EFFECTIVENESS OF SOME INSECTICIDES FOR THE CONTROL OF MUSTARD APHID *Lipaphis erysimi* kalt. AND THEIR EFFECTS ON PREDATOR *Coccinella septempunctata* L.

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CERTIFICATE

This is to certify that the thesis entitled, "**EFFECTIVENESS OF SOME INSECTICIDES FOR THE CONTROL OF MUSTARD APHID** ***Lipaphis erysimi*** **kalt. AND THEIR EFFECTS ON PREDATOR** ***Coccinella septempunctata*** **L.**" 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 **Mohammad Mahbub Hasan Sikder, Roll No. 00234, Registration No. 23861/00234** under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

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

(Professor. Dr. Md. Serajul Islam Bhuiyan)
Supervisor

Dated: 18.02.07
Dhaka, Bangladesh

Dedicated to

My

Beloved Parents & Brothers

LIST OF ABBRIVIATIONS

%	=	Percent
^0C	=	Degree Centigrade
a.i.	=	Active ingredient
ACI	=	Agro-Chemical Industries
AEZ	=	Agro-Ecological Zone
BADC	=	Bangladesh Agricultural Development Corporation
BARC	=	Bangladesh Agricultural Research Council
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
CBR	=	Cost Benefit Ratio
CEC	=	Cation Exchange Capacity
cm	=	Centimeter
CRD	=	Completely Randomized Design
CV%	=	Percentage of Coefficient of Variance
cv.	=	Cultivar(s)
DAT	=	Days After Treatment
DMRT	=	Duncan's Multiple Range Test
EC	=	Emulsifiable concentrate
FAO	=	Food and Agriculture Organization
gm	=	gram(s)
hr	=	hour
Kg	=	Kilogram
LC_{50}	=	Lethal Concentration
Lit	=	Liter
MAII	=	Multiplication Aphid Infestation Index
ml	=	milliliter
MP	=	Muriate of Potash
N	=	Nitrogen
No.	=	Number
P	=	Phosphorus

K	=	Potassium
NS	=	Not Significant
ppm	=	parts per million
RARS	=	Rajshahi Agricultural Regional Station
RCBD	=	Randomized Complete Block Design
RH	=	Relative Humidity
SAU	=	Sher-e-Bangla Agricultural University
S	=	Sulpher
TSP	=	Triple Super Phosphate
UNDP	=	United Nations Development Programme
WSC	=	Water Soluble Concentrate
wt.	=	Weight

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The Author

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by

MOHAMMAD MAHBUB HASAN SIKDER

ABSTRACT

Studies were made in the field and laboratory condition to investigate the effects of insecticides viz., Diazinon, Fenitrothion, Cypermethrin and Chlorpyrifos against mustard aphid *Lipaphis erysimi* (Kalt) and their toxicity to the predator *Coccinella septempunctata* L. during the period from November 2004 to February 2005 at the Sher-e-Bangla Agricultural University farm, Dhaka. The experiment was laid out in a randomized block design and replicated five times. Insecticides were sprayed @ 0.05% on 27 December 2004 and on 12 January 2005. Records on control of mustard aphid and toxic effect to the predator under the different treatments were made at 1,4 and 7 days after first and second spraying of insecticides. Data on seed yield and yield parameters were taken at maturity. The percent reduction of aphid infested plant, percent reduction of aphid population and percent reduction of the predator varied significantly. Most of the crop characters and seed yield were significantly different due to usage of insecticides. Larva of *C. septempunctata* consumed on an average 224.60 aphids during its 10 days of larval period and adult beetle consumed on an average of 885.40 aphids during 30 days period after emergence. The mortality of aphid, larvae and adult of the predator were significantly different. Mortality of the aphid reached highest after 24 hours of spraying. Cypermethrin was the most effective insecticide causing the highest mortality of mustard aphid and less toxic to the predator. Cypermethrin showed higher effectiveness than other three insecticides in increasing growth parameters and seed yield of mustard. Considering benefit cost ratio (BCR), Cypermethrin was found most economic and effective insecticide in controlling *L. erysimi*. The overall effectiveness of Cypermethrin on mustard aphid and predator were found to be the best.

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Chapter 1
Introduction

CHAPTER 1
INTRODUCTION

Mustard (*Brassica* sp.) is one of the major oil seed crops in Bangladesh which is widely cultivated during the winter season and its performance in total seed production is approximately 70%. The crop is well adapted to almost all agro-climatic zones of the country. Production of mustard is very low in Bangladesh in comparison to other countries. About 279235 hectares of land were used for mustard cultivation which produced 520108 tones of mustard but the average mustard production was only 753 kg ha^{-1} (BBS, 2005). The incidence of aphid pest is one of the most important factors for lower yield of this oil seed crop.

The mustard aphid, *Lipaphis erysimi* (Kalt.) (Aphididae : Homoptera) is the most damaging pest of mustard in Bangladesh (Alam *et al.*,1964a; Ahmed *et al.*, 1977; Ahmed and Mannan, 1977; Haque and Miah 1979; and Das and Islam, 1986). It is also a pest of many cruciferous vegetables (Kim *et al.*, 1986; and Lee, 1988). The pest is distributed in Bangladesh, India, Pakistan, U.S.A and many other countries of the world and is recognized as a serious pest of mustard (Arora *et al.*, 1969; Srivastava and Srivatawz, 1970; Jarvis, 1970; Mukhopadhayay and Ghosh, 1979; and Hamid and Ahmed, 1980).

The mustard aphid occurs in the field during December to February. Both the adults and nymphs of mustard aphid. *L. erysimi* causes damage to mustard plant from seedling to maturity (Verma and Singh, 1987) but maximum damage is caused at flowering stage (Brar and Sandu, 1974). They suck sap from leaves, flowers, flower-buds, pods and twigs of the plants and secrete sticky honeydew which acts as a medium for sooty mold fungus. As a result, the photosynthetic efficiency of the plant is reduced. The aphid infestation also cause stunted growth of plant. Severely attacked plants often fail to bear pods or end up with very poor pod settings (Das and Islam, 1986).

In Bangladesh, very little report is available on the estimation of damages caused by this pest. But it is reported from India that the yield losses to rapeseed/ mustard due to the attack of *L. erysimi* alone varied from 35.4 to 96% depending upon the season (Sidhu and Singh, 1964; Saini and Chabra, 1966; Chanal and

Sukhija, 1969; Pradhan, 1970; Singhvi *et al.*, 1973; Phadke, 1980; and Bakhetia, 1983).

The predacious coccinellid beetles, commonly known as lady bird beetles are considered to be of great economic importance in the agro ecosystem. They have been successfully employed in the bio-control of many injurious insects (Nasiruddin and Islam, 1979; and Aggarwal *et al.*, 1988). In the field mustard aphid is naturally controlled to a large extent by its predator *Coccinella septempunctata* and plays a vital role in lowering the population of mustard aphid (Kalra, 1988).

The control of aphids in Bangladesh is principally carried out by the conventional use of insecticides. Many workers have tried to control this pest with varying degrees of success by frequent application of insecticides as foliar treatments (Chowdhury and Roy, 1975). It is difficult to emphasize the effectiveness of particular synthetic insecticides out of many commercially available ones against a certain insect pest. These chemicals should be applied at appropriate dose and at right time against the target pests. For controlling the mustard aphid successfully and to save *C. septempunctata*, judicious application of insecticides is essential. With these views in mind, the effectiveness of different insecticides in controlling mustard aphid and their toxic effect on the predator *C. septempunctata* was selected for this study. In this study, an effort will be taken to find out the most effective insecticide in controlling mustard aphid. To fulfill the overall aims, the experiment was undertaken with the following specific objectives:

(i) To determine the effect of insecticides on mustard aphid and the predator *C. septempunctata.*

(ii) To study the effect of insecticides on seed yield.

(iii) To evaluate the economic use of insecticides in controlling mustard aphid.

(iv) To investigate the predation efficiency of the predator in controlling mustard aphid.

Chapter 2
Review of literature

CHAPTER 2
REVIEW OF LITERATURE

Mustard aphid is one of the major problems in the production of mustard. Mustard crop suffers heavy losses every year due to the attack of mustard aphid, *Coccinella septempunctata* was found to be an important predator of aphids but very few research works have so far been done on predation efficiency and toxicity of insecticides to this predator in Bangladesh. Reports on the effect of insecticides in controlling mustard aphid and their toxicity to the predator *C. septempunctata* and yield of mustard pertinent to this study are reviewed here.

2.1 General review of Mustard aphid, *L. erysimi* Kalt.

2.1.1 Systematic position

Order	: Homoptera
Family	: Aphididae
Genus	: *Lipaphis*
Species	: *L. erysimi*

2.1.2 Nomenclature of mustard aphid *L. erysimi* Kalt.

The mustard aphid *L. erysimi* (Kaltenbach) was originally described by Kaltenbach as *Aphis erysimi* in 1843. In 1928, Mordvilko erected a new genus, *Lipaphis* taking *Aphis erysimi* Kaltenbach as its type species. Prior to this, Davis (1914) described a new species, *Aphis pseudobrassicae* which was considered by Dobrovliansky (1916) to be a synonym of *Aphis erysimi* Kaltenbach. The correct zoological name of *L. erysimi* was confirmed by David in 1975 as reported by Bakhetia and Sohi (1980).

2.13 Status and distribution

Prasad and Pradhan (1971) studied the distribution and sampling of mustard aphid, *Lipaphis pseudobrassicae* (Davis) under cultivation of rape and mustard in 3.3 million hectares in India. Amongst the various pests causing damage to mustard, *L. pseudobrassicae* was the most serious on infesting leaves, stems, pods and thus reducing the yield and quality of the produce to a considerable extent.

Atwal (1976) reported that the mustard aphid found worldwide in distribution but occurred principally in the South East Asia as a serious pest of cruciferous oilseeds. The mustard aphid, *L. erysimi* is a serious pest of mustard in Bangladesh. Bakhetia (1986) and Khurana (1986) reported *L. erysimi* as major pest of rapeseeds and mustard.

Mahal *et al.* (1988) conducted a field experiment in Punjab (India) between 1979 and 1986 and revealed that the aphid, *L. erysimi* had an aggregated distribution on *Brassica juncea* (Indian mustard), which varied with pest density. The density also affected the number of samples required for population estimation. Similar report was made by Ramkishore and Phadke (1988a).

Mahal *et al.* (1990) reported that the population size of *Lipaphis erysimi* (44.5%) in the field was greater than that of *Myzus persicae (26.0%)* 1985-86 and 1986-87.It was 52.8% and 43.9% for *L. erysimi* and *M. persicae,* respectively. In net-house multiplication the population of *L. erysimi* was 3.3 times more than that of *M. persicae* when aphids of both species were placed on the plants in 1:1 ratio.

2.1.4 Biology of Aphid

Sharma and Khatri (1979) studied the biology of mustard aphid, *L. erysimi* (Kalt.) on mustard and observed that the mean number of progeny/female during the winter crop season was 96.87±27.94 and the rate of population increase was 2.95 in 15 days.

Phadke (1982) studied the life table and growth rate of mustard aphid, *L. erysimi* on different varieties of *Brassica* spp. and reported that highest net reproductive rate of 119.38 was found in T_9 and the lowest one of (86.12) was found in Pusabold.

Amjad and Peters (1992) studied the fecundity, survival rate and days to maturity of *L. erysimi* and found fewer days to mature in *Brassica campestris* var. Toria A (7.9 days) than *in B. carinata* and *B. juncea.* Fecundity was significantly higher in *B. campestris* and lower in *B. juncea*. The intrinsic rate of population increase was significantly higher in *B. campestris* than other host plants, while it was the lowest in *B. carinata*. The survival of nymphs was significantly higher in *B. campestris* (95%) and the lower in *B. juncea* (57%).

Mondal *et al.* (1992) studied the biology of *L. eryisimi* (Kalt.) in the laboratory on young leaf of different host plants. They reported that the mean nymphal period were 10.67±0.38, 10.92±0.8, 9.67±.32 and 9.50±2.05 days on *B. chinensis* (China cabbage), *B. juncea* (mustard plant), *Raphanus sativus* (radish) and *Solanum melongena* (brinjal), respectively.

Shahjahan (1994) studied the adult longevity of mustard aphid, *Lipaphis erysimi* on 10 different varieties of mustard. He found that the adult longevity on different varieties varies from 8.7-10.7 days. The duration of adult longevity was the highest (10.7 days) on Nap-3 and the lowest (8.7 days) on Tori-7.

Vekaria and Patel (1998) reported the total number of generations completed by the mustard aphid, *Lipaphis erysimi* (Kalt.) between January and March. The aphid completed 11 overlapping generations at 21.9°C and 52% RH during the first season, and 8 generations at 23.7°C and 57% RH during the second season. The average duration of each generation was 6.04 days during 1996 and 7.15 days during 1997.

Vekaria and Patel (1999) conducted field studies during the *rabi* season of 1995-96 in Gujarat, India, to determine the biology of *Lipaphis erysimi* on three Indian mustard cultivars (GM-1, Varuna and PM-67). The nymphal period was shortest (5.88±0.67 days) on PM-67 and longest (6.58±0.65 days) on GM-1. Adult longevity and total life span were shortest on GM-1 (8.71±0.69 and 15.29±0.69 days, respectively) and longest on PM-67 (10.36±0.99 and 16.24±1.09 days, respectively). Fecundity was lowest on GM-l, intermediate on Varuna and highest on MP-67.

2.1.5 Ecology of Mustard Aphid

Bakhetia and Sidhu (1983) observed the response of temperature and rainfall on the population build up of *Lipaphis erysimi* on mustard (Rai). They found that the fecundity, life span and reproduction of the aphid were adversely affected by rainfall. Mustard aphid *L. erysimi* develop and reproduced most rapidly at temperature between 20 and 30°C.

Bishnol *et al.* (1992) observed that the effect of temperature, relative humidity and cloudiness on infestation of mustard aphid. They observed that a temperature of 10-13°C and relative humidity of 72-85% in the region could be used to predict the rapid multiplication of aphids in rapeseed, *Brassica napus* L. and Indian mustard, *Brassica juncea* L. A sharp rise in air temperature by 6-10°C, the population build-up of aphids further intensified on these crops. The temperature of 10-13°C and relative humidity of 72-85% proved to be optimum.

Samdur *et al.* (1997) observed the effect of environmental factors on mustard aphid. The mean aphid infestation index (MAII) was found significantly and negatively correlated with maximum temperature, evaporation, sunshine and wind velocity and was significantly and positively correlated with maximum RH for *B. juncea* sown in first and third weeks of November.

Nasir *et al.* (1998) studied on the population dynamics of mustard aphid (*L. erysimi)* in relation to abiotic factors. Adults appeared on the crop in the last week of February, the population peaked in the third week of March and disappeared by the third week of April. Aphid population was positively correlated with the average daily temperature, but negatively correlated with relative humidity and rainfall.

Sinha *et al.* (1998) observed the duration of the different stages in life cycle of *Lipaphis erysimi* under ambient temperature and humidity conditions from December to March (18.7±7.9°C and 62.4±11.0% RH). The nymphal periods showed a positive correlation with ambient temperature during December to April while reproductive, post reproductive periods and longevity were negatively correlated with ambient temperature. The fecundity of the aphid was positively correlated with ambient relative humidity and negatively correlated with temperature. The fecundity of offspring from apterous aphids (40.0/female) was greater than in those from alatae aphids (32.6/female). The longest duration of total life span (39.0 days for apterae and 43.7 days for alatae) occurred in January-February and the shortest (24.0 days for apterae and 29.7 days for alatae) in March to April.

Biswas and Das (2000) in relation to weather parameters. They observed that the aphid population build up was noticed during January reaching the peak on the 8th February in both 1997 (98.26 per plant) and 1998 (76.22 aphids per plant). The ambient sunshine (5.76-8.60 hr) and the maximum temperature (23.66 to 25.37°C) during January-February appeared to be the conducive factors for aphid multiplication. Relative humidity (RH) ranging from 62.00 to 74.28% during January-February was congenial for aphid population build up, while the activity of aphids ceased at 52.43% RH and below.

2.1.6 Natural enemies

The mustard aphid like most other aphid is preyed upon by the larvae of syrphids and coccinellids. Six coccinellids, 16 syrphids, one species each of chamaeyiids, chrysopids, hemerobiids as insect predators, four species of hymenopterous parasites, four species of entomogenous four and one predatory bird are known as natural enemies of *L. erysimi* (Bakhetia and Sekhon, 1984).

2.1.7. Nature of damage by the aphid

The aphid, *L. erysimi* directly affects the whole part of the mustard plants except root. Aphids mostly attack the soft portions like apical twig, inflorescence and pods. The aphid infestation caused unhealthy growth of the plant. The poor and stunted growth together with curling of the leaves, drying up of the inflorescence, discoloration of plant leaves and flowers, ultimately caused the plants to lodge in the field. The pods and seeds become unhealthy and unproductive (Kabir and Khan, 1980).

