EFFECTIVENESS OF SOME COMMONLY USED BOTANICALS IN MANAGING TOBACCO CATERPILLAR, *SPODOPTERA LITURA* (FAB.) ON CABBAGE

ANJINA PARVIN

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA 1207

JUNE, 2014

EFFECTIVENESS OF SOME COMMONLY USED BOTANICALS IN MANAGING TOBACCO CATERPILLAR, *SPODOPTERA LITURA* (FAB.) ON CABBAGE

BY

ANJINA PARVIN

REGISTRATION NUNBER: 12-05237

A thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
IN
ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2014

Approved by:

(Prof. Dr. Md. Mizanur Rahman)	**Assoc. Prof. Dr. Tahmina Akter)**
Supervisor	**Co-Supervisor**
Department of Entomology	**&**
SAU, Dhaka	**Department of Entomology**
	SAU, Dhaka

Assoc. Prof. Dr. Mohammed Sakhawat Hossain
Chairman
Department of Entomology
&

Examination Committee

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

Memo No: SAU/Entomology/

CERTIFICATE

This is to certify that thesis entitled, **'Effectiveness of Some Commonly Used Botanicals in Managing Tobacco Caterpillar, *Spodoptera litura* (FAB.) on Cabbage'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of ***Master of Science in Entomology,*** embodies the result of a piece of bonafide research work carried out by **Anjina Parvin**, **Registration No. 12-05237** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:
Place: Dhaka, Bangladesh

Prof. Dr. Md. Mizanur Rahman
Supervisor
&
Professor
Department of Entomology
SAU, Dhaka

ACKNOWLEDGEMENT

The author first wants to articulate her enormous wisdom of kindness to the Almighty Allah for His never ending blessing, protection, regulation, perception and assent to successfully complete the research and prepare thesis.

The author likes to express her deepest sense of gratitude to her respected Supervisor Dr. Md. Mizanur Rahman, Professor, Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for his scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period and gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript writing including data analysis.

The author also expresses her gratefulness to her respected Co-Supervisor Dr. Tahmina Akter, Associate Professor, Department of Entomology, SAU, Dhaka for her scholastic guidance, helpful comments and constant inspiration, inestimatable help, valuable suggestions throughout the research work and in preparation of the thesis.

The author expresses her sincere respect and sence of gratitude to Chairman Dr. Mohammed Sakhawat Hossain, Associate Professor, Departement of Entomology, SAU, Dhaka for valuable suggestions and cooperation during the study period. The author also expresses heartfelt thanks to all the teachers of the Department of Entomology, SAU, for their valuable suggestions, instructions, cordial help and encouragement during the period of the study.

The author expresses her sincere appreciation to her brother, sisters, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study period.

The Author

EFFECTIVENESS OF SOME COMMONLY USED BOTANICALS IN MANAGING TOBACCO CATERPILLAR, *SPODOPTERA LITURA* (FAB.) ON CABBAGE

ABSTRACT

The experiment was conducted in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2013 to February 2014 to study the effectiveness of commonly used botanicals in managing tobacco caterpillar, *Spodoptera litura* (Fab.) on cabbage. The experiment comprised six treatments and one untreated control. Six treatment were: T_1: Neem oil @ 6 ml/L of water, T_2: Neem oil @ 5 ml/L of water, T_3: Neem oil @ 4 ml/L of water, T_4: Mehgoni seed kernel @ 200 mg/L of water, T_5: Neem leaf extract @ 200 mg/L of water, T_6: Neem seed kernel extract @ 200 mg/L of water and an untreated control. Treatments were applied at 7 days intervals starting from the first initiation of the pest attack. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. It was revealed that the highest number of healthy head per plot (24.33) was recorded in T_1, while the lowest number (18.67) was found in untreated control plot. The highest number of infested heads/plot (6.33) was recorded untreated control plot, while the lowest (0.67%) was found in T_1 treatment. The highest percentage of infestation (33.90%) was attained in untreated control plot, whereas the lowest percentage (2.75%) was in T_1 treatment. The highest percentage (91.88%) of cabbage head infestation reduction over control was found in T_1, whereas the lowest value (49.25%) from T_4 treatment. The lowest number of bores/leaf (1.33) was recorded in T_1, while the highest number of bores (25.67) was recorded in untreated control plot. The lowest number of larvae/head (0.33) was recorded in T_1, while the highest number (6.33) was found in untreated control plot. The maximum thickness of head (13.28 cm) was recorded in T_1, while the minimum thickness (10.56 cm) was found in untreated control plot. The maximum diameter of head (11.34 cm), the highest gross yield per plant (2.02 kg), and The highest marketable yield per hectare (65.56 ton) was recorded in T_1 treated plot, while the minimum diameter (9.34 cm), the lowest gross yield per plant (1.52 kg) and the highest marketable yield per hectare (65.56 ton) observed in untreated control plot. The highest benefit cost ratio (3.52) was estimated for T_1 and the lowest (1.86) in T_4 treatment. From the findings it is revealed that spraying of Neem oil @ 6 ml/L of water at 7 days interval (T_1) was more effective among the commonly used botanical for reduction of cabbage plant infestation by tobacco caterpillar.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata* L.) is one of the popular winter vegetables in Bangladesh belongs to the family Cruciferae. This vegetable is rich in vitamins and minerals and its production is increasing day by day (Quayyum and Akanda, 1988). The medicinal values of cabbage include treatment of constipation, stomach ulcers, headache, excess weight, skin disorders, eczema, jaundice, scurvy, rheumatism, arthritis, gout, eye disorders, heart diseases, ageing and Alzeimer's disease (Tanongkankit *et al*., 2011). This unique vegetable has been widely grown in both tropical and temperate regions of the world (Sarker *et al*., 2002). It is also a well known and widely distributed crop within Asia and has been introduced successfully into parts of Central America, West Africa, America, Canada and Europe (Talekar and Selleck, 1982). At present the annual production of cabbage in Bangladesh is about 220 thousand metric tons. Among the five leading vegetables of Bangladesh, the cabbage occupied an area of 11.37 thousand hectares of land (BBS, 2012).

Vegetable production in Bangladesh is far below the actual requirements. In 2010-2011, total vegetable (summer and winter season) production area was 645.04 thousand hectares with total production of 1.87 million tons (BBS, 2012). The per capita consumption of vegetables in Bangladesh is only about 30 g, when the per capita consumption in Nepal (42 g), Pakistan (69 g),

Srilanka (120 g) and India (135 g) are higher than Bangladesh (Ramphall and Gill, 1990). Cabbage can play a vital role in elevating the nutritional status of Bangladesh, as it is rich in vitamins and minerals such as carotene, ascorbic acid and contains appreciable quantities of thiamin, riboflavin, calcium and iron (Thompson and Kelly, 1985). It has been reported that 100 g of edible portion of cabbage contains 92% water, 24 calories of food energy, 1.5 g of protein, 9.8 g of carbohydrate, 40 mg of Ca, 0.6 mg of Fe, 600 IU of Carotene, 0.05 mg of thiamine, 0.05 mg of riboflavin, 0.3 mg of niacin and 60 mg of vitamin E (Rashid, 1993).

According to FAO (1999) the average yield of cabbage (19.35 t/ha) is low in Bangladesh compared to other countries like South Korea (61.17 t/ha), Germany (54.81 t/ha), Japan (40.31 t/ha) and India (29.10 t/ha). However, the low yield of this crop is not an indication of low yielding potentiality of this crop. However, low yield may be attributed to a number of reasons viz., unavailability of quality seeds of high yielding varieties, delayed sowing after the harvest of transplanted aman rice, fertilizer management, improper or limited irrigation facilities and due to the attack of insect pests. Among different factors insect pests can play an important role for decreasing the production of cabbage in Bangladesh. Cabbage is infested by a number of insect pests, which include cutworm, tobacco caterpillar and diamondback moth as the major insect pests. Tobacco caterpillar was the most destructive pest among the nine insect pests of cabbage (Lee, 1986). It is one of the key insect pests of cabbage, which caused more than 50 percent reduction of cabbage yield (Ei-Tom, 1987). The cabbage caterpillar/tobacco caterpillar is also called Prodenia caterpillar, which destroys the leaves of cabbage by making holes in the head and greatly reduces its market value. Larvae bored the newly forming head and reached to the newly emerging little leaf and consumed the whole leaf. Sometimes it caused rotting in the inner portion of cabbage due to the infestation of saprophytic fungi. The nature and extent of

damage differed with age of the caterpillars. The young caterpillar along with mature caterpillar also caused greater damage if the infestation occurred at the head forming stage (Tofael, 2004).

In Bangladesh and in other countries, the management practices of tobacco caterpillar are mostly limited to use of insecticides of different chemical groups such as organophosphates, synthetic pyrethroids and nicotinamides (Deng *et al*., 2002; Sreekanth *et al.,* 2000; Kumar and Krishnaynya, 1999; Ramaprasad *et al*., 1993). Cabbage growers of Bangladesh also use various insecticides to control this obnoxious pest (Ali and Bakshi, 1994). Pyrethroid lambda-cyhalothrin had the greatest toxicity at 24 and 48 hour against *Spodoptera litura* (De Souza *et al*., 1992). But cypermethrin was relatively more toxic than fenvelerate against different larval instars of *S. litura* (Rao and Dhingra, 1996). Therefore, the use of botanicals has been recommended as a suitable alternative of chemicals for plant protection with minimum negative risks (Pavela, 2007).

Plant derived insecticides have a wide range of mode of action such as feeding, deterrents, insecticides, ovicidal, oviposition and also growth inhibitors (Abdullah *et al*., 2011). The efficacy of botanical products against the tobacco caterpillar reported by many researchers (Devaki *et al.*, 2004; Chari *et al.*, 1999; Malathi *et al*., 1999; Sharma *et al*., 1999). Neem leaf extracts reduced food consumption, growth and nutritional efficiency of tobacco caterpillar. It also extended larval and pupal durations and reduced longevity and fecundity of this pest (Kumar *et al.*, 1997). Sharma *et al*. (1999) reported that neem oil markedly decreased feeding of *S. litura* (Fab.). Neem oil at 1.5% concentration was found highly effective against *S. litura* on tobacco in the laboratory (Chari *et al*., 1999).

Considering the above perspective the present study was undertaken to fulfill the following objectives:

- To evaluate the effectiveness of some botanicals along with the different doses for the management of tobacco caterpillar and

- To identify out the best botanical product for the management of tobacco caterpillar in cabbage.

CHAPTER II

REVIEW OF LITERATURE

Cabbage is one of the leading vegetables of rabi season in Bangladesh. Vegetable production in the country is far below of actual requirements, so the demand of vegetable is increasing day by day and horizontal expansion of vegetable yield unit^{-1} area should be increased to meet this ever-increasing demand of vegetable. This will require adoption of new technology such as safer management package, high yielding cultivar, higher input use and management of insect pests etc. Cabbage is infested by large number of insect pests in the field, which cause considerable yield loss in every year. Among them, tobacco caterpillar, *Spodoptera litura* is one of the most serious pests. Numerous studies have been performed for evaluating the management of tobacco caterpillar infesting cabbage. Among them some of the recent past information reviewed under the following headings and sub-headings that reveal some related findings about present study:

2.1 General review of tobacco caterpillar

Nomenclature:

The tobacco caterpillar, *Spodoptera litura* (Fab.) and it synonym are Cabbage caterpillar or Prodenia caterpillar

Common name: Tobacco caterpillar

Systematic position:

Phylum: Arthopoda

Class: Insecta

Order: Lepidoptera

Family: Noctuidiae

Genus: *Spodoptera*

Species: *Spodoptera litura*

Scientific name: *Spodoptera litura* (Fab.)

2.2 Origin and distribution of tobacco caterpillar

The tobacco caterpillar is found throughout the tropical and subtropical parts of the world. It is widly spread in India (Atwal, 1986). This pest has been reported from India, Pakiatan, Ceylon, Burma, Thailand, Malaysia, Cambodia, Laos, Vietnam, Sabah, Indonesia, the Philippines, Taiwan, Queensland, New South Wales, Papua New Guinea, West Iran, Solomon Islands, Gilbert Islands, New Caledonia, Fiji, Samoa, Tonga, Society Islands, Gilbert Islands and Micronesia (Grist *et al.,* 1989).

Hill (1983) reported that *S. litura* (Fab.) is a polyphagous pest of cabbage and cauliflower. It is originated from South and Eastern Old World tropics, including Pakistan, India, Bangladesh, Srilanka, S.E. Asia, Chin, Korea, Japan, The Philippines, Indonesia, Australia, Pacific islands, Hawaii and Fiji. The two old world cotton leaf worm species *S. litura* and *S. littoralis* are allopatric and their ranges covering Asia and Africa.

