent plots. Each application requires the preparation of new spray formulations.

Figure 1. Showing different experimental fields of cabbage at three hill districts of Chattogram

Data collection parameters

Cabbage was grown under different treatments at regular stages from germination to harvest. The following data were collected during the experimental periods. A number of infested insect heads per 10 plants, healthy heads per 10 plants, meteorological data (temperature, RH%, Rainfall data), healthy yield plot^{-1}, infested yield plot^{-1}, total yield plot^{-1}, and yield increases due to treatments applications.

Apparatus used

Samples were taken by placing them on a petridish using a fine camel-hair brush, netting, and vacuum cleaner. A connected vacuum cleaner was used to capture absorbed insects. Hand-held magnifiers, insect collection boxes, and bottles filled with ethanol are used to identify, collect and preserve insects. The healthy head and the sick head are balanced by the weighing device. Polythene bags, mosquito nets, and iron cages were used to identify adult lepidoptera.

Percent head infestation by number

Ten cabbage heads from every plot in the middle rows of each plot were counted and inspected. The data was separated by stage: early, mid, late. The proportion of damaged heads as computed by multiplying the number of healthy and infested cabbage heads using the formula:

$$\%\ \text{Head infestation (by number)} = \frac{\text{Number of infested heads}}{\text{Total number of heads observed}} \times 100$$

Percent head infestation by weight

From 10 randomly selected cabbage plants from each plot, we counted and studied them. The data is separated by time period: early, mid and late. The proportion of head injury was calculated using the following formula:

$$\% \text{ Head infestation (by weight)} = \frac{\text{Weight of infested heads}}{\text{Total weight of heads observed}} \text{ x } 100$$

Cabbage yield per hectare

The cabbage head was harvested after it had grown to a marketable size. Each plot's yield was converted to t ha^{-1} by hand-picking the best marketable size heads.

Increase or decrease of cabbage yield over control

$$\% \text{ Increase of yield over control} = \frac{\text{Yield of treated plot} - \text{Yield of control plot}}{\text{Yield of control plot}} \text{ x } 100$$

Statistical Analysis

Data were collected and then entered into tables for analysis RCBD was used for the analysis of variance in R software version 3.2 (package = "agricolae") (De, Mendiburu, 2009). Duncan's multiple range test was used to determine whether there were any differences between means. To compare the differences between means, we used the LSD test at a significance level of 5% Steel et al., 1997.

RESULTS AND DISCUSSION

Population dynamics of the tobacco caterpillar of cabbage in the three hill districts of Chattogram

In the three hill districts of Chattogram (Figure 3), the different stages of the tobacco caterpillar population infestation levels. This study found that combining different methods of trapping tobacco caterpillars was the most effective treatment to control them in Chattogram hill tracts, Bangladesh. Tobacco caterpillars cause damage to plants (Srivastava et al., 2018). Reddy et al. (2017) stated that it is one of the most severe insect pests of tobacco crops in Asia. Cabbage caterpillars cause 3.99%-13.44% damage to leaves and 23.33%-58.33% damage to plants in Bangladesh, according to (Ahmed, 2008).

Population dynamics of the tobacco caterpillar of cabbage in the Bandarban hill district

The tobacco caterpillar (*S. litura*) is found in cabbage fields in the Bandarban hill area, and its population dynamics have been examined (Figure 3). As shown in Figure 3, the infestation of the tobacco caterpillars into cabbage started in the 1st week of October when the heads started to develop and increased with age at harvest. As the rainfall decreased, the average temperature gradually increased. The results of (Patait et al., 2008) are somewhat different from those of this study. They also found that *S. litura* was increasing. Relative Humidity had a significant effect on its development, but temperature and Humidity had no significant effects. It was influenced positively by morning relative humidity, but negatively by the lowest temperature at night and afternoon humidity.