Like other soft bodied insects such as leaf hoppers, mealy bugs and scales insects, aphids produce honeydew. The honeydew serves as a medium on which a shooty fungus called sooty mold grows. Aphids serve as a vector for many plant diseases that cause greater losses than caused by direct feeding injury. This is often the greatest impact of an aphid infestation (Blackman and Eastop, 1984).

2.1.8 Aphid Population

Kher and Rataul (1992a) tested nineteen strains of rape under field condition in Punjab, India for their resistance to *L. erysimi during* 1987-89. They reported that all strains of *B. napus* except Regent and Gullivar were found relatively resistant. Strains of *B. campestris* had a very high aphid population and were considered highly susceptible and strains of *B. juncea* was moderately resistant.

Kher and Rataul (1992b) carried out a field trial in Ludhiana, India and assessed the resistance of 7 strains of *B. campestris,* strains of *B. juncea* (Indian mustard) and 5 strains of *B. napus* (rape) to *L. erysimi.* They stated that the population levels of 10 and 15 aphids/plant proved optimal for resistance, screening at the cotyledonary and 2-leaf stages, respectively.

Awasthi (1993) investigated the incidence of aphid in a mustard growing region of Balsamand, Rajasthan, India, in January. The aphid population decreased after the end of January and was lowest in the last week of February.

Begum (1994-95) conducted an experiment at ARS, Rajbari, Dinajpur during *rabi* season 1994-95 to find out the population activities of mustard aphid. She observed that aphid population increases gradually as sowing delayed. It was evident that the mustard yield decreased as the aphid population increased and the percent of pod infestation had positive correlation to aphid population.

Singh and Lal (1999) studied mustard aphid, *Lipaphis erysimi,* infestation on *Brassica juncea* (Indian mustard) crops during two successive crop seasons (25th December 1989 to 6th March 1990, and 1st January to 13th March 1990), in India. They found that *L. erysimi* occurred from the last week of December to the first week of March in 1990 and the first week of January to the second week of March in 1990. The peak infestation of *L. erysimi* (414.15 per 10 cm terminal shoot per plant) was recorded on 13th February in the first year, while the maximum infestation (471.10 per 10 cm terminal shoot per plant) was recorded on 6th February.

Sonkar and Desai (1999) reported that delay in sowing caused increase in the aphid population and ultimately resulted in a reduction of yield. The peak incidence of the occurred between the first fortnight of January and the second fortnight to February.

Biswas and Das (2000) observed the population dynamics of the mustard aphid *L. erysimi* at the Oilseed Research Center, Bangladesh Agricultural Research Institute, Joydebpur, during 1997 and 1998 crop season. They reported that the aphid population build-up was noticed January-February, reaching its peak on the 8th February in both 1997 (98.26 aphids per plant) and 1998 (76.22 aphids per plant). Among the fifteen genotypes, Nap-8901 suffered the highest aphid infestation (45.87 aphids per plant) while the lowest aphid infestation (21.18 aphids per plant) was recorded from BC-1592, January-February was found to be congenial for aphid population build-up.

2.1.9. Yield Loss due to Mustard Aphid Infestation

Rohilla *et al.* (1987) conducted a four year investigation with six *Brassica* genotypes for their resistance to *L. erysimi* (Kalt). The investigators used the yield loss as the criteria of resistance and reported decreasing order of resistance *Eruca sativa* T-27 (16.44% yield loss); *B. juncea* parkesh (23.64%); RH30 (27.31%); *B. campestris* brown sarson BSH1 (32.73%), yellow sarson YSPb-24 (34.18%) and *B. napus* HNS (61.32%). Sekhon and Ahman (1992) expressed that *L. erysimi* (Kalt) is most devastating insect pest in India, where it can cause losses of up to 50% seed yield.

Begum (1993-94) conducted a research experiment with three varieties of mustard in Joydebpur in the year 1993-94 to assess the loss due to aphid infestation. It was found that second highest losses occur in the flowering and poding stages and the lowest losses occur in the pod formation and ripening stage.

Kabir and Rouf (1993-94) conducted an experiment at RARS (Rajshahi Agricultural Research Station) are during *rabi* season of 1993 with four mustard varieties to determine the most vulnerable growth stage of mustard to the attack of aphids. The results revealed that a loss of Tk. 10,260.00 to 21,420.00 per hectare could be incurred if no control measures were under taken against aphids.

Field studies were conducted by Mandal *et al.* (1994) in Orissa, India during the *rabi* season of 1991-93 to screen out 25 varieties of rapeseed and mustard for resistance to aphids. They concluded that yield in both years varied from 28.2 to 83.3%.

Rouf and Kabir (1994-95) conducted an experiment at RARS, Jessore during 1994-95 with four mustard varieties for investigation of the most vulnerable growth stage of mustard to the attack of aphids. They reported that the maximum loss of Tk. 11,322.60 to 15,460.20 per hectare be incurred if no control measures were undertaken against aphids.

Srivastava *et al.* (1996), performed field trials in Himachal Pradesh, India during 1991-94 to assessed the yield loss of mustard due to infestation of *Myzus persicae* and *L. erysimi.* They observed that the yellow sarson cultivar (YST-841) showed the maximum yield loss (46.12%) and brown sarson BSH-1 showed (43.58%). *B. juncea* (Varuna) and *B. napus* (HPN-1) showed lower susceptibility with yield losses ranging from 30.90 to 36.01% and *B. carinata* (HPC-1) was the least susceptible cultivar with 22.84% yield loss.

Aggarwal *et al.* (1996) carried out a field experiment under agro climatic conditions of Haryana, India to find out the effect of infestation by *L. erysimi* on yield contributing traits of 20 rape/mustard genotypes . They investigated, on the basis of lesser influence of aphid infestation on yield contributing traits such as plant height, primary branches main shoot length, pods on main shoot, pods length, seeds/pods and 1000-seed weight, the four genotypes HC-2 *(B. carinata)*, T-6342 *(B. juncea)*, TMN-52 8 *(Eruca sativa)* and *B. tournefortii* appeared promising.

2.2 General review of the predator *C. septempunctata* L.

The coccinellid predators are oval, convex and brightly colored insects. They have active habits and have great abundance. The adult predator is hemispherical in shape and the commonest species are brown usually with black spot. The larvae of the predators are carrot shaped flattened gradually with tapering bodies, distinct body regions legs and warty spiny backs.

2.2.1. Systematic position of the predator *C. septempunctata* Linn.

Order	: Coleoptera
Family	: Coccinellidae
Genus	: *Coccinella*
Species	: C. *septempunctata*

2.2.2 Nomenclature of the predator *C. septempunctata*

Lefroy (1909) referred the predator as *C. septempunctata* Lineaeus and considered it to be a very active and voracious feeder of wheat and mustard aphid. Fletcher (1914) stated that this predator occurred chiefly on wheat, mustard, some times on paddy and other crops all the year round throughout Southern India and its life history was very similar to other species of *Coccinella*. Alam *et al.* (1964b) listed the predator as *Coccinella 7- punctata* L. occurring on *Lipaphis pseudobrassicae*.

2.2.3. Biology of the predator

The biology of *C. septempunctata* was studied by Singh and Singh (1993) in laboratory condition and reported that the predator laid eggs in small batches on the leaf surface. The incubation period was 3 days at 28±2°C temperature incubation rate was 87.08%. Pre-oviposition. oviposition and post-oviposition periods were completed in 6.66, 13.33 and 4.75 days. Females laid 634.75 eggs ranging from 198 to 1075 eggs during the life span. In 9.05 days larvae completed 4 instars. The average pupal period was 6.3 days. Males survived for 21.60 days on average and females for 26.74 days. The sex ratio (females: males) was 1.4: 1 in natural populations.

The biology of *C. septempunctata* was studied by Kia *et al.* (1999) on cotton aphid under laboratory condition and observed that *C. septempunctata* developed most rapidly at 35°C with a pre-marginal period of 10.8 days. Survival from egg to adult was the highest at 25°C (47%). Ovipositor was greatest at 25°C, with a life time ovipositor of 287.4 eggs/female and a mean ovipositor rate during the reproductive period of 22.4 eggs/female per day. Threshold temperatures for development of the reproductive stages ranged from 10.9 to 13.9°C, with 12.6%C for the entire life span. The thermal constant was 42.0, 103.7, 63.6 and 302.9 DD for eggs, larvae, pupae and adults, respectively.

In another report on the biology of *C. septempunctata* in the laboratory at constant temperature ranging from 20 to 23°C on cereal aphid by Rana and Kakkor (2000) and reported that incubation period was 4.2 days with a range of 3.5 to 4.5 days. The average hatchability was 81.89 percent with a range of 70 to 90 percent. The predator passed through four larval instar stages and completing the average duration in 2.27, 1.81, 2.25 and 3.06 days. The total larval period was 9.39 with a range of 8.2-10.5 days. The pupal period lasted for 4.7 days with a range 4.0 to 4.9 days. Male longevity was 36.91 days with a range of 33 to 37 days, the female survived for 39.9 days with a range of 33 to 47 days. The beetles started mating 4 to 11 days after emergence with an average pre-mating period of 6.4 days. The mating duration was 54 minutes with a range of 41 to 62 minutes. The average pre-oviposition, ovipositon and post oviposition periods were 8.3, 22.4 and 9.2 days, respectively. Average fecundity was 476.4 eggs/female and their sex ratio was (male: female) 1: 16.

2.3 Effect of insecticides on aphid

Tripathi *et al.* (1985) worked on an experiment to evaluate the relative toxicity of 10 insecticides against the aphid *L. erysimi* on *Brassica campestris* var. toria and reported that the order of toxicity of the different insecticides was Decamethrin, Cypermethrin, Phosphamidon Methyl-o-demeton, Dimethoate, Monocrotophos, Quinalphos, Carbaryl, Endosulfan and Sevisuif.

The relative efficacy of eight insecticides namely Fenvalerate (0.03%). Pormothrin (0.03%), Decis (0.03%), Phosalone (0.05%), Chlorpyrifos (0.02%), Cypermethrin (0.03%), Endosulfan and Metasystox (0.025%) were tested in the field and laboratory against *L. erysimi*. Among the insecticides, Chlorpyrifos (0.02%) was the most toxic to aphid (Kumar *et al.*, 1986).

Tripathi *et al.* (1988a) studied the effectiveness of several pyrethroids and organophosphate insecticides to *L. erysimi* in the laboratory. On the basis of LC_{50}, it was concluded that the order of effectiveness of the compounds were Decamethrin (Deltamethrin) > Cypermethrin > Methyl-o-demoton > Fenvalerate > Permethrin > Dimethoate > Phosphamidon > Quinal-phos.

In a trial on mustard in India, 8 insecticides viz., Decamethrin (0.001%), Oxydemeton methyl and Monocrotophos (0.03%), Permethrin, Chlorpyrifos 0.03% Cypermethrin (0.05%), Phosphamidon (0.03%), Endosulfan (0.035%) were applied in sprays to the drip point against *L. erysimi* all caused 90 to 100% mortality on the first day (Nagia *et al.*, 1989).

The effectiveness of 13 insecticides (5 systemics 5 contact insecticides and 3 pyrethroids) in controlling *L. erysimi* was studied on late sown mustard during the *rabi* seasons in India by Khurana and Batra (1989). Oxydemeton-methyl, Monocrotophos, Cypermethrin and Fenvalerate were the most effective of the tested insecticides. Considering effectiveness, crop yield and economics of the different treatments Fenvalerate, Monocrotophos, Phosphamidon, Dimethoate, Oxydemeton-methyl and Cypermethrin were recommended.

A field experiment was conducted in 1987-88 in Bangladesh to determine the effectiveness of insecticides against *L. erysimi*. On the basis of number of aphids per 5 plants at various intervals after spraying and considering the yields. It was reported that the most effective compounds were Ripcord (Cypermethrin) 1 ml/lit, Zolone (Phosalone) 2 ml/lit and Malathion 2 ml/lit of H_2O (Ahmad and Miah, 1989).

Carbosulfan 57.14 ml a.i/100 lit, Dimethoate 60 ml/100 lit, Dichlorvos ml/100 lit and Dinobuton 75 ml/100 lit water were tested in the field on rape in Pakistan in 1986-87 against *L. erysimi*. Carbosulfan and Dimethoate were significantly toxic than other chemicals (Zaman, 1990a)

A field experiment was conducted on mustard for the control of *L. erysimi* with eight insecticides viz. Carbosulfan (Marshal 20 EC). Malathion (Henpthion 57 EC), Malathion (Maladan 57 EC), Dimethoate (Polygor 40 EC), Oxydemeton methyl (Metasystox 25 EC) at the dose of 2 ml/litre water and Phosphamidon (Benicron 100

WSC), Phosphamidon (Pillacron 100 EC), and Fenvalerate (Sumicidin 20 EC) at the dose of 1 ml/ lit water were applied as foliar spray. It was found that all the insecticides were very toxic against the aphid and reduced 100% aphid population after 120 hours of spray and suggested that Malathion will be very effective in controlling mustard aphid in addition to Carbosulfan (Islam *et al.*, 1990).

In a field trial Zaman (1990b) studied the effectiveness of some insecticides against *L. erysimi* and reported that Dimethoate (80 ml a.i / 100 lit water). Formothion (49.5 ml a.i/100 lit water) and Pirimicarb (75 gm a.i/100 lit water) were highly toxic and significantly reduced aphid population/or more than 3 weeks.

The relative toxicity of 11 insecticides to apterous adult of *L. erysimi* was studied in the laboratory in India. On the basis of LC_{50}, Oxydemeton-methyl, Chlorpyrifos, Dimethoate, Parathion methyl, and Pyrethrum (0.05%) were 25.61, 11.92, 7.56, 3.79 and 1-37 times toxic as Lindane and the other 5 compounds were less toxic than Lindane (0.58 to 0.98 times) (Dhingra. 1991).

In field experiment with different doses of Chlorpyrifos and Quinalphos EC and Dusts (0.03%, 0.05% and 25 kg/ha) were compared to Oxydemeton-methyl 25 EC (0.025%) to evaluate their effects on *L. erysimi* percent reduction of aphid over control was recorded 1, 3. 5, 10 *and* 15 days after first spraying and was continued on he same day's after second spraying. It was showed that Chlorpyrifos EC-was more effective than Quinalphos EC in giving maximum reduction of aphids, although Oxydemeton-methyl was the most effective which reduced 90.48, 92.71, 88.70. 89.60 and 89.34% aphid population of the corresponding days after first spray and 96.73, 97.67, 95.41, 83.22 and 64.56% after second spray. Dust application of both the tested insecticides were less effective than their foliar spray. The bio-efficacy of insecticides against mustard aphid under field conditions was as follows Oxydemeton-methyl 0.05>Chlorpyrifos 0.05>Quinalphos0.05 > Chlorpyrifos 0.03>Quinalophos 0.03>Quinalphos 1.5>Chlorpyriphos 1.5D. (Thomas and Phadke,l992).

A field experiment was carried out by Upadhyay and Aggrawal (1993a) to investigate the effects of Monocrotophos, Phosphamidon, Methyl-Dimethoate, Endosulfan, Chlorpyrifos, Malathion, Cypermethrin and Fenvalerate on *L. erysimi* in

Madhya Pradesh, India in 1988-90. It was reported that all treatments except Dimethoate resulted in 100% mortality after 1 day.

Upadhyay and Aggrawal (1993b) conducted an experiment during winter season to study the toxicity of 9 insecticides viz., Monocrotophos 0.04%, Phosphamidon 0.03%, Oxydemeton-methyl 0.025%, Dimethoate 0.04%, Malathion 0.05%, Chloropyrifos 0.05% (6 are organophosphorus group) and Cypermethrin 0.03%, Fenvalerate 0.01% (2 are synthetic pyrethroid) and Endosulfan 0.07% (Organochlorine) for controlling the *L. erysimi* on "varuna" Indian mustard. It was reported that Oxydemeton-methyl 0.025% and Phosphamidon 0.03% were the most toxic to mustard aphid.

Investigations were conducted to evaluate the effectiveness of Chlorpyrifos, Quinalphos and Oxydemeton-methyl to aphid, *L. erysimi* through laboratory bioassay. The treatments include foliar sprays with Chlorpyrifos and Quinalphos at 0.03 and 0.05% and Oxydemeton-methyl at 20 days . Corrected percentage of mortality counted at different days after treatment. The corrected mortality percentage of Oxydemeton-methyl at 0.025% were 100, and 84.72 at 1, 3 and 7 days after treatment (Thomas and Phadke, 1993).