2.3 Nature of damage of tobacco caterpillar

According to Tofael, 2004, the tobacco caterpillar, *Spodoptera litura* (Fab.) attacks the tender leaves, and only the larvae caused the damage. The female moth of cabbage caterpillar laid eggs on the lower surface of the leaves, the tiny caterpillar starts feeding on host plant. In the early stage of cabbage, caterpillars bored the new forming head and reached to the newly emerging little leaf and consumed it. As a result, many head of cabbage could not form and at that time it was not economical to replace it with another new seedling. Due to the cosmetic nature of cabbage, a hole is enough to devaluate it. In market it is sold in reduced price due to presence of excreta at the damaged site. Sometimes it caused rotting in the inner portion of cabbage. The nature and extent of damage differed with age of the caterpillars. The young caterpillar along with mature caterpillar also caused greater damage if the infestation occurred at the head forming stage. In field, later stage of cabbage was not found to be infested. Succeeding generations can do

greater damage and later instar larvae remained outside the cabbage head and can come out as a serious phase of infestation for their voracious feeding habit.

2.4 Pest status

Lee (1986) in Taiwan investigated the pest's incidence of 9 insect's pests on cabbage and observed that *S. litura* (Fab.) was a serious pest occurred in the warmer months, September to December with peaks in November to December. In Bangladesh, tobacco caterpillar, *S. litura* (Fab.) was one of the key insect pests of cabbage and yield limiting factor of cabbage (Ei-Tom (1987). This pest caused more than 50 percent reduction of cabbage yield in some cabbage genotypes. *S. litura* (Fab.) was a serious pest of cabbage and cauliflower in Bengal.

Tobacco caterpillar, *S. litura* (Fab.) is one of the most destructive lepidopterous pests within its subtropical and tropical range. This caterpillar was essentially a leaf eater, but did occasionally like a cutworm. Heavy infestations resulted in severe defoliation but these were not of frequent occurrence. The young larvae were gregarious but they dispersed as they become older. Hill (1983) stated that tobacco caterpillar was not very frequently a serious pest on any one particular crop but had regular occurrence on different cruciferous crops like cabbage, cauliflower etc. European and Mediterranean Plant Protection Organization (EPPO) have listed *S. litura* as on A1 quarantine pest (OEPP/EPPO, 1979). Alam (1969) revealed that *S. litura* (Fab.) was a general and very destructive pest in agricultural crops.

2.5 Host range of tobacco caterpillar

Surekh *et al.* (2000) reared the tobacco caterpillar, *S. litura* (Fab.) in the laboratory for several generations using different weed and cultivated plant leaves as food. The larval food preference was castor (*Ricinus communis*) > tomato > tobacco > mulberry > brinjal > cabbage. Faster larval growth rate, shorter larval period and better survival were obtained with the first three preferred food plants. Temperature during rearing significantly affected the life cycle.

Hill (1973) stated that prodenia caterpillar a polyphagous pest having major status on cotton, rice, tomato, tobacco, cabbage and cauliflower, *Citrus*, cocoa, sweet potato, rubber, ground nut, castor, legumes, millets, sorghum, maize, and many vegetables. He also indicated that *S. litura* was a polyphagous insect known as a major pest of cotton, tobacco and tomato besides cacao, citrus, sweet potato, rubber, groundnuts, castor, soybeans, many other vegetable crops, millet, sorghum, maize and *Eleusine.*

Patel *et al. (*1987) found that larval survival of noctuidae was the highest (100%) on *Ricinus communis* and cabbage, followed by 94.2% on *Lablab purpureus*, 92.2% on lecerne and 82% on *Coccinea grandis*. The duration of larval development was shorter on *R. Communis* (17.8 days) followed by Lucerne (22.5 days) cabbage (23.1 days) *L. purpureus* (25 days) and *C. grandis* (29.4 days). The growth index was highest on *R. communis* (5.75) followed by cabbage (4.33) Lucerne (4.76) and *C. grandis* (2.79). Apart from feeding on cabbage, the tobacco caterpillar had a very wide range of host plants, including herbaceous cultivated plants and weeds, chiefly amongst the Cruciferae, Malvaceae, Leguminosae and Solanaceae. Tobacco caterpillar *S. litura* (Fab.) was widespread in India and, besides tobacco (*Nicotiana tabacum L.*), fed on castor *(Richinus communis L.)*, ground nut (*Arachis hypogaea L.*), tomato, cabbage and various other cruciferous crop (Atwal, 1986).

Alam (1969) stated that the prodenia caterpillar fed on a very large variety of plants including tomato, cabbage, cauliflower, maize, potato, sweet potato, millet, ground nut, jute, tobacco, etc.

2.6 Biology of tobacco caterpillar

Subramanian *et al.* (2005) stated that the biology of *Spodoptera litura* varied significavtly on seven cotton cultivars. Based on the developmental indices the susceptibility of cultivars to *S. litura* came in the following order LRA > MCU12 > SVPR3 > Surabhi > Sumangala > SVPR2 > MCU5. Higher protein and carbohydrate content of host plant had favourable influence on the growth and

development; phenol and lipid content were maximum in LRA5166; phenol and lipid content restricted the development of insect. Carbohydrate and protein content were high in Sumangala, Surabhi and SVPR2 varieties.

The population dynamics of *Spodoptera litura* was studied by Zheng *et al*. (2005) to establish its continuous generation life table. The cumulative death rates of first, second, third, fourth and fifth generations were 93.6, 98.5, 97.2, 99.1 and 99.99%, respectively. The indices of population trend of the first, second, third, and fourth generations were 17.41, 4.62, 5.63 and 0.55, respectively. This study determined development lasting periods of different metamorphosis for the first, second, third, fourth, and fifth generations of *S. litura*. The emergence sizes and emergence periods of *S. litura* were predicted using the life table.

Soni *et al*. (2001) evaluated host preference of *S. litura* using castor, cabbage, and cauliflower as host plants. Results showed that the overall mean diameter of egg was 0.534mm. The mean incubation period was significantly highest on cabbage (5.60 days) and the lowest on castor (3.40 days). Larval period, pre-pupal period were shortest on cauliflower (16.30, 1.15 and 10.40 days, respectively). The average weight per larvae and pupae was the maximum on cauliflowers (1619.36 and 306.70 mg, respectively) and minimum on castor (1419.24 and 242.65 mg, respectively). Sizes of the full grown larvae and pupae were the maximum on cauliflower (34.83 mm and 17.10 mm length and 5.45 mm width) while, it was the lowest on castor (32.62 mm length and 5.05 mm width). Cauliflower recorded the highest wing span and body length of adult female (34.41 and 17.32 mm) and male (32.18 and 15.55 mm). The percentage of larval survival, pupation and adult emergence were also highest on cauliflower (94.00, 85.10 and 92.50%, respectively), whereas the longevity of female and male moth was recorded on cabbage (8.20 and 7.05 days, respectively), and minimum on castor (6.09 and 5.06 days, respectively. Similarly, the highest fecundity of female was recorded on cabbage and lowest on cauliflower (557.06 and 397.63 eggs, respectively). The highest growth index value (5.22) was recorded on cauliflower and lowest in castor (3.54).

Kharub *et al*. (1993) observed that a peak larval population of *S. litura* on the ground nut cultivar MH4 (Spanish bunch) appeared after 41 weeks. The maximum (38.8^0C) and minimum (18.6^0C) temperature and 61% RH were conducted for the development of larvae of *S. litura* under field conditions. They also found that at 28+ 2^0C in an incubator, *S. litura* completed sixth instar in 3.0, 3.7, 5.5, 4.6, 4.1 and 5.6 days respectively. The male and female pupal period was 8.6 and 8.4 days, respectively. Males survived for 8.8 days and females for 9.7 days. Copulation took place during the night, 3 to 5 times in a lifetime. The female laid an average of 1618.8 eggs (81.82% hatchability) in 12 egg masses in a period of 4.0 days. The incubation period was 3.0 days. In a normal population, the sex ratio (male : female) was 1 : 0.76.

Kumar *et al.* (1992) stated that the egg stage duration of the noctuid *S. litura* on sunflower in the laboratory was 3 days in May-June and 5.4 days in October. The average duration of the larval stage was 15.09 days in June and 16.67 days in October. Larval survival varied from 72 to 92% in May-October. The duration of the pupal stage lasted 7.49 days in September and 12.26 days in October. The adult life span ranged from 4.1-6.2 days in males and 5.1-7.8 days in females. Studies at constant temperature of 20, 25 and 30^0 c showed the egg stage last for 5, 4 and 3 days, respectively. Patil *et al.* (1991) observed that females of *Spodoptera litura* (Fab.) laid 536-1250 eggs and the egg, larval, pre-pupal and pupal stage in laboratory conditions (29.5 + 2^0C, R.H. 80+5%) on rice (variety java) lasted 3-4, 11-21, 1-3 and 9-11 days, respectively.

Singh *et al*. (1998) studied the biology of *Spodoptera litura* at 28.9-31.5^{0}C and 65.3-73.3% RH. The duration of larval stage varied between months being 29.3 days during August and 11.8 days during September. Survival of larvae was lowest (31.8%) in August and highest (92%) in September pupal development took 6-9 days. The pre-oviposition and oviposition period varied from 2 to 4 days and 1 to 4 days respectively. The ration of males to females was 1:2.

Sanjrani *et al.* (1989) in Pakistan studied the effect of temperature on the biology of *S. litura* (Fab.). They found the highest fecundity and fertility of eggs (1034 eggs and 100% respectively) at average temperature of 19.55^0C and the lowest fecundity and fertility of eggs (387.4 eggs and 45.2%) at 34.9^0C. The shortest duration of life cycle (26.6 days) was also found.

In India, Patel *et al.* (1986) observed that the incubation period averaged 4.80+ 1.68 days and hatching percentage was 87. Mean duration of larval period was 18.64+ 2.75 days. Larva pupated in soil at a depth of 2 to 5 cm and pupal period varied from 7 to 11 days with an average of 8.12 + 1.41 days. Longevity of males was averaged 6.30+ 2.49 days whereas that of females was averaged 12.30+ 3.16 days. Male to female sex ratio was 1:0.67. The study was conducted from December to January when maximum and minimum temperature varied from 21^0C to 28^0C and 2^0C to 12^0C, respectively. They observed that the incubation period was 4.80 days in average and 87% of egg hatched on cotton. The five larval instars were averaged 3.12, 2.60, 2.80, 3.68 and 2.80 days in turn. The total larval period was average 18.64 days. The pupal period lasted 9-11 days with averaging 8.12 days. The male and female life span was averaged 6.30 days averaging 41.90 days. The per-oviposition, oviposition and post-oviposition period were averaged 1.60, 7.60 and 3.10 days, respectively. The number of eggs laid by a single female was 2507-3467 with averaging 3032 and number of egg masses were 10-16 with averaging 12.80.

In Bangladesh, Das (1985) studied the development of *S. litura* (Fab.) on four hosts. Larvae of the pest failed to complete their development on maize leaves. Mean larval duration differed significantly on sweet potato (13.67 days), cabbage (15.47 days), and groundnut (17.73 days). Other characteristic did not differ significantly.

Dhandapani *et al.* (1985) in India observed the rate of multiplication of *S. litura* (Fab.) on banana (Musa *sp.*) The population increased with and infinitesimal rate

of (rm) 0.1525 and finite rate (lambda) of 1.165 females per female per day and a generation was completed in 40-48 days.

In the Philippines, Torreno (1985) found that the total development period of *S. litura* (Fab.) was 33 days. Eggs were laid in mass and incubation period was 2-3 (2.92 + 0.03) days. Larval stage lasted for 18.5 to 17 days in six, some times five (34%) moults. The first stadium took three to four days and continued to moult every other day until full grown with a total feeding period of 16.5 days. Pupation ranged from 2 to 3 (2.18 + 0.04) days. Females had 9.6 days pupation period and from that of male it was 2 days sooner. Length of pupa did not differ between sexes but female seemed heavier than male. The sex ratio of 1:1 was recorded.

Urs *et al.* (1974) reared *S. litura* (Fab.) on semi synthetic diet and found that the larval stage lasted 16-19 days and the pupal stage 11-13 days at room temperature and total life cycle from eggs to adult lasted 31-35 days. Larvae and pupae reared on this diet were heavier than those reared on the leaves of castor (*Recinus communis*). Yushima *et al.* (1973) in Japan observed that *S. litura* (Fab.) became an important pest of vegetables crop in south-western Japan. They also found the peaks of adult emergence and pairing occurred 1-2 after sunset or lights off and the more than 80% of adults paired before midnight. Age was an important factor for pairing success and female became mature somewhat more quickly than the male the percentage of adult paired was 63.2 when the adult of the both sexes were two days old and more than 90% when both sexes were 3-4 days old.

Fujiie *et al.* (1973) studied the pairing and laying of *S. litura* (Fab.). He found the mating activities reached at peak during the night; there was no mark duration of male mortality. The numbers of eggs fertilized were constant. Female that had paired successfully laid most of their eggs during the night following that on which pairing occurred, virgin female laid most of their eggs on the fifth night following the start of experiment.

Nakamura (1973) in Japan observed that *S. litura* (Fab.) laid large number of eggs on the first two days emergence than on subsequent days within the 18-30^{0}C. Females laid almost all their eggs by seventh day. Virgin female laid more egg masses but fewer eggs than female that had paired. Male can pair more than once but avoid female that had already paired.