Figure 2. The tobacco caterpillar life cycles and their infestation on cabbage are illustrated

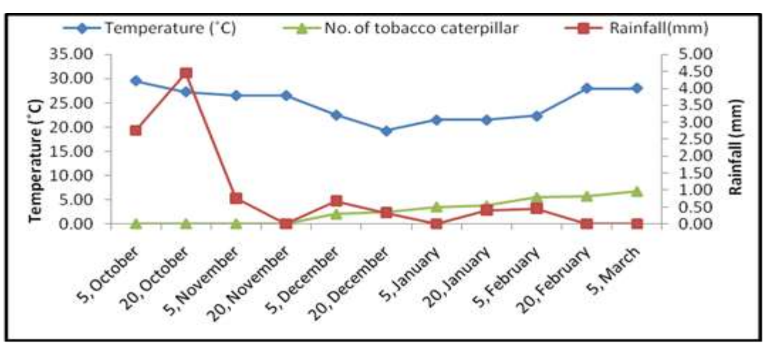

Figure 3. Population dynamics of the tobacco caterpillar on cabbage at the Bandarban hill district

Population dynamics of the tobacco caterpillar of cabbage in the Rangamati hill district

In the Rangamati hill area figure 4, shows the population level of tobacco larvae according to the number of infested heads. According to figure 4, the tobacco caterpillar began after the head development of cabbage from the second week of October, and after head growth started, it steadily increased according to the age of the crop. The average temperature rose dramatically throughout this time, but rainfall decreased. Similar data were recorded by (Badjena and Mandal, 2005), including the incidence and sequencing of *S. litura* on cabbage, which is more or less in accordance with the current experimental findings. This backs up the conclusions of the present study. *S. litura* first emerged on cabbage in the sixth meteorological week of 2002, peaking in the eleventh (94 larvae/ meter-row) and thirteenth (75 larvae/ meter-row) meteorological weeks of 2003 according to (Sailaja et al., 2006). *S. litura* infestation in the late-season cabbage crop start in the last week of January and progressed to its peak in February (4.20 larvae per plant).

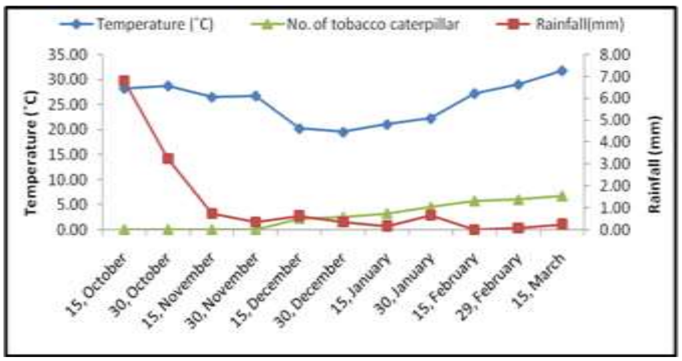

Figure 4. Population dynamics of the tobacco caterpillar on cabbage at the Rangamati hill district

Population dynamics of the tobacco caterpillar of cabbage in the Khagrachari hill district

The data about the tobacco caterpillar found in cabbage fields. In the Khagrachari hill district, figure 5 depicts the link between the population of tobacco caterpillars and the number of cabbage heads infested. Cabbage head infestation started in the first week of October when the heads were developing and then increased as the crop matured.

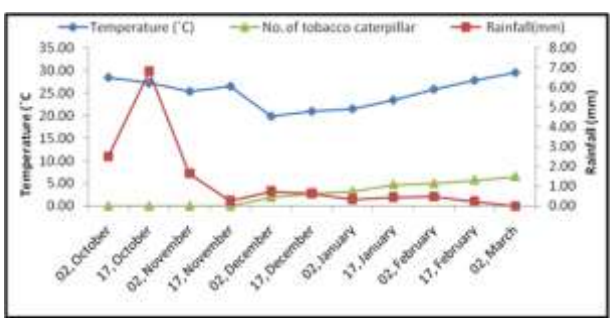

Figure 5. Population dynamics of the tobacco caterpillar on cabbage at the Khagrachari hill district

The temperature of the atmosphere progressively rose throughout this time, while the amount of rain fell. The field population of *S. litura* has been reported to be inversely proportional to RH% (Prasad et al., 2008). All the environmental factors had an adverse effect on *S. litura* larvae developing and growing in onions (Sailaja et al., 2006). Warmer temperatures, lower RH%, less total rainfall, longer daylight hours, and stronger winds tend to increase the insect population according to (Hemchandra and Singh, 2007). Rainy days and cold weather were beneficial for *S. litura* populations, whereas morning relative humidity and rainfall were negatives (Patait et al., 2008).

Effect of management practices on tobacco caterpillars in Bandarban hill districts

There was no statistically significant difference between the two groups one day before spraying. After the first application, observations showed that all treatments were better than control. In the Bandarban district, the impact of various management approaches on the cabbage tobacco caterpillar (*S. litura*) varied significantly. The treatment, T_3 (Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water+Hand collection & destruction of infested fruits and larvae+Pheromone trap+Nappy trap) was most effective in reducing the number of head infestations of cabbage by tobacco caterpillars in Bandarban district (Table 2).