On the basis of LC_{50}, Oxydemeton-methyl (0.025%) was shown more effective to the *L. erysimi* than Chlorpyrifos or Quinalphos. Chlorpyrifos was 1.488 and Oxydemeton-methyl 42.13 times more effective to aphids (Thomas and Phadke, 1996).

Toxicity of 10 insecticides was evaluated against *L. erysimi* in India. All the tested insecticides significantly reduced the pest population. Chlorpyrifos (0.05%), Methyl-o-demeton (0.05%) and Monocrotophos (0.04%) were most toxic, while Malathion (0.05%) was least toxic (Kumar *et al.* 1996).

Field trials were conducted in Bangladesh to determine the effectiveness of the insecticides viz., Malathion, Lebaycid (Fenthion), Sumithion (Fenitrothion), Nogos (Dichlorvos), Zolone (Phosalone), Roxion (Qimethoate), Ripcord (Cypermethrin)., Cymbush (Cypermethrin), Azodrin (Monocrotophos), Diazinon and Dimecron (Phosphamidon) against *L. erysimi* and observed that 3 to 4 sprays with either Azodrin or Malathion at 2.0 ml/lit of water effectively controlled the pest (Rouf and Kabir, 1997).

Prasad (1997) studied the efficacy of four neem products is Oxydemeton-methyl against *L. erysimi* on rapeseed crop under field condition. Oxydemeton-methyl 0.05% giving 75 to 99% reduction and (0.025%) giving 82 to 97% reduction of aphid population at 1, 3, 7 and 14 days after spraying. The population of these days in neem oil treated plots were between giving 4 to 28%' reduction.

Eight insecticides were tested against mustard aphid and their toxic effect was evaluated. Phosphamidon and Dimethoate 0.05% were found to be significantly toxic to *L. erysimi* than other insecticides (Sonkar and Desai, 1998).

A field experiment was carried out in India to compare the efficacy of 5 insecticides at 3 different concentrations against mustard aphid. The best result in reducing *L. erysimi* population was obtained with Fluvalinate (0.023, 0.045 and 0.068%), followed by Deltamethrin (0.002, 0.004 and 0.006%), Phosphamidon (0.026, 0.055 and 0.079%) and Dimethoate (0.028, 0.056 and 0.084%), Oxydemeton-methyl (0.025, 0.05 and 0.075%) showed the least effectiveness. The highest percentage reduction of *L. erysimi* population was observed with Fluvalinate at 0.068% (Sikha *et al.*, 1999).

Five organophosphorus insecticides viz. Phosphamidon, Quinalphos, Malathion, Dimethoate and Diazinon were tested against mustard aphid in field and net house condition. All these insecticides (0.05%) controlled mustard aphid, Qunalphos was comparatively more effective in controlling *L. erysimi* followed by Phosphamidon ((Gazi *et al.*,2001).

Nirmala *et al.* (2001) conducted an experiment to determine the field efficacy of four insecticides viz., Metasystox, Dimethoate, Phosphamidon and Cypermethrin against *L. erysimi* on *Brassica campestris* var. brown sarson (8SH-1) during 1998-97. Results showed that highest reduction in aphid population was obtained treatment with Phosphamidon (0.03%) and Cypermethrin (0.01%) followed by Metasystox (0.025%) and Dimethoate (0.03%) after 5 days of treatment.

The laboratory test or the relative toxicity of insecticides against *L. erysimi*, revealed that Phosphamidon was most toxic insecticide followed by Dimethoate Lindane, Thiometon and Chlorpyrifos (Sinha *et al.*,2001)

2.4 Toxicity of insecticides on the predator *C. septempunctata*

The effects of several insecticides on the various development stages of *C. septempunctata* were studied in the laboratory by placing them on leaves from apple trees treated in the field. It was found that Milbex (a mixture of Chlorfenethol and Chlorfensulphidel), Tetradifon, Bioresmethrin, Chlordimeform, Diflubenzuron and Pirimicorb had relatively toxic to eggs, larvae, pupae and adults while other compounds such as Tetrachlorovinphos, Methoxychlor, Fenitrothion and Malathion had very high immediate toxicity, and remained toxic for a relatively long period (Olszak, 1982).

In a trail of the toxicity of insecticides to the coccinellid predator, Rajagopal and Kareen (1984) found that the dose of 0.05% Fenvalerate and Dichlorvos were least toxic against the predator, while 0.05% Phasalone and 0.05% Dimethoate were safe against adults and larvae, respectively.

The toxicity of insecticides to the predator *C. septempunctata* was determined in the laboratory at 25°C and 70% RH for 28 insecticides. The safest insecticides were Endosulfan and Toxaphene while Trithion (Carbophenothion), Malathion and Fenitrothion and Ethion were among most toxic (Sharma and Adlakhal, 1986).

The comparative toxicity of various systemic insecticides and Malathion to the predatory coccinellid, *C. septempunctata* associated with sucking pest *A. craccivora* on groundnut was assessed in field trials in India. A spray of Thiometon aphid against these pests at 0.03 and 0.05% was found to be the least harmful to the coccinellid, followed by Demeton-o-methyl, Malathion at 0.05% was highly toxic to the coccinellid. The comperative toxicity to coccinellid in ascending order was Thiometon<Demeton-o-methyl<Phosphamidon<Monocrotophos<Dimethoate<Malathion (Upadhyay and Vyas, 1986).

The toxicity of several insecticides to *C. septempunctata* studied by Tripathi *et al.*(1988). It was reported that Decamethrin (Deltamethrin) was most toxic compound followed by Cypermethrin, Phosphamidon, Fenvalerate, Permethrin, Quinalphos, Demeton-o-methyl and Dimethoate and also recommended the latter 2 insecticides for the control of *L. erysimi* without harming the predator.

Shukla *et al*. (1990) carried out laboratory experiments at 27±1°C the toxicity of Chlorpyrifos, Dimethoate, Oxydemeton-methyl, Phosphamidon and Endosulfan to *C. septempunctata*. Oxydemeton methyl 0.04% was the most toxic and Endosulfan 0.07% was least toxic to both larvae and adults of the coccinellid. The 4 organophosphos insecticides tended to be more toxic to the larvae, whereas Endosulfan was more toxic to the adults.

The toxicity of EC and dust formulations of Chlorpyrifos, Quinalphos and Oxydemeton-methyl to *C. septempunctata* was determined in the laboratory by confining different life stages of the coccinellid on rape leaf discs in petridishes for up to 20 days. EC and dust formulations of Quinalphos were less toxic to all life stages of the coccinellid than corresponding formulations. Chlorpyrifos, Quinalphos dust were less toxic to early and late instar larvae of the coccinelid than to adults. Chlorpyrifos dust was highly toxic to immature and adult stages of the coccinellid (Thomas and Phadke, 1991).

The use of insecticides for the control of *Hyadaphis coriandri* on fennel and their effects on coccinellid predator *C. septempunctata* was studied in India. Applications of Carbofuran 3G and Phorate lOG (at 3g /plant) and Methyl parathion (2% dust at 25 kg / ha), and foliar sprays of 0.05% Quinalphos, 0.07 Endosulfan, 0.0099% Cypermethrin, 0.05% DDVP (Dichlorvos), 0.025% Parathion methyl, 0.03% Phosphamidon, 0.03% Dimethoate and 0.01% Fluvalinate were made 15 days after transplanting and at the branching and flowering stages. Insecticide applications reduced the aphid population and increased the yield but also reduced the predator population (Butani *et al.*, 1992).

Durairaj *et al.* (1993) reported that the order of toxicity of 8 insecticides to *C. septempunctata* was phosphamidon = Dimethoate = Malathion > Formothion > Monocrotophos > Quinalphos > Endosulfan > Methyl-demeton.

On the basis of LC_{50}, Thomas and Phadke (1996) reported that Oxydemeton-methyl 0.025% was least toxic to *C. septempunctata*. Quinalphos was less toxic to the coccinellid than Chlorpyrifos. Adults were less susceptible than larvae to the 3 compounds.

A field experiment was conducted by Malik *et al.* (1998) to evaluate the bio-efficacy of fourteen insecticidal schedule for aphid, so as to prevent the harzards to pollinators and coccinellids for maintaining the natural balance in mustard ecosystem. The fourteen insecticidal schedules were applied in the flowering stage, out of which first two sprayes of different insecticides were given with varied dosages during January - February while third application of Methyl-o-demeton 25 EC (0.025%) was given in green pod stage. The population of coccinellids were counted after 1, 7 and 14 days after each spray. It was reported that application of Deltamethrin (0.002%), Endosulfan (0.07%) and Malathion (0.025%) were found less detrimental to coccinellids *(C. septempunctata* and *M. sexmaculatus)* and reduced 41.83%, 49.00% and 40.00% coccinellid population. The use of Chlorpyrifos (0.05%) and Phosphamidon (0.03%) was detrimental for coccinellids and reduced 63.94% and 73.10% population whereas Oxydemeton--methyl (0.025% and 0.0 15%) reduced 61.55% and 50.99% population.

2.5 Predation efficiency of the predator *C. septempunctata* L.

The larvae of *C. s'eptempunctata* consumed on an average 3.3±1.77 aphids on the first day after hatching. The number went up to 58 aphids per day on the 9th day. The feeding rate there after gradually lowered and became 5.3±2.46 aphids on the 10th day before pupation. Similarly, the feeding rate of the adult predator rose up to 75 on the 7th day from an average first day feeding 22.2 aphids after emergence. This however dropped down gradually and became 9 aphids on the 24th feeding day (Islam and Nasiruddin, 1978).

Predation by *C. septempunctata* on *L. erysimi, B . brassicae, A. crcrccivora, Macrosiphum pisi* and *Apis gosssypii* was studied by Anand (1983) and found that the predator consumed the largest number of *L. crysimi* and the least number of *A. gossyppii.*

Rizvi *et al.* (1994) studied the predation of larvae and adults of *C. septempunctata* using *L. erysimi* as prey and reported that fourth instar larvae were more voracious than larvae of other instars and laboratory reared beetles consumed more prey than field collected beetles.

An experiment was conducted the laboratory at 28 ±12°C and. found that 1st to 4th instar larvae of *C septempunctata* consumed averages of 22.78, 66.00, 172.50 and 333.11 individuals (nymphs and adults) of *L. erysimi*. Adult males consumed 119.80 and females 140.68 aphids/day (Singh and Singh, 1994).

In a laboratory experiment Singh *et al.* (1994) observed that the predatory capacity of adults *C. septempunctata* (78 to 80 nymphs) was greater than that of larvae (56 to 57 nymphs). Older larvae consumed more aphid nymphs per day than the younger larvae.

Lakhanpal *et al.* (1998) studied the predation potential of adults of *C. septempunctata* on *L. erysimi* and observed that adult coccinellids consumed a maximum number of 72 (*L. erysimi*). The longevity of adult coccinellids was 30.2±2.46 with a total consumption of 1435±12.01, aphids with *L. erysimi*. The predator prey ratio was 1: 65, respectively. Larvae consumed a total of 215.42±15.2 aphids in the larval instars.

2.6 Effect of insecticides on crop characters and seed yield of mustard

Eleven varieties of Indian mustard were screened against *L. erysimi* in the field in Rajasthan, India. Aphid infestation reduced plant height, number of secondary branches per plant, number of siliqua per plant and seed weight. Treatment with 4 sprays of 0.03% Dimethoate at fortnightly intervals gave significantly higher yields and increased economic returns (Vir and Henry, 1987).

The effect of one to five applications of 0.025% Oxydemeton methyl at 800 lit/ha, for the control of *L. erysimi* on mustard was studied by Ramkishore and Phadke (1988b) and reported that 2 sprays applied to an 80 to 116 day old crop resulted the greatest yield (4.00 to 4.55 tons/ha).

The efficacy of 0.025% Methyl-demeton, 0.025% Quinalphos, 0.025% Formothion, 0.025% Monocrotophos, 0.03% Dimethoate, 2% Ascorbic acid and 1% Acetic acid against *L. erysimi* mustard were evaluated in field by Baral *et al.* (1986) and found that Methyl-demeton was produced higher yield.

Hossain (1993) observed that the growth parameters namely, plant height, number of branches, number of pods, number of seeds per pod, and yield was increased significantly with the application of insecticides both in the field and net house condition. Ekalux (0.075%) was found to comparatively more suitable for various growth parameters and yield followed by Dimecron (0.075%), Roxion and Diazinon (0.075%). Fyfanon (0.075%) was the least responsive.

Kanchan *et al.* (2001) conducted an experiment to test Monocrotophos 0.05%, Chlorpyrifos 0.05%, Fenvalerate 0.01%, Cypermethrin 0.04%, Phosphamidon 0.04%,, Endosulfan 0.06% and Dimethoate 0.04% to determine their effect on *B. campestris* cv yellow sarson B-9 yield. The highest yield was recorded in plants treated with Chlorpyrifos and lowest in the untreated control. Phosphamidon and Endosulfan gave the highest and lowest benefit: cost ratio.

From the above presentation it may be concluded that insecticides have got a decisive influence on controlling the mustard aphid and their toxic effect to the predator.

Chapter 3

Materials and Methods

CHAPTER 3
MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka during the *rabi* season of November 2004 to February 2005 to study the effect of insecticides in controlling mustard aphid and their toxic effect on the predator *C. septempunctata.* In this chapter the details of the different materials were used and methods followed in the investigation are described below.

3.1 General description of the experimental site

3.1.1 Location

The experimental site belongs to Young Brahmaputra and Jamuna Flood plain (AEZ-8) having non-calcarious dark flood plain soils of silty loam texture (UNDP and FAO, 1998; and BARC, 1997).

3.1.2 Soil

The soil was slightly acidic to mildly alkaline with a pH value ranging from 6.0 to 7.3 (Eaqub *et al,* 1984) .The soil sample was collected and analyzed at the soil science laboratory, Department of Soil Science, SAU, Dhaka. The soil of experimental field was silt loam in texture with pH value 6.4, soil contained 0.09% total N, 1% organic matter, available 8.5 ppm P, available 20.8 ppm S, k0.09 (meq /100g soil) and CEC (me%) 8.20 and fertility status were medium and low, respectively.

3.1.3 Climate

The experimental area was under the sub-tropical climate, which is characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds in the *kharif* season (April-September) and scanty rainfall associated with low temperature during the *rabi* season (October-March). The agro-climatic condition pertaining to monthly mean values of daily maximum, minimum and average temperatures, relative humidity, monthly total rainfall and sunshine hours received at the experiment station during the study period have been presented in Appendix I.

3.2 Materials used

3.2.1 Planting material

Troi - 7: It is one of the latest modern variety of mustard developed by the Bangladesh Agricultural Research Institute. The average plant height is 75 cm. It requires about 80 days from sowing to maturity. The average yield is 1100 $kgha^{-1}$. This variety is resistant to lodging. The stem and leaves are green and erect.

3.2.2 Chemical materials

Four insecticides namely, Diazinon 60 EC, Sumithion 60 EC, Cymbush 10 EC and Dursban 20 EC were used as chemicals against mustard aphid. Particulars of these chemicals are given below.

3.2.2.1 Diazinon 60 EC

i. Trade name: Basudin 10 G, Diazinon 60 EC, Diazinon 14 G, Diaton 60 EC, Diaton 10 G, Sabin 10 G, Sabin 60 EC
ii. Common name: Diazinon
iii. Chemical name: 2- isopropyl - 4 - methyl pyrimidyl - 6
iv. Active ingredient: Diazinon 60% EC
v. Description: It is contact and systemic insecticide. It is effective against sucking insects and spiders. It is also effective against soil insects, pests on various crops, and for dairy and livestock pests. Its boiling point is 89^0C. Solubility in water is 40 gm/liter at 20^0C. It is highly soluble in most organic solvents. The technical manufactured is Sundad (S) Private Ltd, Singapore and in Bangladesh only sole agent Magdonald Bangladesh (Private) Ltd.

3.2.2.2 Sumithion 60 EC

i. Trade name: Fentro 50 EC, Folithion 50 EC, Sumithion 50 EC Fenidun 50 EC, Agrothion 50 EC, Edthion 50 EC.
ii. Common name: Fenitrothion
iii. Chemical name: o, o-dimethyl-o-4 nitro- m-tolyl Phosphorothioate.

iv. Description: It is non-systemic insecticide with contact and stomach action. It is used for the control of chewing, sucking and boring insects in cereals, soft fruit, tropical fruit, vines, rice, sugarcane, vegetables, turf and forestry. It is a clear liquid with an unpleasant odour and boiling point is 95^0C. It is manufactured by Sumitomo Chemical Company Limited, Japan and formulator by Setu Agro Industries Limited.