Omino *et al.* (1973) studied the day night behavior of noctuidiae in the laboratory in Japan at 25^{0}C and 16 hours photoperiod. Observation was made on phototaxis. All of *S. litura* (Fab.) remained on the leaf except the last. Sixth (last) instar larvae entered the vermiculite just before pupation. The responses of the species to light were similar to those of *Mamestra brassicae*. The first to fourth instar larvae of *M. brassicae* remained on leaf and the fifth and sixth entered the vermiculite. They found that larvae in the first two instars showed positive phototaxis and those in the last showed negative phototaxis.

Nasir *et al.* (1966) in Egypt observed the abundance of *S. litura* (Fab.) on the leaves, Squares and bolls. They also observed larval color influenced by the food. The larval and pupal stage were shorter on cotton flowers (20.1 days and 9.85 days) than the cotton leaves (22.5 days and 11.28 days) or sweet potato leaves (21.28 days and 10.26 days) but female reared as larvae on sweet potato laid higher average number of eggs (1517) than those on cotton flower (1196) or leaves (720). Adults from larvae reared on cotton flowers lived for an average 7.22 days, those on cotton leaves for 6.33 days and those on sweet potato for 7.91 days.

Hassan *et al.* (1960) in Egypt studied the behavior of adult and the larvae of *S. litura* (Fab.) They found that after hatching larvae aggregate at the site of hatching for a short time and then dispersed by crawling and by means of silken threads. Comparatively cool and humid condition at night induced movement and feeding activity by the larvae and flight by the adults. The most emerged at night mostly between 9 and 10 pm and approximately 80 percent of them rested during the day and feeding took place shortly before sunrise. Most of adult mated on

night of emergence and about 50% of mated females laid their eggs on the same night.

2.7 Monitoring

Larva can be found on the insides of heads. Pupation occurs at the top position position under surface of the leaf making making a silken coccon prepared with the body skin and sometimes uneaten pieces of leaves adhered to it. Pupae tend to move sideways when disturbed. Adults can fly readily. Net catch adults were used for identification (Ahmed, 2004).

2.8 Influence of temperature on biology of tobacco caterpillar

Chu *et al.* (1989) in Taiwan gave an account on adult emergence and mating behavior of the noctuid. *S. litura* (Fab.). They observed that the majority of females emerged 1 hour after dark with males emerging 4-5 hours after dank at 25^0C and 75-5% R.H. and LD 13.11. Mating for one pair occurred mostly between 20.00 and 21.00 h with the minor peak observed between 18.00 h to 19.00 h and 23.00 h to 24.00 and lasted 25 to 179 minute with an average of 92 minute. When one female was kept with 3 males, mating occurred mostly between 19.00 and 21.00 h. The copulation rate of the female was 100% and mating lasted for 50 to 260 minute. When 1male was kept with 3 females mating occurred mostly between 18.00 and 19.00 h. The copulation rate of male was 90% and mating lasted for 52 to 208 minutes for the first copulation and for 24 to 58 minutes for the 2^{nd}.

In Taiwan, Chen (1984) observed variation in the length of life cycle of *S. litura* (Fab,) on soybean, cauliflower and taro leaves at 25^0Cand 30^0C with photoperiod of LD 12:12. According to his report the time required to complete the life cycle depended on temperature as well as food. Development from egg to 50% emergence at 25^0C and 35^0C temperature took 34-41 days and 25-28 days respectively. Age at initial oviposition was 27-35 and 20-26 days. Development took longer on soybean than cauliflower or taro.

In Taiwan, Chen *et al.* (1982) observed the influence of the temperature on larval development and leaf consumption of larvae of *Arotieia rape crucivors* (Boisd.) *Trichoplusia ni* (Hb.) and *S. litura* (Fab.) on cauliflower. They reported that the temperature requirement of 3 species was 258 day degree above a development threshold of 5.8^0 C, 203 day degrees C above 9.8^0C and 261 day degrees C above 10.9^0 C respectively. The mean leaf area consumption by larvae of 3 species at $15\text{-}25^0$C was 58.9, 86.0 and 310.0 cm^2 and relative efficiency of food utilization was found to be 2.30, 2.16 and 1.0, respectively.

2.9 Management practices

The repellent, antifeedant and ovicidal properties of the extracts of *Acorus calamus, Croton oblingifolis, Strychnos nux-vomica, Santalum album, Simarouba glauca* [*Quassia simarouba*] and *Vitox negundo* against *S. litura* infesting vegetables in Bangalore, Karnataka, India were determined under laboratory conditions by Murthy *et al.* (2006). All the extracts exhibited repellent, antifeedant and ovicidal properties, with *Acorus calamus* and *V. negundo* exhibiting the highest biological properties, regardless of the concentration.

Ghatak *et al.* (2005) conducted an experiment in West Bengal, India to investigate the biological efficacy of indigenous plant products in controlling *S. littoralis.* Petroleum ether extracts from seeds of *Pachyrhizus erosus* (PE) and *Annona squamosa* (AS) at 1, 2 and 3% concentration; Neem plus 1500 ppm at 0.5, and 2% concentration ; and Monocil 36 SL [monocrotophos] at 0.03, 0.05, and 0.07% concentration were sprayed on third instar larvae *S. littoralis*, and effects were assessed at 12, 24, 48, 72 and 96 hour after treatment. Larval mortality under PE, AS and neem was 40.00-83.33, 46.66-70.00 and 40.00-60.00, respectively after 96 hour of treatment. Larval mortality due to monocil was 76.66-86.66 even at 48 hour after treatment. Based on LC_{50} values, monocil was the most toxic pesticide, while seed extract of AS was the least toxic.

Sharma *et al.* (1999) conducted and experiment for the effect of host plants like castor (*Ricimus communis*), cabbage, cauliflower, tomatoes and wild cabbage and

also the effect of neem oil on food utilization indices of *S. litura.* They stated that, cauliflower was the most preferred host. Neem oil markedly decreased feeding by *S. litura* larva on these plants.

Neem oil (*S. indica*) at 8 and 16% exhibited complete repellent and antifeedant effect against larvae of *S. litura* on *Vigna mungo* leaves. At 0.5-4% repellency and antifeedant activity increased with increasing concentration. Neem oil at 0.5 and 1.0% lost its antifeedant property after 5 days (Malathi *et al*., 1999).

Kumar *et al.* (1997) investigated the effect of exudates from reddish terminal leaves of neem, *Azadirachta indica* on *S. litura*. A significant increase in the larval mortality, antifeedancy and ovipositional repellency was found after treatment with acetone extracts of neem leaf exudates to fifth instar larvae. Reduced consumption, growth and nutritional efficiency were evident. Extended larval and pupal durations and reduced longevity and fecundity were observed by neem leaf extract treatment.

The repellency, antifeedant activity and development period increased with increase in concentration of biosol, neemark, repelin and neem oil. Moreover, adult emergence, growth, survival, larval and pupal weight, number of eggs laid and hatchability of eggs decreased with increase in concentration and neem oil had the greatest effects on *S. litura*, followed by neemark, biosol and repelin (Rao *et al.,* 1993).

Kaul (1987) determined dose response relationship of *Calamun* oil using food acceptance, feeding ratio, weight gain and larval development as parameters in choice tests against *S. litura.* At concentrations of 0.5% and 1.0% *Calamus* oil was effective in both tests inducing a significant reduction in feeding and inhibition of growth in early 3rd instar larvae. Neem oil had such effect only at 2%, particularly in no choice tests.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2013 to February 2014 to study the effectiveness of commonly used botanicals in managing tobacco caterpillar, *Spodoptera litura* (Fab.) on cabbage. The details of the materials and methods that used to conduct the experiment are presented below:

3.1 Location

The experiment was carried out in the central farm of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^0 74^{//}$N latitude and $90^0 35^{//}$E longitude and an elevation of 8.2 m from sea level (Anon., 1989).

3.2 Climate

The weather of experimental site was under the subtropical climate, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). Details of the meteorological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from the Bangladesh Meteorological Department, Dhaka and presented in Appendix I.

3.3 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka and presented in Appendix II.

3.4 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing all of the treatments. Each experiment consists of total 21 plots of size 3.0 m × 2.0 m. The layout of the experiment is shown in Figure 1.

3.5 Test crop and its characteristics

The test crop used in the experiment was cabbage variety Hatlas-70. It is a imported high yielding variety with average yield 55-60 t/ha^{-1}.

3.6 Treatments of the experiment

The experiment was consisted of seven treatments including an untreated control. These were as follows:

T_1: Spraying Neem oil @ 6 ml/L of water + 15 ml trix detergent at 7 days interval

T_2: Spraying Neem oil @ 5 ml/L of water + 12 ml trix detergent at 7 days interval

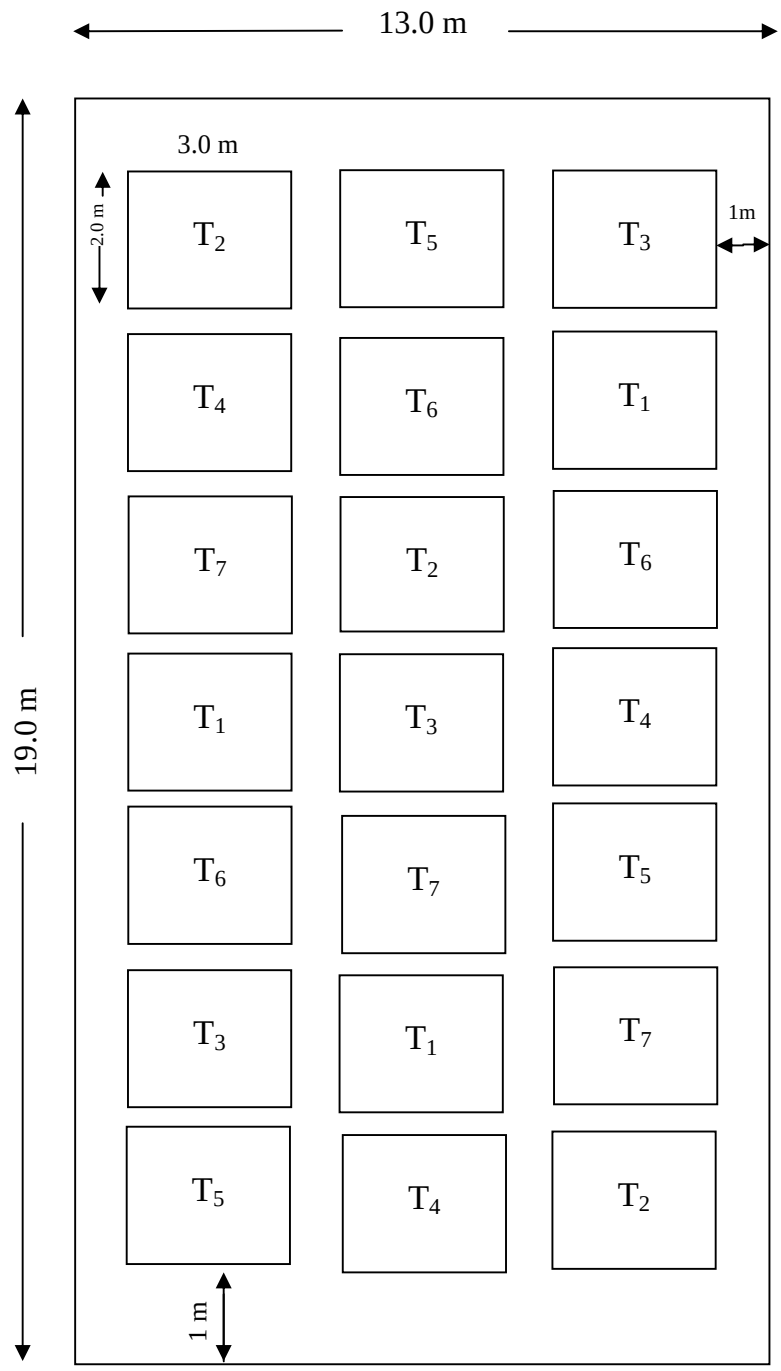
T_3: Spraying Neem oil @ 4 ml/L of water + 10 ml trix detergent at 7 days interval

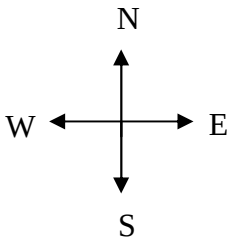
T_4: Spraying Mehgoni seed kernel @ 200 mg/L of water at 7 days interval

T_5: Spraying Neem leaf extract @ 200 mg/L of water at 7 days interval

T_6: Spraying Neem seed kernel extract @ 200 mg/L of water at 7 days interval

Untreated control





Plot size: 3.0 m × 2.0 m

Plot spacing: 50 cm

Between replication: 1.0 m

Treatment

T_1: Neem oil @ 6 ml/L of water + 15 ml trix detergent

T_2: Neem oil @ 5 ml/L of water + 12 ml trix detergent

T_3: Neem oil @ 4 ml/L of water + 15 ml trix detergent

T_4: Mehgoni seed kernel @ 200 mg/L of water

T_5: Neem leaf extract @ 200 mg/L of water

T_6: Neem seed kernel extract @ 200 mg/L of water

Untreated control

*Treatments were applied at 7 da intervals starting from the first initiati of the pest attack

Figure 1. Layout of the experimental plots

3.7 Preparation of neem products

3.7.1 Neem oil

The fresh neem oil was collected from chawkbazar (Plate 1 A), Dhaka and the trix liquied detergent was collected from local market of Agargaon bazar. All sprays were made according to the methods describe earlier. For each neem oil application 6 ml neem oil was mixed with 1 litre of water and 15 ml of trix detergent was added to prepare the treatment neem oil 6 ml/litre of water. Similarly 5 ml neem oil was mixed with 1 litre of water and 12 ml of trix detergent was added to prepare the treatment neem oil 5 ml/litre of water. Four ml neem oil was mixed with 1 litre of water and 10 ml of trix detergent was added to prepare the treatment neem oil 4 ml/litre of water.