Table 2. Effect of management practices on tobacco caterpillars in Bandarban hill district

Treatments	No. of larvae infested plant^{-10}	Percent reduction of larvae	Percent head infestation	Percent reduction of head infestation over control
Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water	3.08 d	60.24 d	2.33 d	64.11 d
Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water +Nappy trap	2.11 b	72.72 b	1.49 b	78.60 b
Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water +Hand collection & destruction of infested fruits and larvae +Pheromone trap+Nappy trap	0.93 a	87.99 a	0.93 a	83.67 a
Ripcord 10EC @ 1.0 ml Liter^{-1} water	3.96 e	48.83 e	2.76 e	57.59 e
Ripcord 10EC @ 1.0 ml Liter^{-1} water +Pheromone trap	2.76 c	64.37 c	1.89 c	70.94 c
Farmer's Practices	5.07 f	34.55 f	3.95 f	39.41 f
Control	7.75 g	--	6.53 g	--
LSD$_{(0.05)}$	**0.64**	**4.12**	**0.39**	**6.50**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**
CV (%)	**7.69**	**3.84**	**5.23**	**3.19**

Note: Data are the average of six observations from 3 replications. In a column, means having the same letter(s) is statistically similar at a 5% level of significance by DMRT. LSD-Least Significance Difference, CV-Coefficient of the Variation

The larvae population and percent head infestation were the lowest in T_3 treatment (0.93 and 0.93%, respectively) and (87.99% and 83.67%, respectively) followed by T_2, T_5, T_1, T_4, and T_6. Pesticides can be classified into several different categories, including feeding, deterrent, insecticide, ovicidal, oviphagous, and growth inhibitor (Abdullah et al., 2011). Botanicals have been shown to be effective against tobacco caterpillars (Devaki and Krishnayya, 2004). Before and after emergence, herbicides have an effect on the development of *Spodoptera litura* (Singh and Bhattacharya, 2004). The findings of the study match with those of (Raghavendra, 2005 & Nagendra, 2009) on pesticide use in significant cabbage-growing areas of the Belagavi district.

Effect of management practices on tobacco caterpillars in Rangamati hill district

Table 3 demonstrates how the influence of various management strategies on the cabbage tobacco caterpillar (*S. litura*) differed greatly in the Rangamati district. It was found that there was no statistically significant difference between the treatments. All the treatments performed better the day after the first treatment compared to the control group, according to observations made immediately after each treatment. At Rangamati (Table 3), Voliam Flexi 300SC (0.5mL per liter water + Hand collection and destruction of fruit and larvae + Pheromone trap + Nappy trap) has been determined to be the most successful treatment in compared to the other treatments. This treatment T_3 gave the most minimal number of tobacco caterpillar larval populace and percent head invasion (1.06 and 0.66%, separately) accordingly the greatest percent decrease of tobacco caterpillar larval populace and head pervasion (85.92% and 87.76%) of cabbage over control treatment followed by $T_2 > T_5 > T_1 > T_4$ and T_6 having significant difference among them. A long-term use of the same pesticides, as observed in Andhra Pradesh and Karnataka, would almost certainly promote insecticide resistance (Kranthi, 2001). On a range of crops, chlorpyriphos has previously been proved to be highly effective against *S. litura* (Sreedhar and Sitaramaiah, 2011; Khan et al., 2011). Based on both laboratory and field experiments, several researchers have stated that pyridalyl is efficient against *S. litura* (Saito et al., 2004; Dhawan et al., 2010).

Table 3. Effect of management practices on tobacco caterpillars in Rangamati hill district

Treatments	No. of larvae infested plant^{-10}	Percent reduction of larvae	Percent head infestation	Percent reduction of head infestation over control
Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water	3.32 d	55.90 d	2.10 d	61.12 d
Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water +Nappy trap	2.24 b	70.25 b	1.13 b	79.01 b
Voliam Flexi 300SC @ 0.5 ml Liter^{-1} water +Hand collection & destruction of infested fruits and larvae +Pheromone trap+Nappy trap	1.06 a	85.92 a	0.66 a	87.76 a
Ripcord 10EC @ 1.0 ml Liter^{-1} water	4.19 e	44.35 e	2.60 e	51.87 e
Ripcord 10EC @ 1.0 ml Liter^{-1} water +Pheromone trap	2.89 c	61.62 c	1.63 c	69.73 c
Farmer's Practices	5.21 f	30.81 f	3.57 f	34.00 f
Control	7.53 g	--	5.40 g	--
$LSD_{(0.05)}$	**0.64**	**5.70**	**0.45**	**8.60**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**
CV (%)	**5.40**	**4.20**	**5.25**	**4.85**

Note: Data are the average of six observations from 3 replications. In a column, means having the same letter(s) is statistically similar at a 5% level of significance by DMRT. LSD-Least Significance Difference, CV-Coefficient of the variation.