3.2.2.3 Cymbush 10 EC

i. Trade name: Ripcord 10 EC, Acrocypermethrin 10 EC, Agromethion 10 EC, Arrivs 10 EC, Bassorthrin 10 EC, Cymbush 10 EC.

ii. Common name: Cypermethrin

iii. Active ingredient: Cymbush 10% EC

iv. Description: It is contact and stomach poison. It is effective against mango hopper, cotton insect, jute hairy caterpillar, vegetables and stored grain pests. It is introduced by ACI as Rega. NO- "AP - 60". It is manufactured by Syngenta India Limited, India.

3.2.2.4 Dursban 20 EC

i. Trade name: Dursban 20 EC

ii. Common Name: Chlorpyrifos

iii. Chemical name: 0,0-Diethyl-0-3,5, 6- Trichloro pyridylthiophosphate

iv. Active ingredient: Dursban 20% EC

v. Description: Dursban is an insecticide for the control of sucking and chewing plant pests, soil inhabiting plant pests and household parasites. It is highly soluble in most organic solvents, but almost insoluble in water. The technical manufactured of Dursban 20 EC is D-Nosil Crop Protection Limited, America and in Bangladesh only sole agent Auto Equipment limited.

3.3 Treatment

One set of treatments included in the experiment was as follows.

Treatments:

i.	Control	T_o
ii.	Diazinon	T_1
iii.	Fenitrothion	T_2
iv.	Cypermethrin	T_3
v.	Chlorpyrifos	T_4

3.4 Design and layout of the experiment

The experiment was laid out in a randomized complete block design. The total numbers of unit plots were thus five in each replication. The experiment was replicate five times, thus giving 5X5 = 25 total number of unit plots. The unit plot size was 4m X 2.5 m or 10 sq. m. (0.0001 hectare). The plot-to-plot distance was 0.5m and that from block to block was 1.0 m. The irrigation and drainage channel were made through space left between two main plots.

3.5 Conduction of the experiment

3.5.1 Seed collection

A seed of high yielding variety cv.Tori-7 was collected from the Bangladesh Agricultural Development Corporation (BADC), branch office, Sher-e-Bangla Agricultural University (SAU), Dhaka.

3.5.2 Preparation of land

A piece of high land was selected in the SAU farm for this experiment. Land preparation was done through ploughing in several days. The land was opened with a tractor ploughing on 30 October 2004. One tractor ploughing was done on 31 October and another was done on 8 November 2004. Later on, the land was ploughing and cross ploughing thoroughly four times with country plough followed by laddering to level the soil. Weeds, stubbles, and residues were collected and removed to cleaned the field. Then the field was made ready for sowing mustard seeds. The field layout was done on 9 November 2004 as per design immediately after land preparation. Finally individual plots were prepared before sowing.

3.5.3 Seed sowing:

The seeds of Tori-7 were sown in the prepared land on 9 November 2004.

3.5.4 Fertilizer application

The land was fertilized with urea, triple super phosphate (TSP), muriate of potash (MP), gypsum, zinc oxide, and boric acid as per recommendation. The half of urea and the entire amount of triple super phosphate, muriate of potash, gypsum, zinc oxide and boric acid were broad cast, and incorporated into the soil at final land preparation. The recommended doses of different fertilizers for Tori-7 are presented below.

Name of fertilizers	**Dose (kg ha^{-1})**
i. Urea	250
ii. Triple super phosphate (TSP)	170
iii. Muriate of potash (MP)	85
iv. Gypsum	150
v. Zinc oxide	5
vi. Boric acid	15

3.5.5 Intercultural operations

The following intercultural operations were done for ensuring and maintaining the normal growth of the crop.

3.5.5.1 Gap filling

Seedlings in same hills if died off, and then were replaced by gap filling on 24 November 2004 with the seedlings from the same source.

3.5.5.2 Weeding

Mustard plants were infested with different weeds. Weeding was done once by hand pulling on 24 November 2004.

3.5.5.3 Water management

Only one flood irrigation was given on 25 December 2004.

3.5.5.4 Diseases management

The crop damage by diseases like *Alternaria* leaf spot of mustard was negligible.

3.5.5.5 Insecticides application

Crops were infested with mustard aphids. A knapsack sprayer sprayed the selected four insecticides in the field when the inflorescence, leaves and shoots were infested with aphids. Insecticides were sprayed at 4 P.M. Insecticides were sprayed on 23 December 2004 and on 12 January 2005.

3.5.8 General observation of the experimental field

Observations were regularly made and the field looked nice with normal green plants. The plants treated with Cypermethrin appeared to be more vigorous and luxuriant than those treated with control treatments. In general, leaf color of Tori-7 was light green. Disease infestation was not too severe to cause damage the crop. Incidence of mustard aphid was observed. Lodging of any plant was not observed. The flowering was not uniform.

3.5.9 Sampling, harvesting, threshing, clearing and processing

Maturity of crop was determined when some of 80-90% of the siliquae become golden yellow. Ten plants (excluding border plant) were selected randomly from each unit plot and uprooted before harvesting for recording of necessary data. After sampling the whole plot was harvested on 28 January 2005. The harvested crop of each plot was properly tagged, separately bundled, and brought to the threshing floor. The harvesting crop was threshed by hand. The seeds were cleaned and sun dried properly. Finally seed yields plot^{-1} were recorded and converted to kgha^{-1}.

3.5.10 Aphid infestation on mustard

The aphid suck sap from leaves, flowers, flower buds, pods, and twigs of the plants. In case of severe infestation leaves become curled, plant fails to develop pods, the young pods when developed failed to mature and cannot produce healthy seeds.

3.6 Collection of data

The data were collected on following broad steps at different dates as per experimental requirement.

Step 1. Data collection on mustard aphid and predator reduction under field condition

i. Percent of plant infested with aphids

ii. Number of aphids per plant

iii. Number of the predator *C. septempunctata* per plant

Step II. Data collection on crop characters

i. Plant height at harvest (cm)
ii. Number of branches per plant
iii. Number of pods per plant
iv. Pod length (cm)
v. Number of seeds per pod
vi. Weight of 1000 seeds (gm)
vii. Seed yield ($kgha^{-1}$)
viii. Protection efficiency (%)
ix. Yield loss (%)

Step III. Data collection on mustard aphid and predator mortality under laboratory condition

i. Predation efficiency of the predator *C. septempunctata*
    a) Predation efficiency of the larvae *C. septempunctata*
    b) Predation efficiency of the adult *C. sepempunctata*
ii. Effects of insecticides on *L. erysimi*
iii. Effects of insecticides on predator larva and adult

Step IV: Economic evaluation of insecticides on the yield of mustard

3.7: Data collection procedure

3.7.1 Data collection on controlling mustard aphid

3.7.1.1 Percent of plant infested with aphid

Infestations of mustard plant by mustard aphid were recorded at 1,4 and 7 days after first and second application of insecticides. Total numbers of infested and healthy plants were collected from five randomly selected rows of each plot to calculate the infestation percent of mustard plants by mustard aphid. Infestation percent was calculated by the following formula:

$$\text{Percent of plants infested} = \frac{B}{A} \times 100$$

Where,

A = Total number of plants

B = Number of infested plants

The percent of plant infestation was converted into percent reduction of aphid-infested plant over the control by the following formula.

$$\text{Percent reduction of aphid infested plant over control} = \frac{To - Tr}{To} \times 100$$

Where,

To = % of aphid infested plant in control plot

Tr = % of aphid infested plant in treated plot

3.7.1.2 Number of aphids per plant

The population of aphids in the field on the five randomly selected plants from each plot were counted at 1,4 and 7 days after first and second spraying of insecticides. The top 10 cm apical twigs of these selected plants were cut and brought to the laboratory in polythene bags separately. The aphids were removed from the plants with the help of a soft brush and placed on a piece of white paper. Their number was counted with the help of magnifying glass and hand tally counter. Infested twigs and inflorescence were checked carefully, so that not a single aphid could escape at the time of counting. The numbers of aphids per plant were converted into percent reduction of aphid population over the control using the following formula:

$$\text{Percent redaction of aphid population over control} = \frac{To- Tr}{To} \times 100$$

Where,

To = Number of aphid in control plot

Tr = Number of aphid in treated plot

3.7.1.3 Number of the predator *C. septempunctata* per plant

In the field, ten randomly selected plants from each plot were selected for counting the population of the predator at 1,4 and 7 days after first and second application of insecticides. Then the numbers of predators per plant were converted into percent reduction of predator over the control with the following formula:

$$\text{Percent reduction of predator over control} = \frac{\text{To-Tr}}{\text{To}} \times 100$$

Where,

To =Number of predator in control plot

T_r = Number of predator in treated plot

3.7.2 Data Collection on crop characters

3.7.2.1 Plant height

Plant height was measured from the ground level to the tip of the longest panicle.

3.7.2.2 Numbers of branches per plant

Total numbers of branches per plant were counted.

3.7.2.3 Number of pods per plant

Total numbers of pods per plant were counted.

3.7.2.4 Pod length (cm)

Pod length was regarded from the basal node of the rachis the apex of each panicle.

3.7.2.5 Number of seeds per pod

Total numbers of seeds per pod were counted.

3.7.2.6 Weight of 1000 seeds (gm)

One thousand seeds were randomly collected from a sample drawn from the bulk of each plot and were dried in an oven at 10% moisture content and weighed by an electric balance.

3.7.2.7 Seed yield ($kgha^{-1}$)

Mustard plants covering a sample area of ten square meter was harvested from each plot. The plants were threshed. Seeds were dried and processed, and the yield was recorded.

3.7.2.8 Protection efficiency and yield loss

Protection efficiency and yield losses for each schedule were calculated with the following formula:

$$\text{Protection efficiency} = \frac{B}{A} \times 100$$

$$\text{Yield losses (\%)} = \frac{A\text{-}B}{A} \times 100$$

Where,

A = Seed yield in best treatment

B = Seed yield in testing treatment

3.7.3 Predation efficiency of the predator *C. septempunctata*

3.7.3.1 Predation efficiency of larvae

The egg masses of *C. septempunctata* were collected from the field and reared in the laboratory to maintain a stock culture. Just after hatching of eggs, newly two hatched grubs were transferred in petridishes and 100 mustard aphid of mixed aged and size were supplied to the predators everyday on a mustard leaf. The base of the leaf was covered by water soaked cotton for protecting it from wilting. The number of aphids consumed by each grub per day was recorded and was continued up to pupation. This experiment was laid out in a completely randomized design with five replications.

3.7.3.2 Predation efficiency of the adult

For determining the predation efficiency of adult predator, one male and one female beetles were transferred to new petridishes. The adult beetles were collected from stock culture. The adults were provided with 150 aphids daily. The numbers of aphids consumed per adult were counted daily. It was continued up to 30 days. This experiment was laid out in a completely randomized design with five replications.

3.7.3.3 Effect of insecticides on *L. erysimi* under laboratory condition

Mustard aphid was reared on mustard plants for stock culture of mustard aphid. At the flowering stage of mustard plant, insecticides were sprayed at the dose of 0.05%. The untreated pots received no insecticides just after spraying the treated leaves were collected from the pots and kept in separate petridishes in laboratory. Twenty equal sized aphids were collected from the stock culture and released in the petridish containing treated leaves. The untreated leaves were supplied to the aphids in the same way. Mortality were counted at 1,4 and 7 daysafter insecticide application. Mortality data were corrected by Abbott's (1925) formula:

$$\text{Corrected mortality} = \frac{\text{Observed mortality-Control mortality}}{\text{100-Control mortality}} \times 100$$

3.7.3.4 Effect of insecticides on predator larva and adult

Adults and larvae of the predator were reared on mustard aphids for stock culture. At the flowering stage of mustard plant, insecticides were sprayed at the dose of 0.05%. The untreated pots received no insecticides. Just after spraying the treated leaves were collected from the pots and kept in separate pertridishes under laboratory condition. Five 4th instar larvae were taken from the stock culture and were released in the petridishes containing treated leaves. The untreated leaves were supplied to the larvae in the same way. The mortality counts were taken at 1,4 and 7 days after insecticide application. Mortality data were corrected by Abbott's (1925) formula:

$$\text{Corrected mortality} = \frac{\text{Observed mortality-Control mortality}}{\text{100-Control mortality}} \times 100$$

Similar procedures were also followed for the adult predator and five adult predators were taken instead of 4th instar larva.

3.8 Economic evaluation of insecticides on the seed yield of mustard

Economic evaluation of insecticides on the seed yield of mustard was made for each treatment based on the Benefit Cost Ratio (BCR). Cost benefit ratio was calculated as follows:

$$\text{BCR} = \frac{\text{Net profit over control}}{\text{Cost of treatment}}$$

where, Cost of treatment = Price of insecticides + Labour charge

3.9 Statistical analysis

Data obtained of different parameters were statistically analyzed using one factor Randomized Complete Block Design (RCBD). Data obtained from laboratory experiments were analyzed using one factor Completely Randomized Design (CRD). Using Duncan's Multiple Range Test (DMRT) separated the means of statistically significant parameters (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER 4
RESULTS AND DISCUSSION

Results obtained from the present study regarding the performance of four insecticides on the control of mustard aphid *Lipaphis erysimi* and their effect to the predator *Coccinella septempunctata* and different crop characters of mustard like Tori -7 and the efficiency of the predator *C. septempunctata* consuming the mustard aphid *L. erysimi* are presented and discussed in this chapter. The results have been presented in Tables 1 to 10. The data on different parameters as per experimental requirement were recorded and analysis of variance was done and presented in Appendices II to XXXVII. The results of each parameter have been adequately interpreted, elaborated and discussed in the light of relevant available research report wherever necessary.

4.1 Effect of insecticides on percent reduction of aphid infested plant after first spray under field condition

The aphid suck sap from leaves, flowers, flower buds, pods, and twigs of the plants (plate 1 and 2). Percent reduction of aphid was significantly (P> 0.01) influenced by insecticides at different dates of sampling (Appendices II- IV). The results on percent reduction of aphid infested plant of different treatments at 1,4 and 7 days are presented in Table 1. Percent reduction of aphid infested plant ranged from 41.46 to 65.64% at 1 DAT, 56.28 to 80.40% at 4 DAT and 47.32 to 70.72% at 7 DAT. The effect of insecticides on percent reduction of aphid infested plant are elaborated and discussed below.

1 DAT: The highest percent reduction of aphid infested plant (65.64%) was observed under the application of Cypermethrin, which was statistically similar to Diazinon (60.34%). The lowest percent reduction of aphid infested plant was observed under the application of Fenitrothion (41. 46%).

4 DAT: The highest percent reduction of aphid infested plant (80.40%) was observed in Cypermethrin (Plate 3), which was statistically identical with Diazinon (73.90%). The lowest percent reduction of aphid infested plant was observed in Fenitrothion (56.28%) which was statistically similar to Chlorpyrifos (68.28%) .

Plate 1. Mustard infloresence infested with *L. erysimi.*

Plate 2. Mustard pod infested with *L. erysimi*

Plate 3. Aphid infested mustard plant after 96 hours of spraying of Cymbush 10 EC

Table 1. Effect of four insecticides on percent reduction of aphid infested plant after first spray under field condition

Name of insecticides		Dose	% Reduction of aphid infested plant.		
Trade name	Common name	(%)	1DAT	4DAT	7DAT
Diazinon 60 EC	Diazinon	0.05	60.34 a	73.90 ab	65.04a
Sumithion 60 EC	Fenitrothion	0.05	41.46c	56.28b	4732b
Cymbush 10 EC	Cypermethrin	0.05	65.64a	80.40a	70.72a
Dursban 20 EC	Chlorpyrifos	0.05	48.96 b	68. 28 b	52.14 b
Level of significance			0.01	0.01	0.01
CV (%)			8.76	6.99	8.92
Sx			2.118	2.183	2.347
Mean			54.1	69.72	58.81

- Means in a column followed by the same letter (s) are not significantly different whereas figures with dissimilar letters different significantly (as per DMRT).
- First spraying was done 45 days after sowing.
- DAT = Days after treatment
- The average aphid infested plant (%) in control treatment were 49.40, 53.60 and 58.80 at 1,4 and 7 days after first spraying of insecticides.

7 DAT: The highest percent reduction of aphid infested plant was found under the treatment of Cypermethrin (70.72%) and statistically similar to Diazinon (65.04%). The lowest percent reduction of aphid-infested plant was observed under the treatment of Fenitrothion (47.32%), which was statistically similar to Chlorpyrifos (52.14%).

All these insecticides (0.05%) controlled mustard aphid, Cypermethrin was comparatively more effective in controlling *L. erysimi* followed by Diazinon.