3.7.2 Neem seed kernel extract

Neem seed kernels were collected from the field of Sher-e-Bangla Agricultural University, Dhaka. After bringing to the laboratory, they were washed in running water and dried in shade. Dust was prepared by pulverizing the kernel in a magnetic stirrer. A 25-mesh diameter sieve was used to obtain fine dust (Plate 1 B).

Plate1. Solution of neem oil **(A)** and neem seed kernel extract in petridish **(B)**

3.7.3 Neem leaf extract

Fresh leaves of neem (Plate 2 A) were collected from the field of SAU campus, Dhaka. After bringing to the laboratory, they were washed in running water and dried in shade. Dust was prepared by pulverizing the dried leaves in a magnetic stirrer. A 25-mesh diameter sieve was used to obtain fine dust (Plate 2 B). The dusts were preserved in airtight condition in polythene bags and were used after mixing with trix detergent @ 10 ml/L of water.

Plate 2. Leaves of neem (A) and neem leaf dusts in petridish (B)

3.7.4 Mehgoni seed kernel extract

Mehgoni seed kernels were collected from the field of Sher-e-Bangla Agricultural University campus, Dhaka. After bringing to the laboratory, they were washed in running water and dried in shade. Dust was prepared by pulverizing the kernel in a magnetic stirrer. A 25-mesh diameter sieve was used to obtain fine dust of Mehgoni seeds.

3.8 Growing of crops

The experiment plot was opened in the 1st week of November 2013 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a

good tilth. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for proper growth and development of cabbage.

3.8.1 Raising of seedlings

The seedlings were raised in 3 m × 1 m size seed bed under special care at SAU central farm Dhaka. The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses and to obtain good tilth to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed. The seed bed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease Cupravit fungicide were applied. Decomposed cowdung was applied in prepared seed bed 10 t/ha. Ten (10) grams of seeds were sown in seedbed on October 15, 2013. After sowing, the seeds were covered with finished light soil. At the end of germination shading was done by bamboo mat (chatai) over the seed bed to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering, weeding was done as and when necessary to provide seedlings with an ideal condition for crop growth.

3.8.2 Transplanting

Healthy and uniform seedlings of 30 days old were transplanting in the experimental plots on 15 November, 2013. The seedlings were transferred carefully from the seed bed to experimental plots to avoid damage to the root system. To minimize the damage to the roots of seedlings, the seed beds were watered one hour before uprooting the seedlings. Transplanting was done in the afternoon. The seedlings were watered immediately after transplanting. Seedlings were transplanted in the plot with distance between row to row was 60 cm and plant to plant was 45 cm. The young transplanted seedlings were provided shade by banana leaf sheath during day to protect them from scorching sunshine and continued up to 7 days until they were set in the soil. Plants were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border if the experimental plots for gap filling.

3.9 Fertilizers and manure application

Manures and fertilizers were applied according to the the recommended fertilizer doses for cabbage production per hectare by BARI (2005).

Table 1. Dose and method of application of fertilizers in cabbage field

Fertilizers and Manures	Dose/ha	Application (%)			
		Basal	10 DAT	30 DAT	50 DAT
Cowdung	20 tonnes	100	--	--	--
Urea	300 kg	--	33.33	33.33	33.33
TSP	150 kg	100	--	--	--
MoP	200 kg	100	--	--	--

The total amount of cowdung, TSP and MoP was applied as basal dose at the time of land preparation. The total amount of Urea was applied in three installments at 10, 30 and 50 day after transplanting (DAT).

3.10 Intercultural operations

After transplanting seedlings, various intercultural operations such as gap filling, weeding, earthing up, irrigation etc. were accomplished for better growth and development of the cabbage.

3.10.1 Gap filling

The transplanted seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after transplanting and that seedling were replaced by new seedlings from the stock. Replacement was done with healthy seedling having a boll of earth which was also planted on the same date by the side of the unit plot. The transplanted seedlings were given shading and watering for 7 days for their proper development.

3.10.2 Weeding

Weeding was done 15, 30 and 45, 60 days after transplanting to keep the plots free from weeds.

3.10.3 Irrigation

Light watering was given by a watering can at every morning and afternoon after transplanting. Following transplanting and it was continued for a week for rapid and well establishment of the transplanted seedlings. Beside this a routine irrigation was given at 3 days intervals.

3.10.4 Earthing up

Earthing up was done at 20 and 40 days after transplanting on both sides of rows by taking the soil from the space between the rows by a small spade.

3.11 Harvesting

Harvesting of the cabbage was not possible on a certain or particular date because the head initiation as well as attaining the head at marketable size in different plants were not uniform. Only the compact marketable heads were harvested with fleshy stalk by using as sharp knife. Before harvesting of the cabbage head, compactness of the head was tested by pressing with thumbs.

3.12 Monitoring of insect pest and data collection

The cabbage plants were closely examined at regular intervals commencing from 20 days after transplanting (DAT) to harvesting of cabbage head. Caterpillars from each plot were recorded at 20, 30 and 40 DAT and then at early, mid and late stage of head compaction. The tobacco caterpillar was collected by a needle and brush in a petridish and counted at laboratory.

3.13 Determination of head infestation

All the healthy and infested heads were counted from the middle area of each plot. The collected data were divided into 20, 30 and 40 DAT and at early, mid and late head formation stage. The healthy and infested plants and heads were counted and the per cent plant and head infestation was calculated using the following formula:

$$\% \text{ Infestation} = \frac{\text{Number of infested plant/head}}{\text{Total number of plant}} \times 100$$

(% Infestation in control – % Infestation in the concerned treatment)

$$\% \text{ Infestation reduction} = \frac{\text{Infestation in control}}{\text{Infestation in control}} \times 100$$

3.14 Data recording on yield contributing characters and yield of cabbage

Data were recorded on yield contributing characters and yield of cabbage on the following parameters:

3.14.1 Plant height

The height of plant was recorded in centimeter (cm) during harvest time from each experimental plot. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. Plant height was measured from sample plants from the ground level to the tip of the longest leaf and mean value was calculated.

3.14.2 Compactness of head

The compactness of head was measured in centimeter (cm) with a meter scale as the vertical distance from the lower to the upper most leaves of the head after sectioning the head vertically at the middle position and mean value was calculated.

3.14.3 Diameter of head

The heads from sample plants were sectioned vertically at the middle position with a sharp knife. The diameter of the head was measured in centimeter (cm) with a meter scale as the horizontal distance from one side to another of the widest part of the sectioned head and mean value was recorded.

3.14.4 Gross weight of head per plant

The heads from sample plants were harvested, cleaned and weighted with folded and unfolded leaves. The gross weight of every head were measured by a weighing scale and mean values were recorded.

3.14.5 Marketable yield per plot

After harvest of head from selected plants from each unit plot the unfolded leaves were removed from the head and weighed by a weighing balance and recorded the weight of head as marketable yield per plot.

3.14.6 Marketable yield per hectare

The marketable yield per hectare was measured by converting marketable yield per plot into yield per hectare and was expressed in tons.

3.15 Statistical Analysis

The data related to tobacco caterpillar incidence and different yield contributing characters were statistically analyzed to observe the significant difference among the treatment. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the effectiveness of commonly used botanicals against the infestation of tobacco caterpillar in cabbage from November 2013 to February 2014 at the central farm of SAU. The results have been presented by using different Table & Graphs and discussed with possible interpretations under the following headings and sub headings:

4.1 Intensity of infestation by tobacco caterpillar on cabbage plant

Intensity of in tobacco caterpillar infestation on cabbage plant was recorded at 20, 30 and 40 DAT and statistically significant variation was recorded for different treatment under the present trial.

4.1.1 Infestation on cabbage plant/plot at 20 DAT

Number of healthy plant, infested plants and percent infestation of cabbage plant showed significant differences at 20 DAT for different treatment with botanicals (Table 2). The highest number of healthy plants (25.00) was recorded in T_1 (Neem oil @ 6 ml/L of water treated plot) and T_2 (Neem oil @ 5 ml/L of water) treated plot which was statistically similar (24.67, 24.33 and 23.33) to T_3 (Neem oil @ 4 ml/L of water), T_5 (Neem leaf extract @ 200 mg/L of water), T_6 (Neem seed kernel extract @ 200 mg/L) and T_4 (Mehgoni seed kernel @ 200 mg/L of water) treated plot, respectively. But the lowest number (21.67) was found in untreated control plot. The highest number of infested plant/plot (3.33) was recorded in untreated control which was followed (1.67) by T_4, whereas the lowest number i.e. no infested plant was observed in T_1 and T_2 which was followed (0.33) by T_3. The highest percentage of infestation (15.37%) was attained in untreated control

which was followed (7.16%) by T_4, while the lowest percentage of infestation (0.00%) was found in T_1 and T_2 treatments which was closely followed (1.34%) by T_3 treatment. Cabbage plant infestation percentage reduction over control at 20 DAT was estimated for different commonly used botanicals and the highest value (100%) was found in T_1 and T_2, whereas the lowest value (53.42%) was in T_4 treatment.

Table 2. Effect of different commonly used botanicals on the infestation of cabbage plant by tobacco caterpillar at 20 days after transplanting (DAT)

Treatments*	Plants at 20 days after transplanting			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)
T_1	25.00 a	0.00 e	0.00 e	100.00
T_2	25.00 a	0.00 e	0.00 e	100.00
T_3	24.67 a	0.33 d	1.34 d	91.30
T_4	23.33 ab	1.67 b	7.16 b	53.42
T_5	24.33 a	0.67 c	2.75 c	82.08
T_6	24.33 a	0.67 c	2.75 c	82.08
Untreated control	21.67 b	3.33 a	15.37 a	--
$LSD_{(0.05)}$	1.48	0.271	1.218	--
Significance level	0.01	0.01	0.01	--
CV(%)	6.78	8.23	5.38	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 3 selected plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Treatments:

T_1: Neem oil @ 6 ml/L of water + 15 ml trix detergent

T_2: Neem oil @ 5 ml/L of water + 12 ml trix detergent

T_3: Neem oil @ 4 ml/L of water + 10 ml trix detergent

T_4: Mehgoni seed kernel @ 200 mg/L of water

T_5: Neem leaf extract @ 200 mg/L of water

T_6: Neem seed kernel extract @ 200 mg/L of water

Untreated control

*Treatments were applied at 7 days intervals starting from the first initiation of the pest attack

4.1.2 Infestation on cabbage plant/plot at 30 DAT

Number of healthy plant, infested plants and per cent infestation of cabbage plant showed significant differences at 30 DAT for different commonly used botanicals (Table 3). The highest number of healthy plants (25.00) was recorded in T_1 (Neem oil @ 6 ml/L of water) treated plot which was statistically similar (24.67, 24.33, 23.67 and 23.33) with T_2 (Neem oil @ 5 ml/L of water), T_3 (Neem oil @ 4 ml/L of water), T_6 (Neem seed kernel extract @ 200 mg/L of water) and T_5 (Neem leaf extract @ 200 mg/L of water), respectively. On the other hand, the lowest number of healthy plants (20.67) was found in untreated control plot which was closely followed (22.67) by T_4 (Mehgoni seed kernel @ 200 mg/L of water) treated plot. The highest number of infested plant/plot (4.33) was recorded in untreated control plot which was followed (2.33) by T_4, whereas the lowest number i.e., no infested plant was observed in T_1 treatment which was followed (0.33) by T_2. The highest percentage of infestation (20.95%) was attained in untreated control which was followed (10.28%) by T_4, while the lowest percentage of infestation (0.00%) was found in T_1 treatment which was closely followed (1.34%) by T_1 treatment. Cabbage plant infestation percentage reduction over control at 30 DAT was estimated for different commonly used botanicals and the highest value (100%) was attained in T_1, whereas the lowest value (50.94%) was recorded from T_4 treatment.