Effect of management practices on tobacco caterpillars in the Khagrachari hill district

In the Khagrachari hill area, different management approaches proved highly effective in controlling the tobacco caterpillar (*S. litura*) causing damage to cabbage (Table 4). There was no statistically significant difference between treatments one day before spraying. After the first spray, observations revealed that all of the treatments were significantly better than their controls. Spraying T_3 (Voliam Flexi 300SC @ 0.5 ml $Liter^{-1}$ water +Hand collection & destruction of infested fruits and larvae +Pheromone trap+Nappy trap) treatment, which was viewed as the best treatment contrasted with any other treatments, had the most minimum level of tobacco caterpillar head infestation of cabbage in the Khagrachari hill district (Table 4). The results showed that T_3 had the lowest numbers of tobacco caterpillar larvae and the highest percent head infestation reduction (0.96 and 0.89%, respectively) and (87.19% and 88.30%, respectively), which was a significant difference from other treatments. The findings of the study match with those of (Raghavendra, 2005 & Nagendra, 2009) on pesticide use in significant cabbage-growing areas of the Belagavi district. On a range of crops, Chlorpyriphos has previously been proved to be highly effective against *S. litura* (Sreedhar and Sitaramaiah, 2011; Khan et al., 2011).

Table 4. Effect of management practices on tobacco caterpillars in Khagrachari hill district

Treatments	No. of larvae infested plant^{-10}	Percent reduction of larvae	Percent head infestation	Percent reduction of head infestation over control
Voliam Flexi 300SC @ 0.5 ml $Liter^{-1}$ water	3.17 d	57.90 d	2.27 d	70.41 d
Voliam Flexi 300SC @ 0.5 ml $Liter^{-1}$ water +Nappy trap	2.18 b	71.03 b	1.26 b	83.47 b
Voliam Flexi 300SC @ 0.5 ml $Liter^{-1}$ water +Hand collection & destruction of infested fruits and larvae +Pheromone trap+Nappy trap	0.96 a	87.19 a	0.89 a	88.30 a
Ripcord 10EC @ 1.0 ml $Liter^{-1}$ water	4.08 e	45.72 e	3.60 e	53.00 e
Ripcord 10EC @ 1.0 ml $Liter^{-1}$ water +Pheromone trap	2.79 c	62.83 c	1.67 c	78.24 c
Farmer’s Practices	5.18 f	31.18 f	4.53 f	40.80 f
Control	7.52 g	--	7.67 g	--
$LSD_{(0.05)}$	**0.60**	**4.90**	**0.40**	**4.82**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**
CV (%)	**6.95**	**5.40**	**5.33**	**7.31**

Note: Data are the average of six observations from 3 replications. In a column, means having the same letter(s) is statistically similar at a 5% level of significance by DMRT. LSD-Least Significance Difference, CV-Coefficient of the variation.

Effect of management practices on the tobacco caterpillar on the yield of cabbage

It was found that all plots treated with different treatments produced significantly more cabbage than control. Table 5 shows the marketability of cabbage and percentage increases in yield above control in the hill districts of Bandarban, Rangamati and Khagrachhari. Sparying T_3 (Voliam Flexi 300SC @ 0.5 ml $Liter^{-1}$ water +Hand collection & destruction of infested fruits and larvae +Pheromone trap+Nappy trap) was produced the highest yield (54.20 tha^{-1}, 42.15 tha^{-1} and 50.25 tha^{-1} in the three hill districts, respectively) followed by T_2, T_5, T_1, T_4, and T_6. However, there were significant differences among the treatments. In comparison to the other treatments, T_3 showed better overall performance by increasing the fruit production of cabbage by 90.17 percent in Bandarban, 86.09 percent in Rangamati, and 98.85 percent in Khagrachari, respectively. The treatment T_3 (Voliam Flexi 300SC @ 0.5 ml $Liter^{-1}$ water +Hand collection & destruction of infected fruits and larvae +Pheromone trap+Nappy trap) was the most effective yield (53.37 tha^{-1} in Bandarban, 40.06 tha^{-1} in Rangamati, and 50.16 tha^{-1} in Khagrachari, respectively) according to (Faruq et al., 2022).