4.2. Effect of insecticides on percent reduction of aphid infested plant after second spray under field condition

There was significant (P>0.01) effect on percent reduction of aphid-infested plant due to insecticides at different sampling dated after second spray under field condition (Appendices V-VII). The reduction of aphid infested plant after second sprays under field condition are presented in the table 2. The percent reduction of aphid infested plant ranged from 51.22 to 71.48 % at 1 DAT, 52.62 to 80.52% at 4 DAT and 48.52 to 71.40 % at 7 DAT. Insecticides effect on percent reduction of aphid infested plant are described below.

1 DAT: The highest percent reduction of aphid-infested plant (71.48%) was found in Cypermethrin, which was at par with Diazinon (65.08%). The lowest percent reduction of aphid-infested plant (51.22%) was recorded from Fenitrothion, which was identical with Chlorpyrifos (58.22%).

4 DAT: The highest percent reduction of aphid infested plant (80.52%) was recorded from Cypermethrin whereas statistically similar to Diazinon (77.52%) and Chlorpyrifos (70.80%). The lowest one was observed in Fenitrothion (52.62%).

7 DAT: The highest percent reduction of aphid-infested plant (71.40%) was found in Cypermethrin, which was statistically similar to Diazinon (67.64%) and identically followed by Chlorpyrifos (60.90%) and the lowest was recorded from Fenitrothion (48.52%).

In case of second spraying similar percent reduction of aphid infested plant was recorded as first spray at 1,4 and 7 DAT. Significant percent reduction of aphid infested plants were recorded after 4 days both first and second spraying of insecticides. The highest percent reduction of aphid-infested plants was observed

Table 2. Effect of four insecticides on percent reduction of aphid infested plant after second spray under field condition

Name of insecticides		Dose	% Reduction of aphid infested plant		
Trade name	Common name	(%)	1DAT	4DAT	7DAT
Diazinon 60 EC	Diazinon	0.05	65.08 ab	77.32 a	67.64 a
Sumithion 60 EC	Fenitrothion	0.05	51. 22 c	52. 62 b	48.52 b
Cymbush 10 EC	Cypermethrin	0.05	71.48 a	80.52 a	71.40 a
Dursban 20 EC	Chlorpyrifos	0.05	58.22 bc	70.88 a	60.90 ab
Level of significance			0.01	0.01	0.01
CV (%)			8.31	9.95	14.91
Sx			2. 286	3.129	4.143
Mean			61.50	70.34	62.12

- Means in a column followed by the same letter (s) are not significantly different whereas figures with dissimilar letters different significantly (as per DMRT).
- Second spraying was done 65 days after sowing.
- DAT = Days after treatment
- The average aphid infested plant (%) in control treatment was 85.40, 99.60 and 115.40 at 1,4 and 7 days after first spraying of insecticides.

under the treatment of Cypermethrin at 1,4 and 7 DAT after first and second spraying of insecticides. Among the insecticides, Cypermenthrin was more effective against mustard aphid. Tripathi *et al.* (1988a) reported that Decamethrin and Cypermethrin were the most effectiveness of mustard aphid *L. erysimi.* Tripathi *et al.* (1985) reported that Decamethrin and Cypermethrin were the most effectiveness of mustard aphid *L. erysimi.* Khurana and Batra (1989) stated that Cypermethrin was more toxic to the mustard aphid. Ahmed and Miah (1989) reported that the most effective compound was Cypermethrin. These findings have similarity with the present study.

4.3 Effect of insecticides on percent reduction of aphid population after first spray under field condition

The aphid population increased and the percent of pod infestation had positive correlation to aphid population (Plate 4). The percent reduction of aphid population varied at different times significantly ($P>0.01$) among the insecticides (appendices VIII-X). Table 3 shows that the reduction of aphid population ranged from 73.78 to 91.06% at 1 DAT 81.91 to 97.90% at 4 DAT and 63.94 to 80.10% at 7 DAT. The results on percent reduction of aphid population after first spray under field condition are presented and discussed here.

1 DAT: The highest aphid population reduction (91.06%)was observed in Cypermethrin, which was statistically similar to Diazinon (88.78%). The lowest aphid population reduction (73.78%) was noted form Fenitrothion (81.91%) which was statistically similar to Chlorpyrifos (86.56%).

4 DAT: The highest aphid population reduction was noted from Cypermethrin (97.90%), which was statistically similar to Diazinon (95.74%). The lowest aphid population reduction was noted from Fenitrothion (81.91%), which was statistically similar to Chlorpyrifos (86.56%).

7 DAT: The highest aphid population reduction was recorded from Cypermethrin (80.10%), which was statistically at par with Diazinon (76.67%). The lowest aphid population reduction was recorded from Fenitrothion (63.94%). Among these insecticides, Cypermethrin was found to be the best treatment in this experiment.

Plate 4. Population of *L. erysimi* on mustard

Table 3. Effect of four insecticides on percent reduction of aphid population first spray under field condition

Name of insecticides		Dose	% Reduction of aphid population		
Trade name	Common name	(%)	1 DAT	4 DAT	7 DAT
Diazinon 60 EC	Diazinon	0.05	88.78 a	95.74 a	76.76 ab
Sumithion 60 EC	Fenitrothion	0.05	73.78 b	81.91 b	63.94 c
Cymbush 10 EC	Cypermethrin	0.05	91.06 a	97.90 a	80.10 a
Dursban 20 EC	Chlorpyrifos	0.05	79.48 b	86.56 b	73.22b
Level of significance			0.01	0.01	0.01
CV (%)			6.95	6.67	6.38
Sx			2.587	2.70	20.98
Mean			83.28	90.53	73.51

- Means in a column followed by the same letter (s) are not significantly different whereas figures with dissimilar letters different significantly (as per DMRT).
- First spraying was done 45 days after sowing.
- DAT = Days after treatment
- The average aphid infested plant (%) in control treatment was 57.00, 84.60 and 112.60 at 1,4 and 7 days after first spraying of insecticides.

4.4 Effect of insecticides on percent reduction of aphid population of after second spray under field condition

All the insecticides were significant ($P>0.01$) in respect of percent reduction of aphid population at several times (Appendices XI-XIII). From table 4, it revealed that the reduction of aphid population ranged from 62.25 to 87.44% at 1 DAT, 64,96 to 97.44% at 4 DAT and 65.58 to 81.80% at 7 DAT. Percent reduction of aphid population are affected by the application of insecticides are elaborated and described here.

1 DAT: The highest percent reduction of aphid population was found with the application of Cypermethrin (87.44%), which was statistically identical with Diazinon (82.24%). The lowest reduction of aphid population was noticed with the application of Fenitrothion (62.25%).

4 DAT. The highest percent reduction of aphid population (97.44%) was noticed from Cypermethrin, which was statistically at par with Diazinon (92.52%). The lowest percent reduction of aphid population (64.96%) was found from Fenitrothion.

7 DAT: The highest percent reduction of aphid population (81.80%) was recorded in the application of Cypermethrin, which was statistically similar to Diazinon (80.88%). The lowest percent reduction of aphid population (65.58%) was found under the treatment of Fenitrothion.

All the insecticides were found to be effective, among them Cypermethrin was more effective against mustard aphids. Significant reduction of aphid population was found after 4 DAT of first and second spraying of insecticides. Lower percent reduction of population was observed after 7 DAT of insecticide application indicating the lowering of their effectiveness with the increasing of time. Significantly the highest percent reduction was recorded from Cypermethrin at 1,4 and 7 days after first and second spray. Significantly the lowest percent reduction was noted under the treated with Fenitrothion at 1,4 and 7 days after first and second spray. Khurana and Batra (1989) reported that Cypermethrin was most toxic to mustard aphid. Nirmala et al. (2001) observed the highest percent reduction in aphid population were obtained the application of Phosphamidon and Cypermethrin. Similar results obtained under the application of Cypermethrin.

Table 4. Effect of four insecticides on percent reduction of aphid population after second spray under field condition

Name of insecticides		Dose	% Reduction of aphid population		
Trade name	Common name	(%)	1DAT	4DAT	7DAT
Diazinon 60 EC	Diazinon	0.05	82.24 ab	92.52 ab	80.88 a
Sumithion 60 EC	Fenitrothion	0.05	62.25 c	64.96 c	65.58 c
Cymbush 10 EC	Cypermethrin	0.05	87.44 a	97.44 a	81.80 a
Dursban 20 EC	Chlorpyrifos	0.05	75.24 b	88.44 b	77.00 b
Level of significance			0.01	0.01	0.01
CV (%)			9.93	8.07	9.80
Sx			3.419	1.897	1.088
Mean			76.79	85.84	76.32

- Means in a column followed by the same letter (s) are not significantly different whereas figures with dissimilar letters different significantly (as per DMRT).
- Second spraying was done 65 days after sowing.
- DAT = Days after treatment
- The average aphid infested plant (%) in control treatment was 123.20, 146.80 and 181.80 at 1,4 and 7 days after second spraying of insecticides.

4.5 Effect of insecticides on percent reduction of the predator *C. septempunctata* after first spray under field condition

Insecticides effect on percent reduction of the predator *C. septempunctata* after first spray under field condition varied significantly (P> 0.01). (Appendices XIV- XVI). Table 5 shows that percent reduction of the predator ranged from 43.28 to 83.50 % at 1 DAT, 34.84 to 76.30 % at 4 DAT, and 28.92 to 79.56% at 7 DAT. The effect of insecticides on the predator of *C. septempunctata* are described below.

1 DAT: The data revealed that Fenitrothion provided with the highest percent reduction of the predator *C. septempunctata* (83.50%) and Cypermethrin resulted in the lowest reduction of the predator *C. septempunctata.* (43.28%), which were statistically different from others.

4 DAT: The highest percent reduction of the predator *C. septempunctata was* observed under the application of Fenitrothion (76.30%), which was statistically similar to Chlorpyrifos (70.24%). The lowest percent reduction of the predator *C. septempunctata* was observed under the use of Cypermethrin (34.84%), which were significantly different from others.

7 DAT: The highest percent reduction of the predator *C. septempunctata* (79.56%) was found under the treatment of Fenitrothion and the lowest percent reduction of the predator *C. septempunctata* (28.92%) was found under the treatment of Cypermethrin, which were significant different from others.

All these insecticides (0.05%) effect on mustard aphid, Cypermethrin was the most responsible for the controlling the mustard aphid *L. erysimi* followed by Diazinon.

4.6 Effect of insecticides on percent reduction of the predator *C. septempunctata* after second spray under field condition

Percent reduction of the predator *C. septempunctata* was significantly influenced by insecticides at different dates of sampling (Appendices XVII- XIX). The results on percent reduction of the predator *C. septempunctata* after second spray presented in the table 6. Percent reduction of the predator *C. septempunctata* ranged from 38.30 to 78.74% at 1 DAT, 25.96 to 82.12% at 4 DAT and 32.46 to 80.64% at 7 DAT. The effect of insecticides on percent reduction of the predator *C. septempunctata* are described below.

Table 5. Effect of four insecticides on percent reduction of the predator *C. septempunctata* after first spray under yield condition

Name of insecticides		Dose (%)	% Reduction of the predator *C. septempunctata.*		
Trade name	Common name		1DAT	4DAT	7DAT
Diazinon 60 EC	Diazinon	0.05	59.04 c	51.52 b	48.52 c
Sumithion 60 EC	Fenitrothion	0.05	83.50 a	76.30 a	79.56 a
Cymbush 10 EC	Cypermethrin	0.05	43.28 d	34.84 c	28.92 d
Dursban 20 EC	Chlorpyrifos	0.05	73.26b	70.24a	67.24b
Level of significance			0.01	0.01	0.01
CV (%)			7.71	11.26	5.46
Sx			2.016	2.931	1.369
Mean			64.77	58.24	56.11

- Means in a column followed by the same letter (s) are not significantly different whereas figures with dissimilar letters different significantly (as per DMRT).
- First spraying was done 45 days after sowing.
- DAT = Days after treatment
- The average aphid infested plant (%) in control treatment were 19.40, 17.20 and 19.80 at 1,4 and 7 days after first spraying of insecticides.

1 DAT: The application of Fenitrothion was obtained the highest percent reduction of the predator *C. septempunctata* (78.74%) and the application of Cypermethrin was obtained the lowest percent reduction of the predator *C. septempunctata* (38.30%) that were significantly different from others.

4 DAT: The treatment of Fenitrothion was noted the highest percent reduction of the predator *C. septempunctata* (82.12%) and the treatment of Cypermethrin was noted the lowest percent reduction of the predator *C. septempunctata* (25.96%), which were significantly dissimilar from others.

7 DAT: The highest percent reduction of the predator *C. septumpunctata* (80.64%) was obtained under the treatment of Fenitrothion and the lowest percent reduction of the predator *C. septempunctata* (32.46%) was found under the treatment of Cypermethrin, which were significantly different from others.
From this study it was evident that Fenitrothion was highly toxic to the predator *C. septempunctata*. On the other hand, Cypermethrin provided to be safer insecticide both after first and second spray.

Olszak (1982) reported that Fenitrothion had very high immediate toxicity and remained toxic for a relatively long period. Sharma and Adlakhal (1986) reported that Fenitrothion was the most harmful to the predator. All these findings are in agreement with the findings of the present study. Few variations were found which might be due to the variation of insecticides and location.

4.7 Effect of insecticides on crop characters and seed yield of mustard

Results obtained from the present study regarding the influence of insecticides under different crop characters of mustard crop are presented and discussed in this chapter. The results have been presented in table 7.

Table 6. Effect of four insecticides on percent reduction of the predator *C. septumpunctata* after second spray under field condition

Name of insecticides		Dose (%)	% Reduction of the predator *C. septempunctata*		
Trade name	Common name		1DAT	4DAT	7DAT
Diazinon 60 EC	Diazinon	0.05	47.08c	39.58c	41.7bc
Sumithion 60 EC	Fenitrothion	0.05	78.74a	82.12a	80.64a
Cymbush 10 EC	Cypermethrin	0.05	38.30d	25.96d	32.46d
Dursban 20 EC	Chlorpyrifos	0.05	57.38b	53.69b	57.46b
Level of significance			0.01	0.01	0.01
CV (%)			4.59	5.66	10.17
Sx			1.225	1.275	2.415
Mean			55.38	50.41	53.08

- Means in a column followed by the same letter (s) are not significantly different whereas figures with dissimilar letters different significantly (as per DMRT).
- Second spraying was done 65 days after sowing.
- DAT = Days after treatment
- The average aphid infested plant (%) in control treatment was 27.20, 22.20 and 21.60 at 1,4 and 7 days after second spraying of insecticides.

4.7.1 Plant height

Plant height was significantly (P>0.01) different due to insecticides (appendix XX). Plant height was affected by insecticides application and it discussed and presented in table7. Plant height varied from 74.40 to 92.00 cm. It was found that Cypermethrin was produced the longest plant height (92.00cm) and identical with Diazinon (88.00cm). The lowest plant height was produced by control treatment (74.40cm), which was statistically at par with Fenitrothion (75.80 cm) and Chlorpyrifos (81.00 cm). The first plant height was under Cypermethrin was highest position in plant architecture in all the insecticides treatment. The treatment of Cypermethrin appeared to be significantly superior of other treatments. A remarkable variable among different insecticides were found at harvest. Hossain (1993) stated that plant height was increased significantly with the application of insecticides in the field condition. These findings was confirmed by the present study. Here, it was observed that the use of different insecticides were found to produce a positive effect on plant height. The increase in plant height due to application of different insecticides might be associated with stimulating effect on various physiological process of the plant.

4.7.2 Number of branches per plant:

Appendix XXI shows that insecticides had significant (P>o.o1) effect on the number of branches per plant at harvest. Table 7 shows that number of branches per plant ranged from 15.80 to 22.20. The data revealed that Cypermethrin provided with the maximum number of branches per plant (22.20), which was statistically at par with Diazinon (20.20) and identically followed Chlorpyrifos (18.60). Control crop (without insecticides) showed minimum number of branches per plant (15.80), which was identical with Fenitrothion (17.40). All the treated plants significantly produced more branches than control treatment. Regarding the branch production of Cypermethrin was significantly superior. Hossain (1993) reported that number of branches per plant were increased significantly under the application of different insecticides in the field.

Table 7. Crop characters and seed yield of mustard when insecticides was used for controlling of *L. erysimi*

Name of insecticides		Dose (%)	Plant height (cm)	No. of branches per plant	No. of pods per plant	Pod length (cm)	No. of seeds per pod	Wt of 1000 seeds (gm)
Trade name	Common name							
Diazinon 60 EC	Diazinon	0.05	88.00ab	20.20ab	444.00	6.70ab	20.60b	2.76ab
Sumithion 60 EC	Fenitrothion	0.05	75.80bc	17.40cd	427.2	5.92bc	17.80c	2. 08c
Cymbush 10 EC	Cypermethrin	0.05	92.00a	22.2a	454.2	7.1a	22.40a	2.92a
Dursban 20 EC	Chlorpyrifos	0.05	81.00abc	18.60 bc	433.4	5.9 bc	19.40 bc	2.52b
Control			74.40c	15.80d	407.2	5.50c	18.00c	1.86c
Level of significance			0.05	0.01	NS	0.05	0.01	0.01
CV (%)			10.64	9.19	10.49	11.14	6.24	9.13
Sx			3.914	2.322	20.33	0.3102	0.5477	0.09899

- Means in a column followed by the same letter (s) or without letter are not significantly different whereas figures with dissimilar letters different significantly (as per DMRT)

4.7.3 Number of pods per plant:

The number of pods per plant is one of the most contributing characters towards seed yield per unit area in mustard. It was evident from table 7 that insecticides had no significant effect on the number of pods per plant (Appendix XXII). Number of pods per plant ranged from 407.20 to 454.20 It was observed that Cypermethrin produced the maximum number of pods plant^{-1} (454.2) whereas the minimum of pods plant^{-1} (407.2) was found in control treatment.

4.7.4 Pod length (cm):

Pod length was significantly (P>0.01) affected by insecticides at harvesting time (appendix XXIII). Table 7 shows that pod length varied from 5.50 to 7.10 cm. However, the longest pod length (7.10cm) was obtained from Cypermethrin, which was statistically identical with Diazinon (6.70cm). The shortest pod length (5.50 cm) was obtained from control treatment, which was statistically at par with Chlorpyrifos (5.90cm) and Fenitrothion (5.92cm). All the treated plants increased pod length significantly over the control due to usage of insecticides.

4.7.5 Number of seeds pod $^{-1}$

The variation due to insecticides was significant (P> 0.01) for the number of seeds pod^{-1} (Appendix XXV). The number of seeds pod^{-1} ranged from 18.00 to 22.40 (Table 7). The highest number of seeds pod^{-1} (22.40) was produced by the application of Cypermethrin and followed by Diazinon (20.60). The lowest number of seeds pod^{-1} (17.80) was obtained from Fenitrothion, which was statistically similar to control treatment (18.00) and identical with Chlorpyrifos (19.40). Hossain (1993) stated that number of seeds per pod were increased significantly by the application of insecticides. All the insecticides were significantly higher than the control treatment. Among the insecticides the Cypermethrin was produced more number of seeds pod^{-1}.

4.7.6 Weight of 1000 seeds (gm)

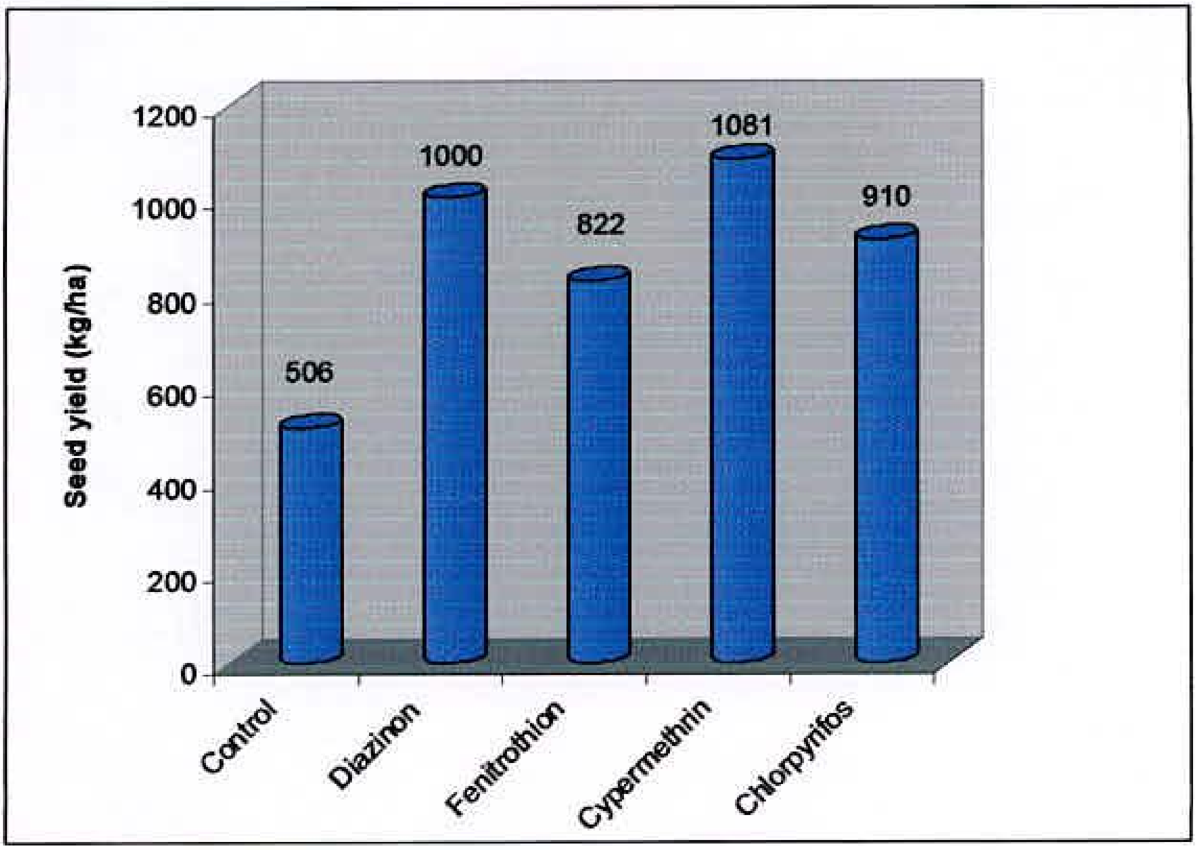
There was significant (P> 0.01) different due to insecticides in respect of 1000- seed weight (Appendix XXV). Table 7 shows that the highest 1000- seed weight (2.92 gm) was obtained under the application of Cypermethrin, which was identical with Diazinon(2.76 gm).The lowest 1000-seed weight (1.86gm) was obtained under the control treatment, which was statistically similar to Fenitrothion (2.08 gm). All the treated plants significantly increased 1000- seeds weight (gm) over the control treatment. Among these insecticides Cypermethrin was the most effective than the other treatments.

4.7.7 Seed yield (kg ha^{-1})

It was evident from analysis of variance that insecticides had a significant (P> 0.01) effect on seed yield of mustard (Appendix XXVI). Seed yield varied from 506 to 1081 kg ha^{-1} due to the application of different insecticides. Figure 1 shows that the seed yield (kg ha^{-1}) was varied due to insecticides applications. The insecticides effect on the seed yield (kg ha^{-1}) of mustard are elaborated and described below.

The highest seed yield was produced by the application of Cypermethrin (1081 kgha^{-1}) and the lowest seed yield was produced by the control treatment (506 kg ha^{-1}). Significantly the seed yield of mustard different from all other treatments due to usage of different insecticides. All the treated plants showed significant increase of seed yield over the control treatment. The application of Cypermethrin was the best in performance. The above results lead to a decision that Cypermethrin is appropriate for the control of mustard aphid.

Hossain (1993) stated that seed yield was increased significantly with the application of different insecticides in the field condition. Considering the seed yields, Ahmed and Miah (1989) reported that Cypermethrin was the most effective treatment for the control of mustard aphid. From the above discussion, it was evident that all the crop characters such as plant height, number of branches per plant, pod length, number of seeds per pod, weight of 1000 seeds and seed yield were significantly increased over the control with the application of insecticides. Number of pods per plant was not significantly different with the application of insecticides. To obtain maximum seed yield per unit area it appears that number of plants per unit area is one of the most important factor. Increase in seed yield due to application of insecticides was mainly due to improvement in yield components such as number of pods per plant, pod length, number of seeds per pod and weight of 1000 seeds. The overall growth in insecticides were treated plants might be due to the control of mustard aphid, which led to the plants a healthy growth over control treatment.



Insecticides

Fig 1. Effect of four insecticides on the seed yield of mustard

4.8 Effect of insecticides on protection efficiency (%) and yield loss (%) of mustard

The insecticides effect on protection efficiency (%) and yield loss (%) were highly significant (P>0.01) (Appendices XXVII-XXVIII). The applications of four insecticides were evaluated for protection efficiency (%) and yield loss (%) of mustard crop. Protection efficiency was ranged from 46.00 to 96.00% and yield loss was varied from 4.00 to 54.00%. The results on protection efficiency (%) and yield loss (%) are presented in the figure 3. Effect of insecticides on protection efficiency (%) and yield loss (%) of mustard are described below.

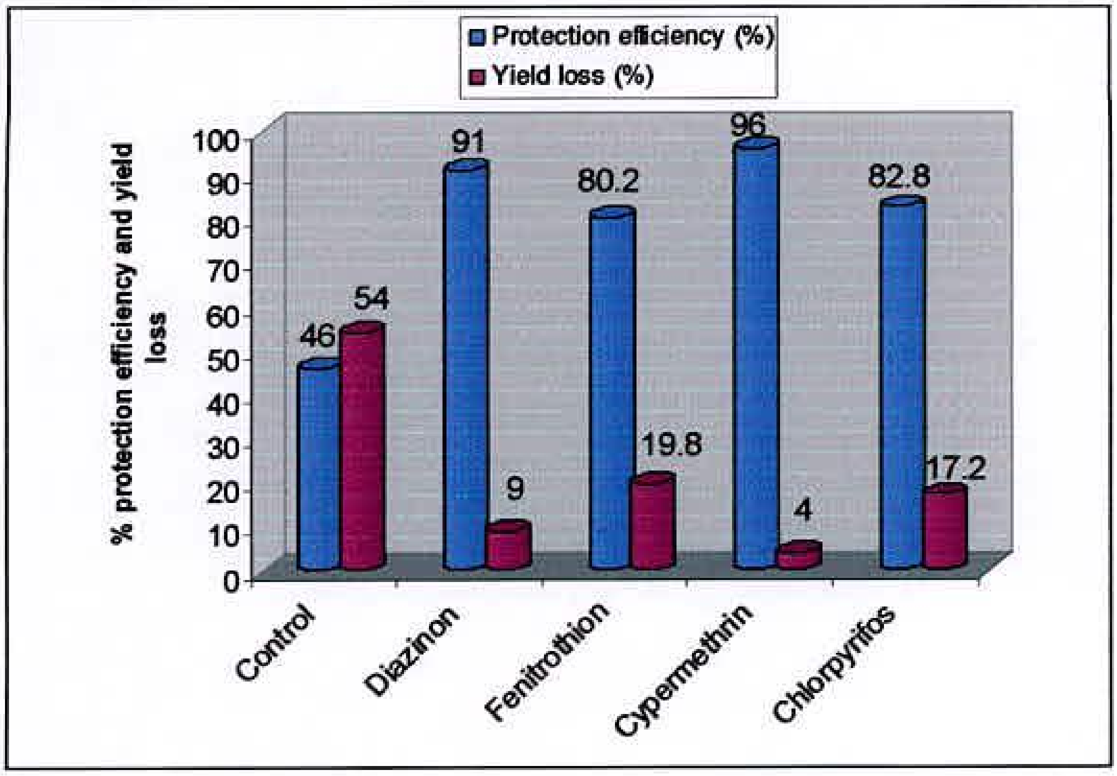
4.8.1 Protection efficiency (%)

The highest protection efficiency (%) was obtained under the treatment of Cypermethrin (96.00%) and followed by Diazinon (91.00%). The lowest protection efficiency (%) was noted under the treatment of control treatment (46.00%). The second lowest protection efficiency (%) was noticed under the application of Fenitrothion insecticide (80.20%), which was statistically similar to Chlorpyrifos (82.80%). All the treatment significantly increased protection efficiency (%) over the control treatment due to usage of insecticides. From this study, it is evident that the application of Cypermethrin was found more effective.

4.8.2 Yield loss (%)

The highest yield loss (%) was found under the treatment of control (54.00%) and the lowest yield loss (%) was found under the application of Cypermethrin (4.00%), which were statistically different from all other treatments. All the treated plants significantly decreased yield loss (%) over the control treatment. From this study, it was seen that Cypermethrin is the best treatment from other treatment.

The highest protection efficiency (96%) but lowest yield loss (4.00%) was found under the treatment of Cypermethrin, whereas the lowest protection efficiency (46.00%) but the highest yield loss (54.00%) was found under the control treatment. It was evident that the treatments in which Cypermethrin was used found more effective for the control of mustard aphid.



Insecticides

Fig 2 . Effect of four insecticides on protection efficiency and yield loss of mustard

4.9 Predation efficiency of the larva C. *septempunctata* under laboratory condition

The results on predation efficiency of the larva *C. septempunctata* are presented in the table 8 and (Plate 5). The average feeding rate of the larva *C. septempunctata* during first day after hatching was 6.40±3.05 aphids (*L. erysimi*). From the next day their feeding rate gradually increased and rose up to an average of 53.00±8.34 aphids on the 8th day. There after it again started to decline and on the 10th day, the feeding rate averaged 11.80± 4.44 aphids. This was due to pupa initiation. From this study it was observed that a larva consumed on an average of 224.60 aphids prior to pupation.

Islam and Nasiruddin (1978) mentioned that *C. septempunctata* larva consumed on an average of 3.5 cotton aphids *(A. gossypii)* during first day 24 hours after hatching. Consumption reached up to a maximum of 58.0 aphids on the 9th day. Lakhapal *et al.* (1998) found that *C. septempunctata* larvae consumed a total of 215.42±15.2 aphids *(L. erysimi)* in the larval instars. The predation efficiency of the larva *C. septempunctata* in the present study is similar to the finding of the above authors. However, the total aphid consumption differed which might be due to different of prey size and prey quality offered.

Plate 5. Fourth instar larva of *C. septempunctata* feeding on aphids

Table 8: Number of aphids consumed by a larva of different aged *C. septempunctata* under laboratory condition

Larval age (days)	Consumption rate Number ± SD
1st	6.40 ± 3.05
2nd	8.40 ± 3.78
3rd	15.60±3.36
4th	18.40±4.78
5th	21.40±4.28
6th	25.00±6.08
7th	26.00±6.67
8th	53.00±8.34
9th	38.60 ± 7.20
10th	11.80 ± 4.44

- 100 aphids (mixed age and size) were supplied for 2 perdator larvae
- Five replications each consisting of 2 individuals
- Room temperature range during experiment was 18.05 to 25.50°C
- Average relative humidity = 74.12%

4.10 Predation rate of the adult *C. septempunctata* under laboratory condition

The results of predation efficiency of adult *C. septempunctata* are presented and discussed in table 9 and (Plate 6). An adult predator *C. septempunctata* consumed an average of 21.4±5.94 aphids *(L. erysimi)* within 24 hours (first day) after emergence. Their consumption gradually increased up to 7th day and the feeding rate of aphid increased to 69.00±3.54 on the 7th day. There after it gradually dropped down and become 8.40±2.07 aphids on the 30th day. Similar feeding rate was observed by Islam and Nasiruddin (1978).

Both the larva and adult of the predator *C. septempunctata* were very active in preying aphids. A predator consumed about 224.60 and 885.40 aphids during its larval and adult stage, respectively. The finding of the present study shows that *C. septempunctata* is a good predator of *L. erysismi*

4.11 Effect of insecticides on the mortality of *L. erysimi* under laboratory condition

Corrected mortality of aphid *L. erysimi* was varied significantly (P>0.01) at different dates of sampling (Appendixes XXIX- XXXI). The results of insecticides on the mortality of *L. erysimi* under laboratory condition showed in figure 3 and ranged from 56.20 to 98.96% at 1 day, 67.32 to 89.48% at 4 days, 52.26 to 81.28% at 7 days after treatment (DAT). The results on the corrected mortality of aphid *L. erysimi* are elaborated and discussed here.

1 DAT: The highest corrected mortality of aphid *L. erysimi* was found under the application of Cypermethrin (98.96%) and the lowest corrected mortality of aphid *L. erysimi* was recorded under the application of Fenitrothion (56.20%), which were significantly different to others.

Plate 6. Adult of *C. septempunctata* feeding on aphids

Table 9: Number of aphids consumed by a adult of different aged *C. septempunctata* under laboratory condition

Adult age (days)	Consumption rate Number ± SD
1st	21.4 ± 5.94
2nd	30.4 ± 4.04
3rd	32.4± 7.72
4th	48.00±5.34
5th	61.20± 8.38
6th	62.40±7.44
7th	69.00±3.54
8th	59.60±3.51
9th	51.60 ±2.41
10th	40.00 ±3.16
11th	33.00 ±3.16
12th	33.00 ±6.08
13th	32.20 ± 4.21
14th	28.00 ± 3.81
15th	27.00 ± 3.16
16th	25.00 ± 3.61
17th	21.60 ± 2.41
18th	21.00 ± 3.39
19th	20.80 ± 1.92
20th	20.40 ± 3.98
21st	20.00 ± 4.64
22nd	18.00 ± 4.36
23rd	18.00 ± 4.30
24th	17.00 ± 2.24
25th	16.00 ± 2.24
26th	14.00 ± 2.55
27th	14.00 ± 2.55
28th	12.00 ± 3.74
29th	10.00 ± 2.24
30th	8.40 ±2.07

- 150 aphids (mixed age and size) were supplied for 1 replication
- Five replications each consisting of 1 male and 1 female
- Room temperature range during experiment was 18.05 to 20.50°C
- Average relative humidity = 74.12%

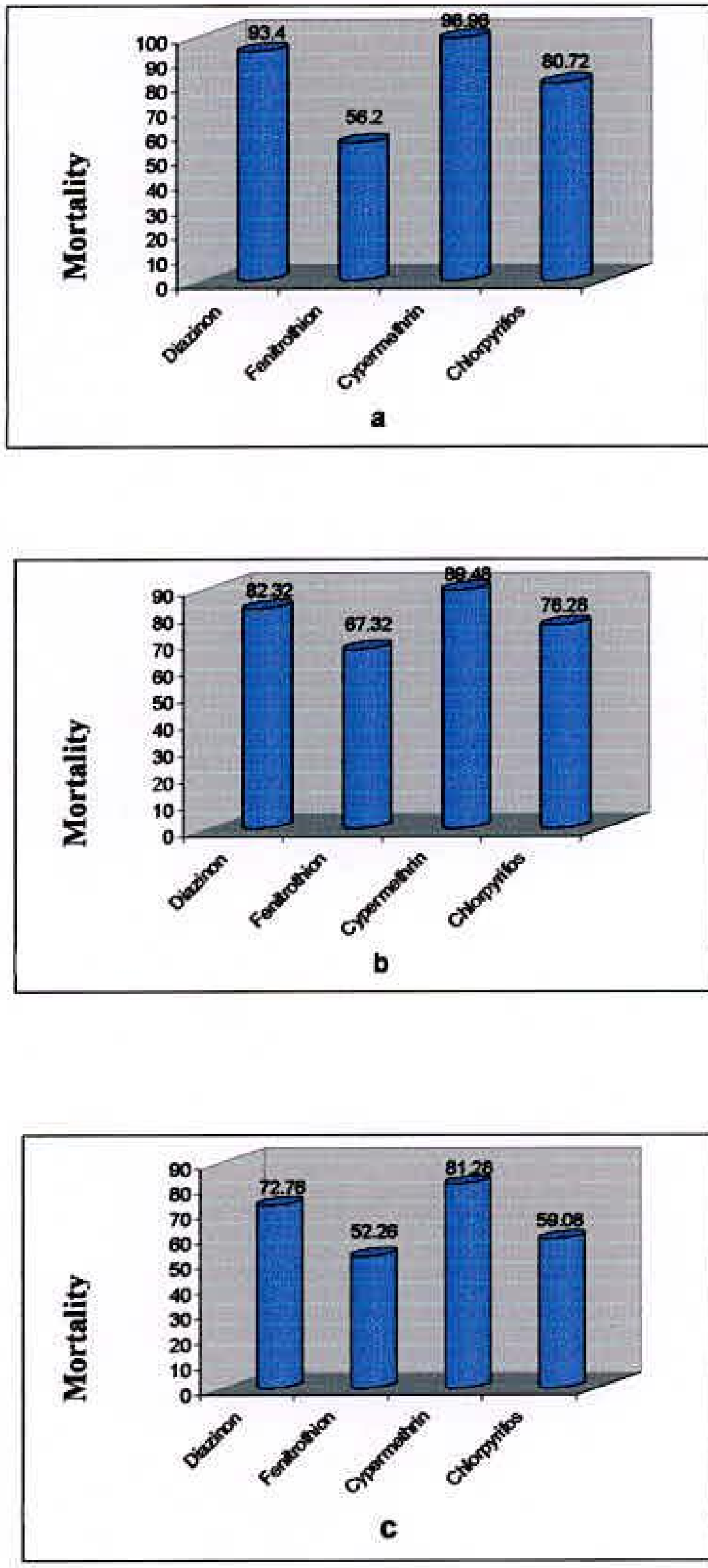


Fig 3. Effect of four insecticides on the mortality of *L. erysimi* under laboratory condition a) 1 DAT b) 4 DAT c) 7 DAT

4 DAT: The highest corrected mortality of *L. erysimi* (89.48%) was noted in Cypermethrin and the lowest corrected mortality of *L. erysimi* (67.32%) was noted in Fenitrothion. The second lowest corrected mortality of *L. erysimi* (82.32%) was found in Diazinon, which was statistically at par with Chlorpyrifos (76.28%).

7 DAT: The highest corrected mortality of *L. erysimi* was recorded from Cypermethrin (81.28%), which was statistically identical with Diazinon (72.76%). The lowest corrected mortality of *L. erysimi* recorded from Fenitrothion (52.26%), which was statistically similar to Chlorpyrifos (59.08%).

The highest corrected mortality of *L. erysimi* was obtained from the application of Cypermethrin and the lowest corrected mortality of *L. erysimi* was obtained from the application of Fenitrothion. From this study, it was also evident that the corrected mortality of *L. erysimi* is relatively lower with the increase of time after spraying. Therefore it is clear from the observation that Cypermethrin in would be appropriate for controlling the aphid.

Tripathi *et al.* (1985) stated that Decamethrin and Cypermethrin were the highest toxic to the mustard aphid *L. erysimi.* Nagia *et al.* (1989) reported that Cypermethrin and Chlorpyrifos were the highest mortality to the mustard aphid. Similar findings was also obtained by Tripathi *et al.* (1988a). All the findings are in agreement with the findings of the present study.

4.12 Effect of insecticides on the mortality of fourth instar larvae *C. septempunctata* under laboratory condition

Insecticides had a significant (P>0.01) effect on the mortality of fourth instar larvae *C. septempunctata* of different sampling dates (appendices XXXII-XXXIV). The corrected mortality of fourth instar larvae *C. septempuncatata* varied from 50.22 to 91.08% at 1 DAT, 43.92 to 77.82% at 4 DAT and 38.5 to 67.06% at 7 DAT. The percent corrected mortality of 4th instar larvae at 1,4 and 7 DAT with different

Plate 7. Mortality test of four insecticides on 4th instar larva of *C. septempuncata*

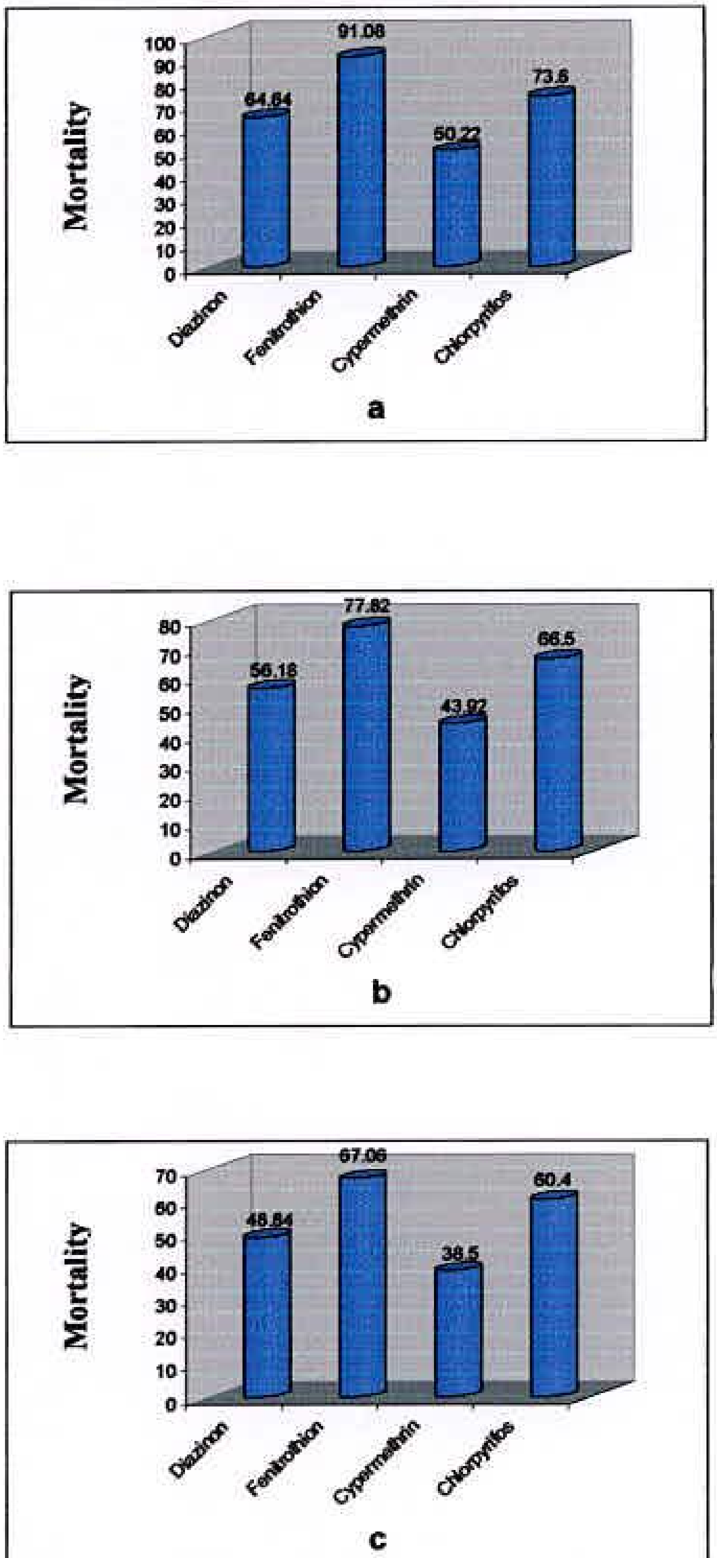


Fig 4: Effect of four insecticides on the mortality of fourth instar larvae *C. septempunctata* under laboratory condition a) 1 DAT b) 4 DAT c) 7 DAT

insecticides are presented in figure 4 and (Plate 7). The effects of different insecticides are elaborated and described here.

1 DAT: The highest corrected mortality of larvae *C. septempunctata* (91.08%) was observed under the usage of Fenitrothion and the lowest corrected morality of larvae *C. septempunctata* (50.22%) was observed under the usage of Cypermethrin which were significantly different from others .

4 DAT: The highest corrected mortality of larvae *C. septempunctata* (77.82%) was obtained under the treatment of Fenitrothion and the lowest corrected mortality of larvae *C. septempunctata* (43.92%) was obtained under the treatment of Cypermethrin which were significantly different to others.

7 DAT: The highest larval mortality was noted under the insecticide of Fenitrothion (67.06%) and the lowest larval mortality was noted under the insecticide of Cypermethrin which were significantly different from other treatments.

The highest corrected larval mortality percent was noted from Fenitrothion at 1,4 and 7 DAT and the lowest larval mortality was recorded from Cypermethrin at 1,4 and 7 DAT. From this study it was evident that Fenitrothion was the most toxic and Cypermethrin was less toxic against the larvae of the predator. Olszak (1982) reported that Fenitrothion was the most toxic to the larvae *C. septempunctata.* Sharma and Adlakhal (1986) reported that Fenitrothion was the most toxic to the predator. The present findings are similar to the findings of above authors. So, it concluded that Cypermethrin is the most effective insecticides among them.

4.13 Effect of insecticides on the morality of adult *C. septempunctata* under laboratory condition

Effect of insecticides on the mortality of adult predator *C. septempunctata* was significantly (P>0.01) different at different samplings dates (Appendices XXXV-XXXVII). The corrected mortality percent of adult predator *C. septempunctata* at different days after spraying of four insecticides were different under laboratory condition are showed and discussed (figure 5) and (Plate 8). The corrected mortality percent of adult *C. septempunctata* among the various treatment ranged from 62.02 - 90.06% at 1 day, 54.56 to 73.30 at 4 days, and 40. 44 to 66.78% at 7 days after

Plate 8. Mortality test of four insecticides on the adult of *C. septempuncata*

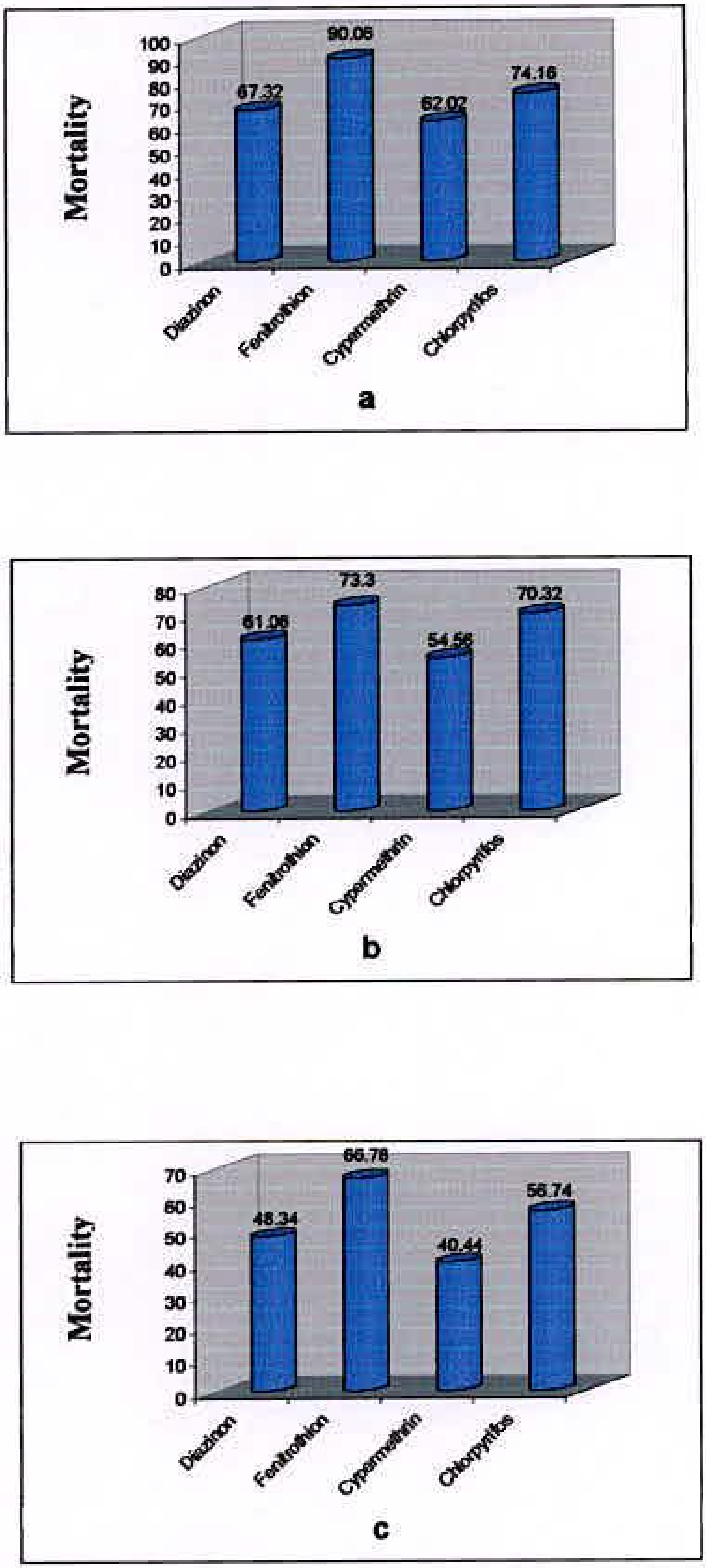


Fig 5. Effect of four insecticides on the mortality of adult *C. septempunctata* under laboratory condition a) 1 DAT b) 4 DAT c) 7 DAT

treatment (DAT). Insecticides effect on the mortality of adult *C. septempuncatata* are discussed here.

1 DAT: The corrected mortality percent of adult *C. septempunctata* was the highest (90.06%) in Fenitrothion and the lowest (62.02%) was recorded from Cypermethrin, which were significantly different from others.

4 DAT: The highest corrected mortality of adult *C. septempunctata* was noted from Fenitrothion (73.30%), which was statistically similar to Chlorpyrifos (70.32%). The lowest corrected mortality of adult *C. septempunctata* was noted from Cypermethrin (54.56%), which was statistically similar to Diazinon (61.06%).

7 DAT: The highest corrected mortality of adult predator was found from Fenitrothion (66.78%) and the lowest corrected mortality of adult predator was found from Cypermethrin (40.44%), which were significantly different from all other treatments.

At 1,4 and 7 DAT, the highest corrected mortality of adult predator *C. septempunctata* was noted from Fenitrothion and the lowest corrected mortality of adult predator *C. septempunctata* was noted from Cypermethrin. From this study, it was evident that Fenitrothion was the most toxic than the other treatments and Cypermethrin was less toxic than the other treatments. Larval predator *C. septempunctata* was less susceptible to the insecticides than their adult predator. Significant reduction of corrected mortality was found 1 day after spraying of insecticides application indicating the lowering of their effectiveness with the increasing of time. Significantly the highest corrected mortality of adult predator *C. septempunctata* was observed of Fenitrothion at 1,4 and 7 days after spraying of insecticides. From above this study it was also evident that the mortality is relative lower with the increase of time after spraying therefore it is clear from the observation that Cypermethrin would be appropriate for controlling the mustard aphid. Olszak (1982) stated that malathion and Fenitrothion had very high immediate toxicity to egg, larva, pupa and the adult *C. septempunctata*. These findings have similarity with the present findings. Similar results obtained under the application of Fenitrothion against *C. septempuncata* (Sharma and Adlakhal, 1986).

4.14 Economic evaluation of four insecticides on the seed yield of mustard

Economic evaluation of tested four insecticides based on the seed yield of mustard has been presented in table 10. The highest benefit was obtained from Cypermethrin treated plants, which gave the highest cost benefit ratio (6.96). The lowest cost benefit ratio (CBR) was observed from Fenitrothion, which gave the lowest cost benefit ratio (4.05). As the highest cost benefit ratio was observed from the treatment of Cypermethrin, this insecticide might be considered as most effective insecticide controlling the mustard aphid, *L. erysimi* among the other treatments.

From the study it may be concluded that the insecticides were significantly influenced in controlling mustard aphid and insecticides were significantly influenced to the predator. Insecticides also significantly influenced the seed yield of mustard. Application of Cypermethrin was the best treatment among the treatments. The results obtained in the study needs confirmation by further investigation. Insecticides application reduced the aphid population and increased the seed yield but also reduced the predator population.

Table 10: Economic evaluation of four insecticides on seed yield of mustard based on benefit cost ratio (BCR) obtained from controlling of mustard aphid

Name of insecticides		Dose (%)	Amount of insecticides (Litre ha^{-1})	Cost (Tk)	Return		Gross benefit ($Tkha^{-1}$)	Benefit over control $Tkha^{-1}$	Cost benefit ratio (CBR)
Trade name	Common name				Seed yield ($kgha^{-1}$)	Price of seed ($Tkha^{-1}$)			
Cymbush 10 EC	Cypermethrin	0.05	0.75	1020.00	1081	18917.50	17897.50	9042.50	6.96
Diazinon 60 EC	Diazinon	0.05	1.50	1032.00	1000	17500.00	16425.00	7570.00	6.31
Darsban 20 EC	Chlorpyrifos	0.05	1.50	900.00	910	15925.00	15025.00	6160.00	5.36
Sumithion 60 EC	Fenitrothion	0.05	1.25	900.00	822	14385.00	13225.00	4660.00	4.05
Control					506	8855			

Chapter 5

Summary and Conclusion

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SUMMARY AND CONCLUSION

The experiment was conducted at Sher-e-Bangla Agricultural University farm, Dhaka during the *rabi* season of November 2004 to February 2005 with a view to evaluate the effectiveness of insecticides in controlling mustard aphid and their effect on the predator *C. septempunctata* and seed yield of mustard cv. Tori - 7.

The experiment was laid out in randomized block design with insecticides such as Diazinon 60 EC, Sumithion 60 EC, Cymbush 10 EC, and Darsban 20 EC in the unit plots, respectively replicated five times. The plot size was 4m X 2.5m. The land was prepared finally by ploughing with the country plough followed by laddering to level the soil on 8 November 2004. The land was fertilized with urea, TSP, MP, gypsum, zinc oxide, and boric acid@ 250, 170, 85, 150, 5 and 15 kg ha^{-1}, respectively. The seeds of Tori -7 were sown in the prepared plot on 9 November 2004. Intercultural operations such as gap filling, weeding, water and diseases management were done as and where necessary. The experimental plots were treated with insecticides as per experimental requirements. Data were analyzed statistically using the "Analysis of variance" technique and mean differences were adjudged by DMRT.

Percent reduction of aphid-infested plant was significantly different and affected by both spraying of insecticides at different dates of sampling. All the insecticides were found to be effective. Among the insecticide Cypermethrin was the most effective in controlling mustard aphid and Fenitrothion was less toxic to the mustard aphid.

There was significant variation due to insecticides on percent reduction of aphid population per plant at both spraying of insecticides. Among the insecticides Cypermethrin is the most effective in controlling aphid and Fenitrothion was less toxic to the mustard aphid.

Insecticides had a significant effect on percent reduction of the predator *C. septempunctata*. Cypermethrin was less toxic to the predator and Fenitrothion was the most toxic to the predator.

Insecticides had a significant effect on crop characters except number of pods per plant. The seed yields of all the treatments were significantly better than the control. The response of Cypermethrin was comparatively better for different crop characters and seed yield. The application of Cypermethrin provided with the highest protection efficiency with the lowest yield loss.

Study of predation performance of *C. septempunctata* reflected that the larva consumed 224.60 aphids during 10 days of larval duration. An adult beetle consumed an average 885.40 aphids in 30 days period after emergence.

The corrected mortality of aphid *L. erysimi* was significantly affected under laboratory condition at different dates. The highest corrected mortality was found under the treatment of Cypermethrin and the lowest corrected mortality of aphid *L. erysimi* was found under the treatment of Fenitrothion.

The corrected mortality of the larvae *C. septempunctata* significantly different at several dates of sampling by insecticides. Fenitrothion was the most toxic to the larvae *C. septempunctata* and Cypermethrin was less toxic to the larvae *C. septempunctata*.

Insecticides affected the corrected mortality of the adult *C. septempunctata* at different dates. Fenitrothion was the highest corrected mortality of adult *C. septempunctata* and Cypermethrin was the lowest corrected mortality of adult *C. septempunctata*.

The application of Cypermethrin had the highest benefit cost ratio (BCR) followed by Diazinon and Chlorpyrifos. The application of Fenitrothion was the lowest benefit cost ratio (BCR).

So, it can be concluded that Cypermethrin is the most effective insecticide for controlling mustard aphid *L. erysimi* with less toxic to the predator *C. septempunctata*. Fenitrothion was less effective for controlling mustard aphid with the most toxic to the predator. So, Cypermethrin was the most appropriate insecticide for control of mustard aphid, which also provides with less toxic to the predator. However, more studies are necessary to confirm the findings.

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APPENDICES

Appendix I : Distribution of air temperature, relative humidity, rainfall and sunshine hours of the experimental site during the period from November 2004 to February 2005

Month	** Air temperature (^0C)			**Relative humidity (%)	*Rainfall (mm)	*Sunshine (hrs)
	Maximum	Minimum	Average			
November	29.49	19.55	24.52	84.27	0.00	222.7
December	26.52	13.19	19.85	80.84	0.00	220.2
January	26.9	10.7	18.8	85.86	7.00	200.5
February	31.5	16.6	25.05	90.00	3.00	205.1

** = Monthly average

* = Monthly total

Source : Department of weather, Head Office, Sher-e-Bangla Nagar, Dhaka-1207.

Appendix II : Analysis of variance on percent reduction of aphid infested plant after first spraying in insecticides (1 DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	220.50	55.125	2.5545	
Treatment	3	1791-49	597.164	26.5899	0.0000
Error	12	269.50	22.458		
Total	19	2281.49			

Appendix III : Analysis of variance on percent reduction of aphid infested plant after first spraying in insecticides (4DAT

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	442.00	110.50	4.6364	
Treatment	3	1489.35	496.451	20.8301	0.0000
Error	12	286.00	23.833		
Total	19	2217.345			

Appendix IV : Analysis of variance on percent reduction of aphid infested plant after first spraying in insecticides (7DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	343.500	85.875	3.1180	
Treatment	3	1785.850	595.283	21.6139	0.0000
Error	12	330.500	27.542		
Total	19	2459.850			

Appendix V : Analysis of variance on percent reduction of aphid infested plant after second spraying in insecticides (1 DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	264.500	66.125	2.5311	
Treatment	3	1144.268	381.423	14.5999	0.0000
Error	12	313.500	26.125		
Total	19	1722.268			

DAT = Day/Days after treatment

Appendix VI : Analysis of variance on percent reduction of aphid infested plant after second spraying in insecticides (4 DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	662.500	165.625	3.3830	
Treatment	3	2333.213	777.738	15.8857	0.0002
Error	12	587.500	48.958		
Total	19	3583.213			

Appendix VII : Analysis of variance on percent reduction of aphid infested plant after second spraying in insecticides (7 DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	556.274	137.569	1.6031	
Treatment	3	1514.910	504.970	5.8845	0.0104
Error	12	1029.770	85.814		
Total	19	3094.955			

Appendix VIII : Analysis of variance on percent reduction of aphid population after first spraying in insecticides (1 DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	760.500	190.125	5.6824	
Treatment	3	977.341	325.780	9.7369	0.0015
Error	12	401.500	33.458		
Total	19	2139.341			

Appendix IX : Analysis of variance on percent reduction of aphid population after first spraying in insecticides (4DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	1012.500	253.125	6.9429	
Treatment	3	856.770	285.590	7.8333	0.0037
Error	12	437	36.458		
Total	19	2306.770			

DAT = Day/Days after treatment

Appendix X : Analysis of variance on percent reduction of aphid population after first spraying in insecticides (7DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	648.000	162.000	7.3636	
Treatment	3	728.297	242.766	11.0348	0.0009
Error	12	264.000	22.000		
Total	19	1640.298			

Appendix XI : Analysis of variance on percent reduction of aphid population after second spraying in insecticides (1DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	500.001	125.000	2.1429	
Treatment	3	1727.410	575.803	9.8709	0.0015
Error	12	700.002	58.334		
Total	19	2927.413			

Appendix XII : Analysis of variance on percent reduction of aphid population after second spraying in insecticides (4DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	1152.000	288.000	6.0000	
Treatment	3	1165.84	388.62	21.5943	0.0000
Error	12	576.000	18.000		
Total	19	4837.584			

Appendix XIII : Analysis of variance on percent reduction of aphid population after second spraying in insecticides (7DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	677.000	169.250	3.0268	
Treatment	3	88.154	29.382	4.9667	0.0181
Error	12	671.000	5.917		
Total	19	2181.169			

DAT = Day/Days after treatment

Appendix XIV : Analysis of variance on percent reduction of *C. septempunctata* after first spraying in insecticides (1DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	759.500	189.875	8.8143	
Treatment	3	4587.730	1529.243	70.9900	0.0000
Error	12	258.500	21.542		
Total	19	5605.730			

Appendix XV : Analysis of variance on percent reduction of *C. septempunctata* after first spraying in insecticides (4DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	438.500	109.625	2.5519	
Treatment	3	5314.406	1771.469	41.2369	0.0000
Error	12	515.500	42.958		
Total	19	6268.406			

Appendix XVI : Analysis of variance on percent reduction of *C. septempunctata* after first spraying in insecticides (7DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	129.502	32.375	3.4534	
Treatment	3	7373.658	2457.886	262.1792	0.0000
Error	12	112.498	9.375		
Total	19	7615.658			

Appendix XVII : Analysis of variance on percent reduction of *C. septempunctata* after second spraying in insecticides (1DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	170.000	42.500	5.6667	
Treatment	3	4551.529	1517.176	202.2902	0.0000
Error	12	90.000	7.500		
Total	19	4811.529			

DAT = Day/Days after treatment

Appendix XVIII : Analysis of variance on percent reduction of *C. septempunctata* after second spraying in insecticides (4DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	84.500	21.125	2.6000	
Treatment	3	8666.090	288.697	355.5318	0.0000
Error	12	97.500	8.125		
Total	19	8848.090			

Appendix XIX : Analysis of variance on percent reduction of *C. septempunctata* after second spraying in insecticides (7DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	250.000	62.500	2.1429	
Treatment	3	6660.324	2220.108	76.1180	0.0000
Error	12	350.000	29.167		
Total	19	7260.324			

Appendix XX : Analysis of variance on plant height treated with insecticides

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	254.400	63.600	0.8303	
Treatment	4	1164.560	291.140	3.8008	0.0234
Error	16	1225.600	76.600		
Total	24	2644.560			

Appendix XXI : Analysis of variance on number of branches per plant treated with insecticides

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	50.000	12.500	4.1667	
Treatment	4	122.560	30.640	10.2133	0.0003
Error	16	48.000	3.000		
Total	24	220.560			

Appendix XXII : Analysis of variance on number of pods per plant treated with insecticides

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	6464.002	1616.000	0.7822	
Treatment	4	6336.559	1584.140	0.7668	
Error	16	33056.007	2066.000		
Total	24	45856.568			

Appendix XXIII : Analysis of variance on pod length treated with insecticides

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	3.924	0.981	20.395	
Treatment	4	8.578	2.144	4.4582	0.0131
Error	16	7.696	0.481		
Total	24	20.198			

Appendix XXIV : Analysis of variance on seeds per pod treated with insecticides

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	26.000	6.500	4.3333	
Treatment	4	73.360	18340	12.2267	0.0001
Error	16	24.000	1.500		
Total	24	123.360			

Appendix XXV : Analysis of variance on weight of thousand seed treated with insecticides

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	1.027	0.257	5.2226	
Treatment	4	4.022	1.006	20.4640	0.0000
Error	16	0.780	0.049		
Total	24	5.835			

Appendix XXVI : Analysis of variance on seed yield treated with insecticides

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	35360.000	8840.000	3.7778	
Treatment	4	988144.000	247036.000	105.5709	0.0000
Error	16	37440.000	2340.000		
Total	24	1060944.000			

Appendix XXVII : Analysis of variance on protection efficiency (%) treated with insecticides

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	27.20	6.75	0.608	
Treatment	4	7688.4	19.22	173.15	0.0000
Error	16	177	11.1		
Total	24	7892.60			

Appendix XXVIII : Analysis of variance on yield loss (%) treated with insecticides

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	27.8	6.95	0.630	
Treatment	4	7655	1913.75	173.35	0.0000
Error	16	176.6	11.04		
Total	24	7859.4			

Appendix XXIX : Analysis of variance on corrected mortality of aphid treated with insecticides (1DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	180.500	45.125	4.9452	
Treatment	3	5382.950	1794.317	196.6374	0.0000
Error	12	109.500	9.125		
Total	19	5672.950			

Appendix XXX : Analysis of variance on corrected mortality of aphid treated with insecticides (4 DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	110.500	27.625	1.2775	
Treatment	3	1254.956	418.319	19.3442	0.0001
Error	12	259.500	21.625		
Total	19	1624.956			

Appendix XXXI : Analysis of variance on corrected mortality of aphid treated with insecticides (7 DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	512.000	128.000	3.0968	
Treatment	3	2576.870	858.957	20.7812	0.0000
Error	12	496.000	41.333		
Total	19	3584.870			

Appendix XXXII : Analysis of variance on corrected mortality of larvae *C. septempunctata* treated with insecticides (1DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	180.500	45.125	6.0503	
Treatment	3	4386.258	1462.086	196.0339	0.0000
Error	12	89.500	7.458		
Total	19	4656.258			

Appendix XXXIII : Analysis of variance on corrected mortality of larvae *C. septempunctata* treated with insecticides (4 DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	338.000	84.500	20.2800	
Treatment	3	3140.386	1046.795	251.2309	0.0000
Error	12	50.000	4.167		
Total	19	3528.386			

- DAT = Days after treatment

Appendix XXXIV : Analysis of variance on corrected mortality of larvae *C. septempunctata* treated with insecticides (7 DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	220.500	55.125	6.0411	
Treatment	3	2390.196	796.732	87.3131	0.0000
Error	12	109.500	9.125		
Total	19	7220.196			

Appendix XXXV : Analysis of variance on corrected mortality of adult *C. septempunctata* treated with insecticides (1 DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	264.500	66.125	10.7959	
Treatment	3	2223.006	741.002	120.39798	0.0000
Error	12	73.500	6.125		
Total	19	2561.006			

Appendix XXXVI : Analysis of variance on mortality of adult *C. septempunctata* treated with insecticides (4DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	455.000	113.750	4.3060	
Treatment	3	1107.826	369.275	13.9789	0.0003
Error	12	317.000	26.417		
Total	19	1879.826			

Appendix XXXVII : Analysis of variance on mortality of adult *C. septempunctata* treated with insecticides (7DAT)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value	Probability
Replication	4	218.000	54.000	4.1392	
Treatment	3	1916.614	638.871	48.5219	0.0000
Error	12	158.000	13.167		
Total	19	2292.613			

- DAT = Days after treatment