4.1.3 Infestation on cabbage plant/plot at 40 DAT

Number of healthy plant, infested plants and per cent infestation of cabbage plant showed significant differences at 40 DAT for different commonly used botanicals (Table 4). The highest number of healthy plants (25.00) was recorded in T_1 (Neem oil @ 6 ml/L of water) treated plot which was closely followed (24.0) by T_2 (Neem oil @ 5 ml/L of water), while the lowest number of healthy plants (19.33) was found in untreated control plot which was closely followed (19.33) by T_4 (Mehgoni seed kernel @ 200 mg/L of water) treated plot. The highest number of infested plant/plot (5.67) was recorded in untreated control which was followed (3.33) by T_4, whereas the lowest number i.e., no infested plant was observed in T_1

Table 3. Effect of different commonly used botanicals on the infestation of cabbage plant by tobacco caterpillar at 30 days after transplanting (DAT)

Treatments*	Plants at 30 days after transplanting			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)
T_1	25.00 a	0.00 g	0.00 g	100.00
T_2	24.67 a	0.33 f	1.34 f	93.61
T_3	24.33 a	0.67 e	2.75 e	86.85
T_4	22.67 b	2.33 b	10.28 b	50.94
T_5	23.33 ab	1.67 c	7.16 c	65.83
T_6	23.67 a	1.33 d	5.62 d	73.18
Untreated control	20.67 c	4.33 a	20.95 a	--
$LSD_{(0.05)}$	1.345	0.315	1.108	--
Significance level	0.01	0.01	0.01	--
CV(%)	4.68	7.91	5.98	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 3 selected plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Treatments:

T_1: Neem oil @ 6 ml/L of water + 15 ml trix detergent

T_2: Neem oil @ 5 ml/L of water + 12 ml trix detergent

T_3: Neem oil @ 4 ml/L of water + 10 ml trix detergent

T_4: Mehgoni seed kernel @ 200 mg/L of water

T_5: Neem leaf extract @ 200 mg/L of water

T_6: Neem seed kernel extract @ 200 mg/L of water

Untreated control

*Treatments were applied at 7 days intervals starting from the first initiation of the pest attack

Table 4. Effect of different commonly used botanicals on the infestation of cabbage plant by tobacco caterpillar at 40 days after transplanting (DAT)

Treatments*	Plants at 40 days after transplanting			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)
T_1	25.00 a	0.00 f	0.00 f	100.00
T_2	24.00 b	1.00 e	4.17 e	85.80
T_3	23.33 c	1.67 d	7.16 d	75.60
T_4	21.67 e	3.33 b	15.37 b	47.61
T_5	22.67 d	2.33 c	10.28 c	64.96
T_6	22.67 d	2.33 c	10.28 c	64.96
Untreated control	19.33 f	5.67 a	29.33 a	--
$LSD_{(0.05)}$	0.917	0.591	2.791	--
Significance level	0.01	0.01	0.01	--
CV(%)	5.81	9.33	10.21	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 3 selected plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Treatments:

T_1: Neem oil @ 6 ml/L of water + 15 ml trix detergent

T_2: Neem oil @ 5 ml/L of water + 12 ml trix detergent

T_3: Neem oil @ 4 ml/L of water + 10 ml trix detergent

T_4: Mehgoni seed kernel @ 200 mg/L of water

T_5: Neem leaf extract @ 200 mg/L of water

T_6: Neem seed kernel extract @ 200 mg/L of water

Untreated control

*Treatments were applied at 7 days intervals starting from the first initiation of the pest attack

treated plot which was followed (1.33) by T_2. The highest percentage of infestation (29.33%) was attained in untreated control plot which was followed (15.37%) by T_4, while the lowest percentage of infestation (0.00%) was found in T_1 treatment which was followed (4.17%) by T_2 treatment. Cabbage plant infestation percentage reduction over control at 40 DAT was estimated for different commonly used botanicals and the highest value (100%) was found in T_1, whereas the lowest value (47.61%) was recorded from T_4 treatment.

From the above findings, it is revealed that spraying of Neem oil @ 6 ml/L of water applied at 7 days interval was more effective against the commonly used botanical for reduction of cabbage plant infestation by tobacco caterpillar at 20, 30 and 40 DAT and this was followed by Neem oil @ 5 ml/L of water sprayed at 7 days interval. Literature available on the similar results of the study of different researchers which were similar with present study are discussed below. Reports are also available on the efficacy of botanical products against the tobacco caterpillar (Devaki *et al.,* 2004; Chari *et al.,* 1999; Malathi *et al*., 1999; Sharma *et al*., 1999; Dayan, 2009). Neem leaf extracts reduced food consumption, growth and nutritional efficiency of tobacco caterpillar. It also extended larval and pupal durations and reduced longevity and fecundity of these pests (Kumar *et al.*, 1997). Sharma *et al*. (1999) reported that neem oil markedly decreased feeding of *S. litura* (Fab.).

4.2 Intensity of infestation by tobacco caterpillar on the leaf of cabbage head

Intensity of infestation by tobacco caterpillar on leaves of cabbage head was recorded at early, mid and late stage of head formation and found statistically significant variation among different treatment.

4.2.1 Early head formation stage of cabbage

Number of healthy leaves, infested leaves and percent infestation of leaves of cabbage head showed significant differences at early head formation stage in different treatments (Table 5). The highest number of healthy leaves/plants (52.22) was recorded in T_1 (Neem oil @ 6 ml/L of water) which was statistically similar (51.45 and 50.64) with T_2 (Neem oil @ 5 ml/L of water) and T_3 (Neem oil @ 4 ml/L of water) and closely followed (48.67, 48.56 and 45.38) by T_5 (Neem leaf extract @ 200 mg/L of water), T_6 (Neem seed kernel extract @ 200 mg/L of water) and T_4 (Mehgoni seed kernel @ 200 mg/L of water) treated plots. But the lowest number (40.87) was found in untreated control plot. The highest number of infested leaves/plant (8.33) was also recorded in untreated control which was followed (4.55) by T_4. The lowest number (1.15) was observed in T_1 treated plot which was followed (1.67 and 2.34) by T_2 and T_3 and they were statistically similar. The highest percentage of infestation (20.38%) was attained in untreated control plot which was followed (10.03%) by T_4, while the lowest percentage of infestation (2.20%) was found in T_1 treatment which was statistically similar (3.25% and 4.62%) to that of T_2 and T_3 treatment. Leaves of cabbage head infestation reduction over control at early head formation stage was estimated for different treatment and the highest value (89.20%) was found in T_1, whereas the lowest value (50.81%) was in T_4 treatment.

4.2.2 Mid head formation stage of cabbage

Number of healthy, infested and per cent infestation of leaves of cabbage head showed significant variation at mid head formation stage for different treatment (Table 6). The highest number of healthy leaves/plants (57.37) was recorded in T_1 (Neem oil @ 6 ml/L of water which was statistically similar (56.33 and 55.29) with T_2 (Neem oil @ 5 ml/L of water) and T_3 (Neem oil @ 4 ml/L of water)

Table 5. Effect of different commonly used botanicals on the leaf infestation of cabbage by tobacco caterpillar at early stage of head formation

Treatments*	Leaves/plant at early stage of head formation			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)
T_1	52.22 a	1.15 e	2.20 d	89.20
T_2	51.45 a	1.67 d	3.25 d	84.07
T_3	50.64 a	2.34 d	4.62 d	77.33
T_4	45.38 b	4.55 b	10.03 b	50.81
T_5	48.67 b	3.33 c	6.84 c	66.43
T_6	48.56 b	3.28 c	6.75 c	66.86
Untreated control	40.87 c	8.33 a	20.38 a	--
$LSD_{(0.05)}$	3.541	0.891	3.081	--
Significance level	0.01	0.01	0.01	--
CV(%)	6.78	9.22	5.98	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 3 selected plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Treatments:

T_1: Neem oil @ 6 ml/L of water + 15 ml trix detergent

T_2: Neem oil @ 5 ml/L of water + 12 ml trix detergent

T_3: Neem oil @ 4 ml/L of water + 10 ml trix detergent

T_4: Mehgoni seed kernel @ 200 mg/L of water

T_5: Neem leaf extract @ 200 mg/L of water

T_6: Neem seed kernel extract @ 200 mg/L of water

Untreated control

*Treatments were applied at 7 days intervals starting from the first initiation of the pest attack

Table 6. Effect of different commonly used botanicals on the leaf infestation of cabbage by tobacco caterpillar at mid stage of head formation

Treatments*	Leaves/plant at mid stage of head formation			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)
T_1	57.37 a	1.56 c	2.72 d	88.62
T_2	56.33 a	2.06 c	3.66 d	84.69
T_3	55.29 a	2.67 c	4.83 d	79.78
T_4	47.93 c	5.46 b	11.39 b	52.31
T_5	51.45 b	4.56 b	8.86 c	62.90
T_6	51.32 b	4.41 b	8.59 c	64.03
Untreated control	42.49 d	10.15 a	23.89 a	--
$LSD_{(0.05)}$	4.134	1.231	2.307	--
Significance level	0.01	0.01	0.01	--
CV(%)	5.98	7.88	4.33	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 3 selected plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Treatments:

T_1: Neem oil @ 6 ml/L of water + 15 ml trix detergent

T_2: Neem oil @ 5 ml/L of water + 12 ml trix detergent

T_3: Neem oil @ 4 ml/L of water + 10 ml trix detergent

T_4: Mehgoni seed kernel @ 200 mg/L of water

T_5: Neem leaf extract @ 200 mg/L of water

T_6: Neem seed kernel extract @ 200 mg/L of water

Untreated control

*Treatments were applied at 7 days intervals starting from the first initiation of the pest attack

and closely followed (51.45 and 51.32) by T_5 (Neem leaf extract @ 200 mg/L of water) and T_6 (Neem seed kernel extract @ 200 mg/L of water), respectively. The lowest number (42.49) was found in untreated control plot which was followed (47.93) by T_4 (Mehgoni seed kernel @ 200 mg/L of water) treated plot. The highest number of infested leaves/plant (10.15) was recorded in untreated control plot which was followed (5.46, 4.56 and 4.41) by T_4, T_5 and T_6, respectively, whereas the lowest number (1.56) was observed in T_1 and this was statistically similar (2.06 and 2.67) with T_2 and T_3, respectively. The highest percentage of infestation (23.89%) was attained in untreated control which was followed (11.39%) by T_4 treated plot, while the lowest percentage of infestation (2.72%) was found in T_1 treatment and this was statistically similar (3.66% and 4.83%) with T_2 and T_3 treatment, respectively. Leaves of cabbage head infestation reduction over control at mid head formation stage was estimated for different treatments and the highest value (88.62%) was attained in T_1, whereas the lowest value (52.31%) was in T_4 treatment.

4.2.3 Late head formation stage of cabbage

Number of healthy leaves, infested leaves and percent infestation of leaves of cabbage head showed significant variation at late head formation stage for different treatment (Table 7). The highest number of healthy leaves/plants (64.33) was recorded in T_1 (Neem oil @ 6 ml/L of water) which was statistically similar (62.56 and 60.55) to that of T_2 (Neem oil @ 5 ml/L of water) and T_3 (Neem oil @ 4 ml/L of water), respectively and closely followed (54.45, 54.12 and 53.55) by T_5 (Neem leaf extract @ 200 mg/L of water), T_6 (Neem seed kernel extract @ 200 mg/L of water) and T_4 (Mehgoni seed kernel @ 200 mg/L of water) treatment, while the lowest number (44.78) was found in untreated control plot. The highest number of infested leaves/plant (12.05) was recorded in untreated control which was followed (7.04) by T_4, whereas the lowest number (1.87) was observed in T_1 and this was statistically similar (2.33 and 3.14) with T_2 and T_3. The highest percentage of infestation (26.91%) was attained in untreated control which was followed (13.15%) by T_4, while the lowest percentage of infestation (2.91%) was

Table 7. Effect of different commonly used botanicals on the leaf infestation of cabbage by tobacco caterpillar at late stage of head formation

Treatments*	Leaves/plant at late stage of head formation			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)
T_1	64.33 a	1.87 de	2.91 e	89.20
T_2	62.56 a	2.33 d	3.72 e	86.16
T_3	60.55 a	3.14 d	5.19 d	80.73
T_4	53.55 b	7.04 b	13.15 b	51.14
T_5	54.45 b	5.44 c	9.99 c	62.87
T_6	54.12 b	5.32 c	9.83 c	63.47
Untreated control	44.78 c	12.05 a	26.91 a	--
$LSD_{(0.05)}$	3.891	2.198	1.451	--
Significance level	0.01	0.01	0.01	--
CV(%)	4.89	5.09	8.91	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 3 selected plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Treatments:

T_1: Neem oil @ 6 ml/L of water + 15 ml trix detergent

T_2: Neem oil @ 5 ml/L of water + 12 ml trix detergent

T_3: Neem oil @ 4 ml/L of water + 10 ml trix detergent

T_4: Mehgoni seed kernel @ 200 mg/L of water

T_5: Neem leaf extract @ 200 mg/L of water

T_6: Neem seed kernel extract @ 200 mg/L of water

Untreated control

*Treatments were applied at 7 days intervals starting from the first initiation of the pest attack

found in T_1 treatment which was statistically similar (3.72%) to that of T_2 treatment. Leaves of cabbage head infestation reduction (%) over control at late head formation stage was estimated for different treatments and the highest value (89.20%) was found in T_1, whereas the lowest value (51.14%) was calculated in T_4 treatment.