Table 5. Effect of management practices on the tobacco caterpillar on the yield of cabbage at three hill districts

Treatments	Marketable yield of cabbage (tha^{-1})			Percent increase of yield over control		
	Bandarban	**Rangamati**	**Khagrachari**	**Bandarban**	**Rangamati**	**Khagrachari**
Voliam Flexi 300SC @ 0.5 ml $Liter^{-1}$ water	40.42 d	30.35 d	35.49 d	41.82 d	33.99 d	40.44 d
Voliam Flexi 300SC @ 0.5 ml $Liter^{-1}$ water +Nappy trap	48.50 b	36.50 b	44.26 b	70.18 b	61.15 b	75.14 b
Voliam Flexi 300SC @ 0.5 ml $Liter^{-1}$ water +Hand collection & destruction of infested fruits and larvae +Pheromone trap+Nappy trap	54.20 a	42.15 a	50.25 a	90.17 a	86.09 a	98.85 a
Ripcord 10EC @ 1.0 ml $Liter^{-1}$ water	35.50 e	27.75 e	33.88 e	24.56 e	22.51 e	34.07 e
Ripcord 10EC @ 1.0 ml $Liter^{-1}$ water +Pheromone trap	44.26 c	34.38 c	40.30 c	55.29 c	51.79 c	59.48 c
Farmer's Practices	32.18 f	25.22 f	29.50 f	12.91 f	11.34 f	16.73 f
Control	28.50 g	22.65 g	25.27 g	--	--	--
$LSD_{(0.05)}$	**3.30**	**2.10**	**1.60**	**11.60**	**11.15**	**6.35**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
CV (%)	**1.79**	**1.95**	**1.68**	**5.30**	**4.99**	**3.75**

Note: Data are the average of six observations from 3 replications. In a column, means having the same letter(s) is statistically similar at a 5% level of significance by DMRT. LSD-Least Significance Difference, CV-Coefficient of the Variation.

The T_4 (Spodolure + Spinosad) treatment, according to (Begum et al., 2021), generated the most marketable cabbage head $plot^{-1}$ (19.48 kg). The lowest marketable cabbage head $plot^{-1}$ was produced by the control treatment T_6 (8.30 kg). The lowest marketable cabbage head $plot^{-1}$ (12.34 kg) was observed in the T_2 (*S. litura* nuclear polyhedrosis virus @ 2.47/ha at 7 days interval) treatment. Economic value can be reduced by 25.8% to 100% when *S. litura* is present. According to (Faruq et al., 2021) T_3 reduced the highest infestation of the bean pod by 90.07% in Bandarban, 89.29% in Rangamati, and 89.80% in Khagrachari compared to control. The same treatment generated the highest pod yields throughout the season (17.64 tha^{-1} in Bandarban, 15.14 tha^{-1} in Rangamati, and 15.93 tha^{-1} in Khagrachari, respectively). Spraying voliam flexi 300SC @ 0.5 ml $Liter^{-1}$ water +hand collection and destruction of infested fruits and larvae+pheromone trap+nappy trap, resulted in the highest brinjal production (31.56 ton/ha) according to (Faruq et al., 2021). The tobacco caterpillar is a major pest in the cabbage crop, causing up to 50% yield losses (Bhat et al., 1994). In terms of head infection and yield, (Khan, 2007) found that the Atlas-70 cultivar was more sensitive to common cutworm.

CONCLUSION

Farmers considered the tobacco caterpillar a major insect pest of cabbage. Its outbreak started in the 1st week of October and peaked in the last week of October, according to research. From the above study, it could be concluded that in terms of the lowest head infestation and the highest yield may be achieved by the integrated management package comprising voliam flexi, hand collection and destructions of larvae, pheromone trap, and nappy trap as the best treatment for suppressing tobacco caterpillar in a cabbage field. Further multilocational trials at different agroecological zones are also recommended for more precise findings.

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AUTHOR CONTRIBUTIONS

Md. O Faruq, Md. A Latif, Md. MH Khan and G P Das developed the concept and contributed to the manuscript write-up. Md. O Faruq was designed the experiment, conducted field experiments, analyzed the data, drafted and finalized the manuscript.

COMPETING INTERESTS

The authors have declared that no conflict of interest exists.

ETHICS APPROVAL

Not applicable

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