From the above findings, it is revealed that spraying of Neem oil @ 6 ml/L of water at 7 days interval was more effective among used botanical in reducing the cabbage plant infestation by tobacco caterpillar at early, mid and late head formation stage. This was followed by Neem oil @ 5 ml/L of water at 7 days interval. Different researchers' findings support the result of the present study. Tofael (2004) reported that young and mature caterpillar also caused greater damage if the infestation occurred at the head forming stage. Succeeding generations can do greater damage and later instar larvae remained outside the cabbage head, can come out as a serious phase of infestation for their voracious feeding habit. Reports are also available on the efficacy of botanical products against the tobacco caterpillar (Devaki *et al.*, 2004; Chari *et al.*, 1999; Malathi *et al*., 1999; Sharma *et al*., 1999). Neem leaf extracts reduced food consumption, growth and nutritional efficiency of tobacco caterpillar. It also extended larval and pupal durations and reduced longevity and fecundity of this pest (Kumar *et al.* 1997). Sharma *et al*. (1999) reported that neem oil markedly decreased feeding of *S. litura* (Fab.).

4.3 Intensity of infestation by tobacco caterpillar on cabbage head

Intensity of infestation by tobacco caterpillar on cabbage head was recorded and statistically significant variation was obtained in different treatment under the present study. Number of healthy head, infested head and percent infestation of cabbage head plot^{-1} showed significant differences in different treatment (Table 8). The highest number of healthy head plot^{-1} (24.33) was recorded in T_1 (Neem oil @ 6 ml/L of water) which was statistically similar (23.67, 22.67, 22.33 and 21.33, respectively) with T_2 (Neem oil @ 5 ml/L of water), T_3 (Neem oil @ 4 ml/L of water), T_5 (Neem leaf extract @ 200 mg/L of water), T_6 (Neem seed kernel extract @ 200 mg/L of water) and T_4 (Mehgoni seed kernel @ 200 mg/L of water) treated plot, respectively. The lowest number (18.67) was found in untreated control. The highest number of infested heads/plot (6.33) was recorded in untreated control, while the lowest percentage of infestation (0.67%) was found in T_1 treatment this was statistically similar (1.33, 2.33, 2.67 and 3.67) to that of T_2, T_3, T_5, T_6 and T_4 treatments, respectively. The highest percentage of infestation (33.90%) was obtained in untreated control plot which was followed (17.21%) by T_4. But the lowest percentage (2.75%) was recorded from T_1 which was followed (5.62%) by T_2 treatment. Cabbage head infestation reduction over control was estimated for different treatments and the highest value (91.88%) was found in T_1, whereas the lowest value (49.25%) was calculated in T_4 treatment.

From the above findings, it is revealed that spraying of Neem oil @ 6 ml/L of water at 7 days interval was more effective among the treatment with botanical for reduction of cabbage head infestation by tobacco caterpillar which was followed by Neem oil @ 5 ml/L of water at 7 days interval. Results indicated that the Neem leaf extracts reduced food consumption, growth and nutritional efficiency of tobacco caterpillar.

Table 8. Effect of different commonly used botanicals on the infestation of cabbage head by tobacco caterpillar

Treatments*	Head of cabbage plot^{-1}			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)
T_1	24.33 a	0.67 c	2.75 e	91.88
T_2	23.67 a	1.33 b	5.62 d	83.43
T_3	22.67 a	2.33 b	10.28 c	69.69
T_4	21.33 ab	3.67 b	17.21 b	49.25
T_5	22.33 a	2.67 b	11.96 c	64.73
T_6	22.33 a	2.67 b	11.96 c	64.73
Untreated control	18.67 b	6.33 a	33.90 a	--
$LSD_{(0.05)}$	3.412	2.781	2.451	--
Significance level	0.01	0.01	0.01	--
CV(%)	6.57	9.04	7.34	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 3 selected plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Treatments:

T_1: Neem oil @ 6 ml/L of water + 15 ml trix detergent

T_2: Neem oil @ 5 ml/L of water + 12 ml trix detergent

T_3: Neem oil @ 4 ml/L of water + 10 ml trix detergent

T_4: Mehgoni seed kernel @ 200 mg/L of water

T_5: Neem leaf extract @ 200 mg/L of water

T_6: Neem seed kernel extract @ 200 mg/L of water

Untreated control

*Treatments were applied at 7 days intervals starting from the first initiation of the pest attack

4.4 Number of bore leaf^{-1} and larvae head^{-1} of cabbage

Number of bore leaf^{-1} and number of larvae infested head^{-1} of cabbage head was recorded and statistically significant variation was noted in different treatment of the present study.

4.4.1 Number of bore leaf^{-1}

Number of bores leaf^{-1} showed significant variation in different treatments (Table 9). The lowest number of bores leaf^{-1} (1.33) was recorded in T_1 (Neem oil @ 6 ml/L of water) which was statistically similar (2.67, 3.33, 4.33, 4.67 and 7.67) with T_2 (Neem oil @ 5 ml/L of water), T_3 (Neem oil @ 4 ml/L of water), T_6 (Neem seed kernel extract @ 200 mg/L of water), T_5 (Neem leaf extract @ 200 mg/L of water) and T_4 (Mehgoni seed kernel @ 200 mg/L of water) treatment, respectively. But the highest number of bore leaf^{-1} (25.67) was found in untreated control plot. Number of bores leaf^{-1} of cabbage head reduction (%) over control was estimated for different treatment and the highest value (94.82%) was found in T_1, whereas the lowest value (70.12%) was in T_4 treatment.

4.4.2 Number of larvae head^{-1} of cabbage

Number of larvae head^{-1} showed significant differences for variations in different treatments utilizing botanicals (Table 9). The lowest number of larvae head^{-1} (0.33) was recorded in T_1 (Neem oil @ 6 ml/L of water) which was statistically similar (1.00) to that of T_2 (Neem oil @ 5 ml/L of water) and closely followed (2.33) by T_3 (Neem oil @ 4 ml/L of water) treatment. The highest number of larvae head^{-1} (6.33) was found in untreated control plot which was followed (4.33) by T_4 (Mehgoni seed kernel @ 200 mg/L of water) treatment. Number of larvae head^{-1} of cabbage reduction (%) over control was estimated for different treatments with botanicals and the highest value (94.79%) was found in T_1, whereas the lowest value (31.60%) was in T_4 treatment.

Table 9. Effect of different commonly used botanicals on number of bore infested leaf^{-1} of cabbage and number of larvae head^{-1} by tobacco caterpillar

Treatments*	Number of bores leaf^{-1}	Reduction of bore over control (%)	Number of larvae head^{-1}	Reduction of larvae over control (%)
T_1	1.33 b	94.82	0.33 e	94.79
T_2	2.67 b	89.60	1.00 e	84.20
T_3	3.33 b	87.03	2.33 d	63.19
T_4	7.67 b	70.12	4.33 b	31.60
T_5	4.67 b	81.81	3.67 c	42.02
T_6	4.33 b	83.13	3.33 c	47.39
Untreated control	25.67 a	--	6.33 a	--
$LSD_{(0.05)}$	4.091	--	0.791	--
Significance level	0.05	--	0.05	--
CV(%)	8.45	--	9.22	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 3 selected plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Treatments:

T_1: Neem oil @ 6 ml/L of water + 15 ml trix detergent

T_2: Neem oil @ 5 ml/L of water + 12 ml trix detergent

T_3: Neem oil @ 4 ml/L of water + 10 ml trix detergent

T_4: Mehgoni seed kernel @ 200 mg/L of water

T_5: Neem leaf extract @ 200 mg/L of water

T_6: Neem seed kernel extract @ 200 mg/L of water

Untreated control

*Treatments were applied at 7 days intervals starting from the first initiation of the pest attack

4.5 Effect of temperature, rainfall and humidity on head infestation of cabbage at different harvesting time

With increasing of temperature at different DAT and at early, mid and late head formation stage of cabbage and percent head infestation presented in Figure 2 showed that with the increasing the temperature percent cabbage head infestation also followed increasing trend and it was highest in late head formation stage, when the highest mean temperature was raised at 27.1^{0}C. Percent head infestation trend was found more or less similar when the mean rainfall was 30 mm. Like temperature positive effect was also found in case of relative humidity. With decreasing relative humidity, percent head infestation increased. It was highest when the highest relative humidity was 78% (Figure 2).

4.6 Yield contributing character and yield of cabbage

Yield contributing characters and yield of cabbage was recorded and statistically significant variation was found in for different treatment under the present study.

4.6.1 Plant height

Plant height of cabbage showed significant variations for different treatments with botanicals (Figure 3). The longest plant (51.45 cm) was recorded in T_1 (Neem oil @ 6 ml/L of water) which was statistically similar (50.96 cm, 50.04 cm, 49.45 cm, 49.32 cm and 48.56 cm) to that of T_2 (Neem oil @ 5 ml/L of water), T_3 (Neem oil @ 4 ml/L of water), T_5 (Neem leaf extract @ 200 mg/L of water), T_6 (Neem seed kernel extract @ 200 mg/L of water) and T_4 (Mehgoni seed kernel @ 200 mg/L of water) treated plot, respectively. The shortest plant (43.33 cm) was found in untreated control plot.

4.6.2 Compactness of head of cabbage

Compactness the head of cabbage showed significant variation in different treatment utilizing botanicals (Table 10). The maximum compactness of head (13.28 cm) was recorded in T_1 (Neem oil @ 6 ml/L of water) which was statistically similar (13.16 cm, 13.02 cm, 12.83 cm, 12.78 cm and 12.23 cm) with T_2 (Neem oil @ 5 ml/L of water), T_3 (Neem oil @ 4 ml/L of water), T_6 (Neem seed kernel extract @ 200 mg/L of water), T_5 (Neem leaf extract @ 200 mg/L of water) and T_4 (Mehgoni seed kernel @ 200 mg/L of water) treated plots, respectively, while the minimum compactness of head (10.56 cm) was found in untreated control plot.

4.6.3 Diameter of head

The diameter of cabbage head showed significant variation in different treatments using botanicals (Table 10). The maximum diameter of head (11.34 cm) was recorded in T_1 (Neem oil @ 6 ml/L of water) which was statistically similar (11.31 cm, 11.24 cm, 10.73 cm, 10.67 cm and 10.22 cm, respectively) to that of T_2 (Neem oil @ 5 ml/L of water), T_3 (Neem oil @ 4 ml/L of water), T_6 (Neem seed kernel extract @ 200 mg/L of water), T_5 (Neem leaf extract @ 200 mg/L of water) and T_4 (Mehgoni seed kernel @ 200 mg/L of water) treated plot, respectively. The lowest thickness of head (9.34 cm) was found in untreated control plot.

4.6.4 Gross yield plant^{-1}

Gross yield plant^{-1} of cabbage showed significant variation for different treatment with botanicals (Figure 4). The highest gross yield plant^{-1} (2.02 kg) was recorded in T_1 (Neem oil @ 6 ml/L of water) which was statistically similar (1.98 kg, 1.86 kg, 1.81 kg, 1.78 kg and 1.70 kg) with T_2 (Neem oil @ 5 ml/L of water), T_3 (Neem oil @ 4 ml/L of water), T_6 (Neem seed kernel extract @ 200 mg/L of water), T_5 (Neem leaf extract @ 200 mg/L of water) and T_4 (Mehgoni seed kernel @ 200 mg/L of water) treated plot, respectively. The lowest gross yield plant^{-1} (1.52 kg) was found in untreated control plot.

Table 10. Yield and yield contributing characters of cabbage due to different commonly used botanicals for controlling tobacco caterpillar

Treatments*	Thickness of head (cm)	Diameter of head (cm)	Marketable yield (kg plant)$^{-1}$	Marketable yield (t ha^{-1})
T_1	13.28 a	11.34 a	1.77 a	65.56 a
T_2	13.16 a	11.31 a	1.73 a	64.07 a
T_3	13.02 a	11.24 a	1.64 b	60.74 b
T_4	12.23 a	10.22 ab	1.45 d	53.70 d
T_5	12.78 a	10.67 a	1.52 c	56.30 c
T_6	12.83 a	10.73 a	1.58 c	58.52 c
Untreated control	10.56 b	9.34 b	1.16 e	42.96 e
$LSD_{(0.05)}$	1.561	1.202	0.291	3.091
Significance level	0.05	0.05	0.01	0.01
CV(%)	6.33	9.08	4.90	5.56

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 3 selected plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Treatments:

T_1: Neem oil @ 6 ml/L of water + 15 ml trix detergent

T_2: Neem oil @ 5 ml/L of water + 12 ml trix detergent

T_3: Neem oil @ 4 ml/L of water + 10 ml trix detergent

T_4: Mehgoni seed kernel @ 200 mg/L of water

T_5: Neem leaf extract @ 200 mg/L of water

T_6: Neem seed kernel extract @ 200 mg/L of water

Untreated control

*Treatments were applied at 7 days intervals starting from the first initiation of the pest attack

4.6.5 Marketable yield plant^{-1}

Marketable yield plant^{-1} of cabbage showed significant variations in different treatment using botanicals (Table 10). The highest marketable yield plant^{-1} (1.77 kg) was recorded in T_1 (Neem oil @ 6 ml/L of water) which was statistically similar (1.73 kg) with T_2 (Neem oil @ 5 ml/L of water) treated plots and closely followed (1.64 kg) by T_3 (Neem oil @ 4 ml/L of water). However, the lowest marketable yield plant^{-1} (1.16 kg) was found in untreated control plot which was followed (1.45 kg) by T_4 (Mehgoni seed kernel @ 200 mg/L of water) treatment.

4.6.6 Marketable yield hectare^{-1}

The marketable yield of cabbage hectare^{-1} showed significant variations with different botanicals (Table 10). The highest marketable yield hectare^{-1} (65.56 ton) was recorded in T_1 (Neem oil @ 6 ml/L of water) which was statistically similar (64.07 ton) to T_2 (Neem oil @ 5 ml/L of water) and closely followed (60.74 ton) by T_3 (Neem oil @ 4 ml/L of water). But the lowest marketable yield hectare^{-1} (42.96 kg) was found in untreated control plot which was followed (53.70 ton) by T_4 (Mehgoni seed kernel @ 200 mg/L of water) treated plot.

4.7 Economic analysis

The analysis was done in order to find out the most profitable treatments using botanicals through cost and benefit ratio considering price of various components. The results of economic analysis of cabbage cultivation showed that the highest net benefit of Tk. 242,240 ha^{-1} was obtained in T_1 treatment and the second highest was found Tk. 238,280 ha^{-1} in T_2 treated plot (Table 11). The highest benefit cost ratio (3.52) was estimated in T_1 treatment and the lowest (1.86) in T_4 treatment. The highest BCR was found in the treatment T_1 may be due to the minimum tobacco caterpillar infestation compared to the treatments and resulted higher yield.

Table 11. Cost of cabbage production for different commonly used botanicals in controlling tobacco caterpillar

Treatments*	Cost of pest Management (Tk.)	Yield (t/ha)	Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	Benefit cost ratio
T_1	20,000	65.56	262,240	242,240	70,400	3.52
T_2	18,000	64.07	256,280	238,280	66,440	3.69
T_3	16,000	60.74	242,960	226,960	55,120	3.45
T_4	15,000	53.70	214,800	199,800	27,960	1.86
T_5	16,000	56.30	225,200	209,200	37,360	2.34
T_6	16,000	58.52	234,080	218,080	46,240	2.89
Untreated control	0	42.96	171,840	171,840	0	--

Treatments:

T_1: Neem oil @ 6 ml/L of water + 15 ml trix detergent

T_2: Neem oil @ 5 ml/L of water + 12 ml trix detergent

T_3: Neem oil @ 4 ml/L of water + 10 ml trix detergent

T_4: Mehgoni seed kernel @ 200 mg/L of water

T_5: Neem leaf extract @ 200 mg/L of water

T_6: Neem seed kernel extract @ 200 mg/L of water

Untreated control

*Treatments were applied at 7 days intervals starting from the first initiation of the pest attack

.

4.8 Relationship between yield contributing characters and infestation of head

4.8.1 Relationship between plant height and head infestation of cabbage

The data on plant height were regressed against head infestation of cabbage and a positive linear relationship was obtained between them. It was evident from the Figure 5 that the equation y = -0.262x + 52.53 gave a good fit to the data, and the co-efficient of determination (0.986) showed that, fitted regression line had a significant regression co-efficient. It is evident from the regression line and equation that, the plant height decreased with the increased of head infestation of cabbage as influenced by treatments with botanicals.

4.8.2 Relationship between girth of fruit and yield ha^{-1}

Correlation study was done to establish a relationship between on cabbage head yield and head infestation of cabbage (Figure 6). From the study it was revealed that the equation -0.019x + 1.816 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.977) showed that, fitted regression line had a significant regression co-efficient. It is evident from the regression line and equation that, the yield of cabbage head decreased with the increase of head infestation of cabbage as influenced by botanicals treatments.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2013 to February 2014 to study the effectiveness of commonly used botanicals in managing tobacco caterpillar, *Spodoptera litura* (Fab.) on cabbage. The experiment comprised six treatments and one untreated control. Six treatment were: T_1: Neem oil @ 6 ml/L of water, T_2: Neem oil @ 5 ml/L of water, T_3: Neem oil @ 4 ml/L of water, T_4: Mehgoni seed kernel @ 200 mg/L of water, T_5: Neem leaf extract @ 200 mg/L of water, T_6: Neem seed kernel extract @ 200 mg/L of water and an untreated control. Treatments were applied at 7 days intervals starting from the first initiation of the pest attack. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Considering the infestation of cabbage plant/plot at 20 DAT, the highest number of healthy plants/plot (25.00) was recorded in T_1, while the lowest number (21.67) was found in untreated control plot. The highest number of infested plant/plot (3.33) was recorded in untreated control plot, whereas the lowest number i.e. no infested plant was observed in T_1 and T_2. The highest percentage of infestation (15.37%) was attained in untreated control plot, while the lowest percentage of infestation (0.00%) was found in T_1 and T_2 treatment. Cabbage plant infestation percentage reduction over control at 20 DAT the highest value (100%) was found in T_1 and T_2, whereas the lowest value (53.42%) from T_4 treatment. Plant/plot infestation of cabbage at 30 DAT, the highest number of healthy plants/plot (25.00) was recorded in T_1 and, the lowest number of healthy plants/plot (20.67) was found in untreated control plot. The highest number of infested plant/plot (4.33) was recorded in untreated control plot, whereas the lowest number i.e. no infested plant was observed in T_1 treatment which was followed (0.33) by T_2. The highest percentage of infestation (20.95%) was attained in untreated control plot, while the lowest percentage of infestation (0.00%) was found in T_1 treatment. Cabbage plant

infestation percentage reduction over control at 30 DAT and the highest value (100%) was found in T_1, whereas the lowest value (50.94%) was recorded from T_4 treatment. Infestation of cabbage plant/plot at 40 DAT, the highest number of healthy plants/plot (25.00) was recorded in T_1, while the lowest number of healthy plants/plot (19.33) was found in untreated control plot. The highest number of infested plant/plot (5.67) was recorded in untreated control plot, whereas the lowest number i.e. no infested plant was observed in T_1 treatment. The highest percentage of infestation (29.33%) was attained in untreated control plot, while the lowest percentage of infestation (0.00%) was found in T_1 treatment. Cabbage plant infestation percentage reduction over control the highest value (100%) was found in T_1, whereas the lowest value (47.61%) was recorded from T_4 treatment.

During early head formation stage, the highest number of healthy leaves/plants (52.22) was recorded in T_1 treatment, while the lowest number (40.87) was found in untreated control plot. The highest number of infested leaves/plant (8.33) was recorded in untreated control plot, whereas the lowest number (1.15) was observed in T_1. The highest percentage of infestation (20.38%) was attained in untreated control plot, while the lowest percentage of infestation (2.20%) was found in T_1 treatment. Leaves of cabbage head infestation percentage reduction over control at early head formation the highest value (89.20%) was found in T_1, whereas the lowest value (50.81%) from T_4 treatment. Similarly, at mid head formation stage, the highest number of healthy leaves/plants (57.37) was recorded in T_1, while the lowest number (42.49) was found in untreated control plot which was followed (47.93) by and T_4. The highest number of infested leaves/plant (10.15) was recorded in untreated control plot which was followed (5.46, 4.56 and 4.41) by T_4, T_5 and T_6, whereas the lowest number (1.56) was observed in T_1 which was statistically similar (2.06 and 2.67) with T_2 and T_3. The highest percentage of infestation (23.89%) was attained in untreated control plot which was followed (11.39%) by T_4, while the lowest percentage of infestation (2.72%) was found in T_1 treatment which was statistically similar (3.66% and 4.83%) with T_2 and T_3 treatment. Leaves of cabbage head infestation percentage reduction over control at

mid head formation stage was estimated for different commonly used botanicals and the highest value (88.62%) was found in T_1, whereas the lowest value (52.31%) from T_4 treatment. Final at late head formation stage, the highest number of healthy leaves/plants (64.33) was recorded in T_1 treatment, while the lowest number (44.78) was found in untreated control plot. The highest number of infested leaves/plant (12.05) was recorded in untreated control plot, whereas the lowest number (1.87) was observed in T_1 treatment. The highest percentage of infestation (26.91%) was attained in untreated control plot, while the lowest percentage of infestation (2.91%) was found in T_1 treatment. Leaves of cabbage head infestation percentage reduction over control at late head formation stage the highest value (89.20%) was found in T_1, whereas the lowest value (51.14%) from T_4 treatment. Number of healthy heads, infested head and percent infestation of cabbage head per plot the highest number of healthy head per plot (24.33) was recorded in T_1 treatment, while the lowest number (18.67) was found in untreated control plot. The highest number of infested heads/plot (6.33) was recorded in untreated control plot, while the lowest percentage of infestation (0.67%) was found in T_1 treatment. The highest percentage of infestation (33.90%) was attained in untreated control plot, whereas the lowest percentage (2.75%) was recorded from T_1 treatment. Cabbage head infestation percentage reduction over control the highest value (91.88%) was found in T_1, whereas the lowest value (49.25%) from T_4 treatment.

The lowest number of bores/leaves (1.33) of cabbage was recorded in T_1 treatment, while the highest number of bore (25.67) was found in untreated control plot. Number of bores per infested leaf of cabbage head percentage reduction over control the highest value (94.82%) was found in T_1, whereas the lowest value (70.12%) from T_4 treatment. The lowest number of larvae/head (0.33) was recorded in T_1 treatment, while the highest number of larvae/head (6.33) was found in untreated control plot. Number of larvae per infested head of cabbage percentage reduction over control the highest value (94.79%) was found in T_1, whereas the lowest value (31.60%) from T_4 treatment. The longest plant (51.45 cm) was recorded in T_1 treatment, while the shortest plant (43.33 cm) was found in untreated

control plot. The maximum compactness of head (13.28 cm) was recorded in T_1 treatment, while the minimum (10.56 cm) was found in untreated control plot. The maximum diameter of head (11.34 cm) was recorded in T_1 treatment, while the minimum thickness of head (9.34 cm) was found in untreated control plot. The highest gross yield per plant (2.02 kg) was recorded in T_1 treatment, while the lowest gross yield per plant (1.52 kg) was found in untreated control plot. The highest marketable yield per plant (1.77 kg) was recorded in T_1, while the lowest marketable yield per plant (1.16 kg) was found in untreated control plot which was followed (1.45 kg) by T_4 treatment. The highest marketable yield per hectare (65.56 ton) was recorded in T_1, while the lowest marketable yield per hectare (42.96 kg) was found in untreated control plot. The highest net benefit of Tk. 242,240 ha^{-1} was obtained in T_1 treatment and the highest benefit cost ratio (3.52) was estimated for T_1 treatment and the lowest (1.86) for T_4 treatment under the trial.

Conclusion

From the findings of the study, it is revealed that spraying of Neem oil @ 6 ml/L of water at 7 days interval was more effective among the commonly used botanical for reduction of cabbage plant infestation by tobacco caterpillar.

Recommendations

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study needs to be conducted in different agro-ecological zones (AEZ) of Bangladesh for drawing any conclusion;

2. Other component of integrated pest management practices may be included in further study.

REFERENCE

Abdullah, N., Majeed, I. and Oyeyi, T. I. (2011). Studies on efficacy of *Vitellara paradoxa* seed oil on the oviposition, hatchability of eggs and emergence of *Callasobruchus maculates* (F) (Coleoptera: Bruchidae) on treated cowpea. *Seed J. Entom.,* **8**: 391-397.

Ahmed, T. (2004). Study on the biology and management of cabbage caterpillar, *Spodoptera litura*. M. S. thesis, BAU, Mymensingh, Bangladesh.

Alam, M. Z. (1969). Pest of vegetable. In Insect pests of vegetables and their control in East Pakistan. Agril. Infor. Serv., Dept. Agric. Dacca. P 114.

Ali. M. I. and Bakshi, A. I. (1994). Management strategy for the diamondback moth and the tobacco caterpillar on cabbage in Bangladesh. Entomology Division, Bangladesh Agricultural Research. Institute, Gazipur-1701, Bangladesh. *Bangladesh J. Entom.,* **4**: 9-16.

Anonymous. (1989). Textile Outlook International. The Economist Intelligence Unit. 40, Duke Street, London, U.K. p. 3-4.

Atwal, A. S. (1986). Agricultural Pests of India and South-East Asia. Plant Protection Department. Punjab Agricultural University, Ludhiana, India. p. 251.

BARI. (2005). Krishi Projukti Hatboi, Bangladesh Agricultural Research Institute, Joydevpur, Gazipur. p. 304.

BBS. (2012). Monthly Statistical Bulletin, Bangladesh. Statistics Division. Ministry of Planning. Government of the Peoples Republic of Bangladesh. Dhaka. p. 72.

Chari, M. S. Ramprasad, G., Sitaramaiah, S., Muthy, P. S. N. and Singh, R. F. (1999). Laboratory and field evaluation of Neem (*Azadirachta indica A.*), Pongamia (*Pongamia pinnata L.*), Chinaberry (*Melia azedarach L.*) extracts

and commercial neem formulation against tobacco caterpillar; *Spodoptera litura* F. Central Tobacco Research Institute, Fajahmundry, *Azadirachta indica. A Juss*., **23**: 111-129.

Chen, C. N. and Hsiao, W. F. (1984). Influence of food and temperature on life history traits and population parameters of *Spodoptera litura* (Fab.) Plant Protection Bulletin, Taiwan. **26**(3): 219-229.

Chen, C. N. and Su, W. U. (1982). Influence of temperature on development and leaf consumption of three caterpillars on cauliflower. Plant Protection Bulletin, Taiwan. **24**(2): 131-141.

Chu, Y. I. and Yang, O. U. (1989). Biology of the tobacco cutworm [*Spodoptera litura (*Fab.)], The emerging and mating times of adults. *Chinese J. Entom.*, **9**(1): 49-57.

Das, G. P. (1985). Development potential of *Spodoptera litura* (Fab.) (Noctuidae: Lepidoptera) on some common host plants [of Bangladesh]. *Bangladesh J. Zoology.*, 13(1): 43-48.

Dayan, F. E., Cantrell, C. L. and Duke, S. O. (2009). Natural products in crop protection. *Bioorganic & Medicinal Chem.*, **17**: 4022-4034.

De Souza, K. R., Mcveigh, L. J. and Wright, D. J. (1992). Selection of insecticides for lure and kill studies against *Spodoptera littoralis* (Lepidoptera: Noctuidae). *J. Eco. Entom.*, **85**(6): 2101-2106.

Deng, Y., Wang, Y., Li, J. and Yang, L. (2002). A study on the insecticidal activity of acotaniprid on insects. Deprtment of Biology, Buangxi Normal University, Guilin, China. *Southwest China J. Agril. Sci.*, **15**(1): 50-53.

Devaki, K. and Krishnayya, P. V. (2004). Combination effect of three proprietary formulations of B.t. with neem against *Spodoptera litura* (Fab.). *Indian J. Plant Prot.*, **32**(2): 34-36.

Dhandapani, N., Kaareem, A. A. and Jayaraj, S. (1985). Life table studies of *Spodoptera litura* (Fab.) (Noctuidae : Lepidoptera) on banana. *Annals of Entom.*, **3**(2): 45-48.

Edris, K.M., Islam, A.T.M.T., Chowdhury, M.S. and Haque, A.K.M.M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, Govt. People's Republic of Bangladesh. p. 118.

Ei-Tom, H. A. (1987). Integrated pest management for cotton in Bangladesh (Terminal Report). FAO/UNDP Cotton improvement programme. Cotton Research Station, Rangpur, Bangladesh. p. 4.

FAO. (1988). Production Year Book. Food and Agricultural of the United Nations Rome, Italy. **42**: 190-193.

FAO. (1999). Production Year Book. Food and Agriculture Organization of the United Nations. Rome, Italy. p. 212-214.

Fujiie, A. and Miyashita. K. (1973). Further studies on the relative mating ability in males of *Spodoptera litura* F. (Lepidoptera; Noctuidae). *Applied Entom. Zool.*, **8**(3): 131-137.

Ghatak, S. S. Reza, M. W. and Bhattacharjhya, M. (2005). Bio-efficacy of indigenous plant products on tobacco caterpillar, *Spodoptera littoralis* (F.) (Noctuidae: Lepidoptera). Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur 741 252. *India Env. Ecol.*, **23**(S4): 751-753.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for Agricultural Research. Second Edition. A Wiley Interscience Publications Jhon Wiley and Sons, New York, Chichester, Torento, Singapore. p. 680.

Grist, D. H. and Lever, R. J. A. W. (1989). Pests pf Rice. Published by Longmans, Green and Company Limited, London, Great Britain. p. 139-140.

Hassan, A. S., Moussa, M. A. Sayed, E. and Nasr, A. (1960). Behavior of larvae, adults of the cotton leafworm *Prodenia litura* (Fab.) Lepidoptera : Noctuidae. *Bull. Soc. Entom. Egypt*., **44**(1): 337-343.

Hill, D. S. (1983). Agricultural Insect Pests of the Tropics and their Control. 2nd edn. Cambridge University Press, London. p. 746.

Kaul, B. (1987). *Calamun* oil using food acceptance, feeding ratio, weight gain and larval development as parameters in choice tests against *S. litura. Indian J. Entom.*, **52**(2): 151-154.

Kharub, R. S., Singh, H., Rohilla, H. R. and Chopra, N. P. (1993). Population dynamics and biology of *Spodoptera litura* (Fab.) on ground nut *Arachis hypogaea L. Ann. of Biol. Ludhiana*. **9**(2): 257-262.

Kumar, D. A. and Krishnaynya, P. V. (1999). Effect of diflubenzuron in combination with selected insecticides on major lepidopteran pests of groundnut, *Arachis hypogaea L. J. Appl. Zool. Res.*, **10**(1): 1-5.

Kumar, D., Singh, R. and Mahal, M.S. (1992). Biology of *Spodoptera lituta* (Fab.) on sunflower. *J. Insect Sci.*, **5**(1): 33-36.

Kumar, S. N., Jeyabalan, D. and Murugan, K. (1997). Antifeeding and growth inhibiting effect of neem leaf exudates on *Spodoptera litura. Indian J. Entom.*, **59**(2): 151-154.

Lee, H. S. (1986). A study on the ecology of tobacco caterpillar. *Plant Prot. Bull. Taiwan*. **14**(1): 175-182.

Malathi, S., Sriramulu, M. and Babu, T. R. (1999). Evaluation of certain eco-friendly insecticides against lepidopterous pests of cabbage. Department of Entomology, College of Agriculture, Rajendranagar, Hyderabad-500030 (A.P), India. *Indian. J. Entom.*, **61**(2): 127-133.

Murthy, M. S., Jagadeesh, P. S. and Sannaveerappanavar, V. T. (2006). Evaluation of plant extracts for their repellent, antifeedant and ovicidal action against *Spodoptera litura* (Fab.) (Noctuidae : Lepidoptera). Department of Entomology, University of Agricultural Sciences, GKVK, Bangalore 560065. *India. Env. Ecol*., **24**(2): 293-297.

Nakamura, K. (1973). Egg production and rate of hatching in *Spodpotera litura* F. under different temperature and sex ratio. *Japanese J. Appl. Entom. Zool.*, **17**(4): 187-192.

Nasir, E. A. and Ibrahim, M. M. (1966). Contribution to the biology of the cotton leaf worm *Prodenia litura* (F) with reference to larval colouration (Lepidoptera : Noctuidae). *Bull. Soc. Ent. Egypt*., **49**: 159-161.

OEPP/EPPO, (1979). Data sheets on quarantine organisms. No. 42, *Spodoptera litura*. *Bulletin OEPP/EPPO Bull.*, **9**(2): 63-67.

Omino, T., S. Yokoi and Tuii, H. (1973). Experimental studies on the daytime behavior of Noctuid larvae, the cabbage armyworm *Mamestra brassicae*, the tobacco cutworm *Spodoptera litura* and the black cutworm *Agrotis ipsilon. Japanese J. Appl. Entom. Zool.*, **17**(4): 215-220.

Patel, I. S., Rote, N. B., Shah, A. H., Patel, U. G. and Patel, B. K. (1986). Biology of Cotton leafworm *Spodoptera litura* Fab. (Noctuidae : Lepidoptera) on cotton. *Gujarat Agril. Uni. Res. J.*, **11**(2): 67-68.

Patel, I. S., Shah, A. H. and Rote, N. B. (1987). Effect of different food plants on development of leaf eating caterpillar *Spodoptera litura* F. *Gujarat Agril. Uni. Res. J.*, **12**(2): 57-58

Patil, R. S., Bhole, S. D. and Patil, S. B. (1991). Studies on the biology and chemical control of rice cutworm. *J. Maharashtra Agril. Uni.*, **16**(1): 66-68.

Pavela, R. (2007). Possibilities of botanical insecticides exploitation in plant protection. *Pest Tech*., **1**: 47-52.

Quayyum, M. A. and Akanda, M. E. (1988). Productivity and profitability of cabbage inter cropped with vegetables. *Bangladesh Hort*., **16**(2): 40-44.

Ramaprasad, G., Rao, S. N. and Joshi, B. G. (1993). Relative efficacy of synthetic pyrethroids and some other insecticides against *Spodoptera litura* on Tobacco. *Indian J. Plant Prot.*, **21**(2): 201-204.

Ramphall, A. and Gill, H. S. (1990). Demand and supply of vegetables and pulses in South Asia. In: Vegetable Research and Development in South Asia. S. Shanmugasundaram (ed.). Proc. Workshop held at Islamabad, Pakistan on 24-29 September, 1990. AVRDC Publication NO. 90 331, AVRDC, Tainan, Taiwan.

Rao, G. R. and Dhingra, S. (1996). Relative susceptibility of different larval instars of *Spodoptera litura* (Fab.) to some synthetic pyrethroids. *J. Entom. Res.*, **20**: 103-108.

Rao, G. R., Raghavaiah, G. and Nagalingam, B. (1993). Effect of botanicals on certain behavioral responses and on the growth inhibition of *Spodoptera litura* F. *Bot. Pesticides in Integ. Pest Manag.*, **13**: 175-182.

Rashid, M. M. (1993). Sabjibigyan. First edition. Bangla Academy, Dhaka. pp. 189-196.

Sanjrani, M. W. S., Munshi, G, H. and Abro, G. H. (1989). Effect of temperature on the biology of *Spodoptera litura* (Fab.) *Philippine Entom.*, **7**(6): 573-578.

Sarker, M. Y., Azad, A. K., Hasan, M. K., Nasreen, A., Naher, Q. and Baset, M. A. (2002). Effect of plant spacing and source of nutrients on the growth and yield of cabbage. *Pakistan J. Biol. Sci*., **5**(6): 636-639.

Sharma, B.L., Kulkarni G.G., Ashok, K. and Kumar, A. (1999). Effect of host plants and neem oil on food utilization indices of *Spodoptera litura* (Fab.). *J. Agril Biol. Res*., **4**(1): 37-40.

Singh, D. S. and Singh, J. P. (1998). Relative susceptibility and development of resistance in *Spodoptera litura* larvae against some pyrithroid and non-pyrithroid insecticides. *Indian J. Entom.*, **60**(2): 177-180.

Soni, V. K., Dixit, A. and Dubey, V. K. (2001). Host-biology relation of *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae).Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattishgarh), India. *Insect Env*., **7**(3): 111-112.

Sreekanth, M., Babu, T. R., Sultan, M. A. and Rao, B. N (2000). Evaluation of certain new insecticides against lepidopteran pests of cabbage. Department of Entomology, College of Agriculture, Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad-500 030, India. *Intl. Pest Control*. **42**(4): 134-137.

Subramanian, K., Raja, N. and Ignacimuthu, S. (2005). Biology of *Spodoptera litura* on different cotton cultivars. Entomology Research Institute, Loyola College, Chennai 600034. *India. Entom*., **30**(4): 355-357.

Surekh, G., Fukazawa, N., and Kumar, A. (2000). Tobacco caterpillar, *Spodoptera litura* (Fab.) in the laboratory for several generations using different weed and cultivated plant leaves as food. *Indian J. Entom.*, **63**(2): 177-180.

Talekar, N. S. and Selleck, G. W. (1982). Fareward. In: N. S. Talekar and T. D. Griggs, (eds.). Cabbage. AVRDC, Shanhua, Taiwan, China.

Tanongkankit, Y., Chiewchan, N. and Devahastin, S. (2011). Evolution of anticarcinogenic substance in dietary fibre powder from cabbage outer leaves during drying. *J. Food Che*., **127**: 67-73.

Thompson, H. C. and Kelly, W. C. (1988). Cole Crops. In: Vegetable Crops McGraw Hill Book Co. New York. p. 15, 280-281, 370.

Tofael, C. (2004). Tobacco caterpillar in vegetable crops. Entomology Research Institute, Loyola College, Chennai 600. p. 63.

Torreno, N. S. (1985). The biology of cotton cutworm *Spodoptera litura* (F.) on flue-cured tobacco. *Philippines Tobacco Abstracts*. P. 56-57.

UNDP. (1988). Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2: Agro-ecological Regions of Bangladesh, FAO, Rome. pp. 212, 577.

Urs, K. C. D. and Subramanya, B. V. (1974). A simplified semisynthetic diet for rearing *Spodoptera litura* (Fabricius) in the laboratory. *Current Res*., **3**(4): 40-41.

Yushima, T., Hoguchi, H., Tamaki, Y., Fukazawa, N. and Sugino, T. (1973). Mating and sex pheromone of *Spodoptera litura* (F.) (Lepidoptera : Noctuidae) an introductory report. *Appl. Entomol. Zool*., **8**(1): 14-26.

Zheng, L., Abro, G. H. and Selleck, G. W. (2005). The population dynamics of *Spodoptera litura*. *India. Entom*., **30**(4): 355-357.

APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2013 to February 2014

Month	*Air temperature (°c)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2013	25.8	16.0	78	00	6.8
December, 2013	22.4	13.5	74	00	6.3
January, 2014	24.5	12.4	68	00	5.7
February, 2014	27.1	16.7	67	30	6.7

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix II. Soil characteristics of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture farm field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka