EFFICIENCY OF SOME CHEMICAL INSECTICIDES IN CONTROLLING MUSTARD APHID AND THEIR IMPACT ON PREDATORY LADY BIRD BEETLE

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DHAKA-1207

JUNE, 2015

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A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka-1207
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (M.S.)
IN
DEPARTMENT OF ENTOMOLOGY
SEMESTER: JANUARY- JUNE, 2015

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This is to certify that the thesis entitled, **"EFFICIENCY OF SOME CHEMICAL INSECTICIDES IN CONTROLLING MUSTARD APHID AND THEIR IMPACT ON PREDATORY LADY BIRD BEETLE"** 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 *bona fide* research work carried out by **MD. BELAL HOSSAIN**, Registration No.: 14-06330, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

Dated:
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Dedicated

To

Almighty to bless me ever with the best of all the choices

&

My loving parents
and teachers
who laid the foundation of my success

ACKNOWLEDGEMENT

At first the author expresses his gratefulness to almighty Allah who has helped him to pursue his higher education in Agriculture and for giving the strength of successful completion of this research work.

With deepest emotion the author wishes to express his heartfelt gratitude, indebtedness, regards, sincere appreciation to his benevolent research Supervisor **Dr. Md. Mizanur Rahman** Professor Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for his intellectual guidance, intense supervision, affectionate feelings and continuous encouragement during the research work and for offering valuable suggestions for the improvement of the thesis.

The author is highly grateful and obliged to his Co-Supervisor, **Dr. S. M. Mizanur Rahman**, Associate Professor, Department of Entomology (SAU) Dhaka, Bangladesh for his continuous encouragement, innovative suggestion, and affectionate inspiration throughout the study.

Cordial thanks are extended to all respected teachers of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh and all the staffs especially to **Ishrat Jahan Simu**, Asst. Register, Department of Entomology (SAU) for their co-operation throughout the study.

Finally, the author expresses his heartfelt indebtedness to his beloved father **Md. Lutfar Rahman**; mother **Mst. Buly Bibi**, for their sacrifice, encouragement and blessing to carry out higher study which can never be forgotten.

June, 2015 The Author

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ABSTRACT

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the Rabi season 2014-2015 to evaluate the effectiveness of some promising insecticides on aphid population abundance as well as their impacts on the incidence of predatory lady bird beetle in field and laboratory condition. The treatments composed of five chemical insecticides viz., foliar spray of Morter 48 EC (chlorpyrifos) @ 1 ml/L of water, Imitaf 20 SL (imidacloprid) @ 1 ml/L of water, Marshal 20 EC (carbosulfan) @ 1 ml/L of water, Ripcord 10 EC (cypermethrin) @ 1 ml/L of water, Diaraz 60 EC (diazinon) @ 1 ml/L of water and an untreated control. Among five insecticides, Imitaf 20 SL performed as the most effective insecticide in reducing the highest percent of aphid population on leaves (60.00%) whereas Ripcord 10 EC showed the least performance (39.54%). In inflorescence, Morter 48 EC performed as the most effective insecticide in reducing the highest percent of aphid population (68.06%) whereas Imitaf 20 SL showed the least performance (53.57%). In stem, Ripcord 10 EC performed as the most effective insecticide in reducing the highest percent of aphid population (62.69%) whereas Diaraz 60 EC showed the least performance (57.73%). In pod, Imitaf 20 SL performed as the most effective insecticide in reducing the highest percent of aphid population (61.11%) whereas Ripcord 10 EC showed the least performance (58. 22%). Under field condition Ripcord 10 EC reduced the highest number of lady bird beetle population, the percent reduction was (63.74%) and the least reduction was performed by Imitaf 20 SL (55.56%). In laboratory condition the highest percent of aphid reduction performed by Imitaf 20 SL (90.00%) and the least performance was Diaraz 60 EC (66.67%) as it was the highest percent of lady bird beetle reduction performed by Imitaf 20 SL (44.00%) and the least performance by Ripcord 10 EC was (28.67%). The maximum yield obtained from treatment Imitaf 20 SL (812 kg/ha) due to lower aphid abundance. On the other hand, low yield performance obtained from the T_6 treatment due to an untreated control (310.2 kg/ha).

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INTRODUCTION

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INTRODUCTION

Mustard is one of the important oleiferous crops which and constitutes a major source of edible oil for human consumption and cake for animals. Mustard plant belongs to the genus *Brassica* under the family Cruciferae. In our country, mainly three mustard species are cultivated viz, *Brassica campestris*, *Brassica juncea* and *Brassica napus*. This crop is well adapted to almost all agro-climatic zones and grows in Rabi season. It occupies an area of 2,42,000 ha land and produces about 2,22,000 ton of oilseeds per year. The yield of mustard is 916.00 kg/ha in Bangladesh (BBS, 2010).

Among the oil seed crops, mustard ranks first in Bangladesh and its performance in total oilseed production is approximately 70 percent. It occupies first position in the list in respect of area and production among the oilseed crops grown in this country (BBS, 2004). Annual requirement of edible oil for Bangladesh is 0.5 million metric tons. That is, the internal production of edible oil can meet up only less than one-third of the annual requirement of Bangladesh and it has been in short of 65 to 70% of the requirement. As a result, a huge amount of foreign currency is spent every year for importing oil and oilseed from abroad. Mustard seed contain 40-45% oil and 20-25% protein. Using local ghani on average 33% oil may be extracted (Mondal and Wahab, 2001).

It is not only a rich source of energy (about 9 kcal), but also rich in fat soluble vitamins A, D, E and K. The national nutrition council (NCC) of Bangladesh reported that recommended dietary allowance (RDA) per capita per day is 6 g of oil for a diet with 2700 kcal, Oil cake is also a nutritious food item for cattle and fish and used as good organic fertilizer. The oil cake has a very low content of the glucosinolates responsible for metabolic disruption in cattle and pigs (USDA, 2011).

The average yield of mustard per ha is very low in Bangladesh. There are many limiting factors in mustard production such as weather, insufficient nutrient in soil, disease and insect pests is responsible for such low yield. Bangladesh and elsewhere mustard aphid, *Lipaphis erysimi* (Kalt) is the most serious and destructive pest of mustard and a major limiting factor for successful cultivation of mustard seed production (Begum,1995, Biswas *et al.,* 2000) and has attained the level of key pest. Mustard aphid belongs to the superfamily Aphidoidea of the order Homoptera. Both nymphs and adults of this pest cause damage to mustard plants from early vegetative to siliqua maturity stage (Verma and Singh, 1987) by de-sapping inflorescence, flower and pods, resulting stunted growth of the plant, flowers wither and pod formation is hindered. Although aphid is a minute insect it may destroy the plants even quicker than larger insects and adversely affects the productivity. Honeydews secreted by aphids are favorite medium for the development of sooty mold on plants. As a result, crop gets black and dies before bearing of seeds. Increase in population beyond 9.45 aphids per plant; reduce the seed yield by 59.3 percent with an economic injury level of 2.04 aphids/plants and infestation of 37.4 percent (Singh and Malik, 1998).

The use of synthetic chemical pesticides has accounted for astonishing gains in production, as the pesticides have reduced the hidden toll exacted by the aggregated attack of insect-pests. Keeping in view the importance of this crop and its substantial loss by mustard aphids, farmers generally spray insecticides in their field.

Said and Begum (2005) reported that chemical insecticides reduced aphid population on mustard with application of Curacron (43.45 aphid per inch of inflorescence), followed by Ripcord, Actara, Bestox, Karate, Thiodan, Lorsban, Advantage, Methamidophos and Sevin with 26.31, 26.92, 27.68, 30.45, 31.26, 33.79, 37.32, 42.32 and 43.77 aphid per cm of inflorescence respectively. Amer *et al.,* (2010) reported that the lowest numbers of aphids were observed where Talstar was applied as compared to Advantage, Actara and Confidor. Bakhetia (1984) and Khurana and Batra (1989) also reported that good control of mustard aphid has been obtained by spraying traditional organic insecticides. Mannan *et al., (*2002) reported that different doses (1 ml, 2 ml, 3 ml/L water) of Malathion 57 EC were more effective than same doses of Diazinon 60 EC for the control of aphids and it was less toxic to the predator and other beneficial insects. The lower dose of insecticides has less adverse effect on the predator and other beneficial insects than the higher dose. Sing and Sircar (1983) reported that most toxic compounds against eight species of aphids and *Coccinella septempunctata* were Phorate, Dimethoate and Carbaryl, whereas Endosulfan, Lindane and Phidan were effective against aphid and relatively safe against *C. septempunctata*. Bunker and Ameta (2009) and several earlier workers worked on the feeding potential of coccinellids on aphids and found large variations. Bilashini and Singh (2009) observed and reported that the coccinellids were found to prey on the life stages of prey available within their reach. Among the larval stages highest voracity was observed in IV instars larvae.

The indiscriminate uses of synthetic insecticides cause resistance of this insect pest, destruction of beneficial organisms and environmental pollution (McIntyre *et al.,* 1989). Therefore, it is necessary to find out the ecologically sound and environmentally safe methods for this aphid control.

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 to many injurious insects (Agarwala *et al.*, 1988). In the field, mustard aphid population is naturally controlled to a large extent by its predator *Coccinella septempunctata* and plays a vital role in lowering the population of mustard aphid in the field (Kalra, 1988). For controlling the mustard aphid successfully and to save *C. septempunctata*, insecticides should be applied at appropriate dose and at right time.

Considering these facts as stated above, the present investigation was undertaken both in field and laboratory condition with the following objectives:

1. to find out the level of infestation caused by aphids on mustard;
2. to explore the effectiveness of different insecticides on the reduction of aphid infestation on mustard;
3. to evaluate the impact of insecticides on the lady bird beetle and other beneficial insects during the management of mustard aphid.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Mustard aphid, *Lipaphis erysimi* (Kalt.) is one of the most important insect pests of cruciferous crops in Bangladesh. Good number of research works has been done on different aspects of mustard in different parts of the world. Although considerable literature dealing with loss occurred due to aphid infestation, effect of different insecticides on aphid infestation and reducing the loss occurred by aphid with treating different dose of insecticide and increasing the yield are available. Some of the works related to the present study have been presented below under the following sub-headings:

2.1 General review on mustard aphid and ladybird beetle

Literature dealing with taxonomy, distribution and host range of mustard aphid, *L. erysimi*, extent of damage and yield loss caused by mustard aphid have been presented below:

2.1.1. Taxonomy of mustard aphid

The taxonomic features of apterae and alate of *Lipaphis erysimi* (Kalt). It is a short bodied, yellowish and green or greenish colored species measuring 2-2.5 mm length when they are fully grown. The adults may be wingless (Apterae) or winged (Alate) with two pairs of hyaline wings. The fifth abdominal segment bears a pair of cornicles. The winged adults usually have black body markings and blackish head.

Taxonomic position of mustard aphid

Kingdom: Animalia

Class: Insecta

Sub-Class: Pterygota

Division: Exopterygota

Order: Homoptera

Family: Aphididae

Subfamily: Aphinidae

Genus: Lipaphis

Species: *Lipaphis erysimi* Kalt.

2.1.2. Distribution of mustard aphid

The mustard aphid, *L. erysimi* (Kalt.) is distributed worldwide (Martin 1983, Pradhan 1995). It is found in all tropical and subtropical countries (Scmutterer, 1978) and is recognized as a worldwide serious cruciferous pest (Atwal *et al.*, 1976).

2.1.3. Host range of mustard aphid

Jahan and Rahman (2011) conducted a study to know the diverse response on growth stages of mustard varieties to mustard aphids. Among ten mustard varieties, the maximum aphid population was recorded on Tori-7 at flowering stage but the population reached to the peak in BS-5 variety. Pod formation stage was more vulnerable for aphid infestation and increased population. Aphid infestation received higher at pod formation stage than flowering stage and consequently produced lower yield.

(Dixon 1982) Vegetable crops viz turnip, Chinese kale, mustard, flowering cabbage and Chinese cabbage possess 63.43, 10.04, 24.93, 23.32 and 114.31 aphids/plant, respectively. In temperate climate, many aphid species are host alternating and have a primary host, which is usually a woody plant and secondary hosts, which are generally herbaceous.

Lipaphis erysimi is well known as a serious pest of mustard, cauliflower, turnip, kohlrabi, radish, Chinese cabbage, rai, tori, Brussels sprout, broccoli, kale and rutabaga and a minor pest of bean, beet spinach, pea celery, onion, stock, cucumber and potato (Scmutterer 1978).

2.1.4. Seasonal abundance of mustard aphid and its predators

Bhadra and Parna (2010) found that the mustard aphid, *Lipaphis erysimi* (Kalt) is a serious pest of mustard in tropical regions in the world. The population dynamics of this species is considerably influenced by immigrant alate, which migrate to the mustard crop from the off-season shelter. Aphids reproduce at a higher rate in the early vegetative stage of mustard plants when the developmental period is shortest and production of winged morphs is lowest. The population reaches an asymptote when the crop is 70 days old. The species regulates its developmental period, fecundity and intrinsic rate of increase in response to developmental changes of the mustard plant and maintains its dispersal throughout the duration of the mustard crop. In succeeding generations on a mustard plant new born nymphs took increasingly longer to develop into adults and over the same period these adults produced decreasingly fewer numbers of offspring. In the inflorescence and fruiting stages of mustard plants a higher proportion of the nymphs developed into alatae.

Aphids are an important group of plant insect pests. They have a high biological potential with some of aphid’s species (Aphididae) having more than ten generations in one year (Iversen and Harding, 2007). Because of their direct (sucking) and indirect (transmission of viruses and honeydew secretion) damage on cultivated and wildgrowing plants, the producers of food plant, ornamental plants and feed for livestock and control them in different ways.

Vekaria and Patel (2005) conducted an experiment during Rabi 1993-94 and 1994-95 revealed that the incidence of aphid commenced from 6 weeks after sowing (WAS) i.e., the third week of December and reached the peak intensity (3.94 AT) at 14 weeks after sowing coinciding with second week of February during 1993-94, however, during 1994-95 aphid incidence commenced at late (8 WAS), i.e. during last week of December and reached the peak intensity (3.08 AT) at 13 WAS coinciding with first week of February. The aphid population exceed above economic threshold level (ETL) between 11 and 14 WAS coinciding with the third week of January to second week of February. The predominant coccinellid predator *Coccinella septempunctata* was active between last week of January and last week of February with maximum population (5.52 and 3.07 beetles/plant) during third week of February in both the years.

Panda *et al.* (2000) conducted an experiment during the 1998-99 winter seasons to study the intensity and population fluctuation of *Lipaphis erysimi* on *Brassica juncea* in relation to the prevailing abiotic and biotic conditions. The aphid species infested the crop from the 2nd to the 14th standard week (SW) with its peak (302.10 aphids per plant) during 7th SW in 70 day old crops. The minimum temperature between 7.1 and 15.1°C, maximum temperature between 24.9 and 29°C were found to be congenial for the proper development of aphid population. The natural enemies like *Menochilus sexmaculatus* influenced the aphid population during their activity period from January to February.

Nayak *et al.* (2000) studied during the Rabi season of 1996-97 to determine the seasonal abundance of the *L. erysimi* pest. The highest aphid population was recorded on the second week of January, when it reached 42.95, 22.95, 22.30, 17.35, 16.32 and 11.72

on Indian mustard, cabbage, cauliflower, knolkhol, radish and turnip respectively. Thereafter, the aphid numbers declined. Overall, the mean aphid population during the season was highest (10.59) on radish and lowest (6.97) on turnip.

2.1.5. Extent of damage and yield loss caused by mustard aphid

Shelly (2009) found that two aphid species, *Brevicoryne brassicae* L., and *Lipahis eyrsimi* (Kalt.) were observed as the most devastating pests. Populations of B. *brassicae* were more than that of *L. eyrsimi*. All the varieties evaluated were found susceptible and weekly population of both the species of aphids did not differ significantly from their appearance till maturity of the crop. Appearance of aphids at all the locations was not uniform. However, the highest population was recorded during last week of February to second week of March.

Sam and Pang (1999) observed that the population dynamics of alates and apterous of turnip aphid, *Lipaphis erysimi* (Kalt.) on five host vegetable varieties in the field. The results showed that the average populations of apterous aphid on host vegetable varieties turnip, Chinese kale, mustard leaf, flowering cabbage and Chinese cabbage were 63. 425, 10. 041, 24. 928, 23. 323 and 114. 308 aphids/plant, respectively.

The mustard aphid *Lipaphis erysimi* (Kalt) causes serious losses of yield in Mustard crops and reduces its marketable value. Increase in population beyond 9.45

aphids per plant; reduce the seed yield by 59.3 per cent with an economic injury level of 2.04 aphids/plants with an index of 0.98 and infestation 37.4 per cent (Singh and Malik, 1998).

The yield loss due to aphid infestation in mustard ranged from 87.16 to 98.16% (Anon., 1995). Greatest loss reported in yield only due to mustard aphid, (*Lipaphis eyrsimi* Kalt.) is 83% to rapeseed and mustard in India (Mandal *et al.*, 1994). Losses due to insect pests are estimated to be 70-80% in Pakistan. But in case of severe infestation in years of sporadic attack there may be no grain formation at all (Khattak *et al.*, 2002). The colonies of mustard aphids feed on the new shoots, inflorescence and underside of leaves. Loss in yield up to 91.3 % (Sharma and Kashyap, 1998) and oil contents up to 15 % (Verma and Singh, 1987).

The damage is caused by both nymphs and the adults, these are louse-like and pale greenish insects, is seen feeding in large numbers, often covering the entire surface of the flower buds, shoots, pods etc. (Ahmed and Jalil, 1993). In case of severe aphid infestation, leaves become curled, plant fails to develop pods, the young pods when developed fail to become mature and cannot produce healthy seeds. As a result, plants loss their vigor and growth becomes stunted (Morzia and Huq, 1991).

Khan and Munir (1986) observed the effect of aphid infestation on seed yield and other characteristics of Raya. The number of pods per plant in the treated (506.25) and in un-treated (187.02) was found significantly different from each other.

2.2. Management of mustard aphid

The most frequently mentioned control methods are spraying the plants with insecticides (Parker *et al.*, 2006), the use of corresponding agro-technical measures and in a lower extent the use of biological control agents (Du *et al.*, 2004).

2.2.1. Role of chemical insecticides for the management of mustard aphid

Sarwar (2011) conducted a study to evaluate the effects of new insecticides like, Imidacloprid (Confidor 200 EC), Thiamethoxam (Actara 25 WG) and Acetamiprid (Megamos 20 SL) along with conventional insecticides such as, Chlorpyrifos (Lorsban 40 EC) and Dimethoate (Systoate 40 EC) belonging to Organophosphate group against aphid's population. The study reflected that, newer insecticides were superior in reducing the population of aphids and yield enhancement as compared to conventional insecticides. The best results were achieved with the application of Imidacloprid by recording the lowest number of aphids (2.2 per plant) than obtained with Thiomethoxam and Acetamiprid (3.22 and 4.66, respectively). Other insecticides, viz., Chlorpyrifos and Dimethoate were also found to be effective in maintaining the aphids' population at lower levels per plant (16.2 and 17.5, respectively) over untreated control (227.7).

Amer (2010a) conducted an experiment with conventional and neonicotinoid insecticides to test their toxicity to cabbage aphid, *Brevicoryne brassicae* L. and turnip aphid, *Lipaphis erysimi* (Kalt). Insecticides were Actara 25WG @ 15g a.i/ha, Confidor 20SL @ 0.125 L. a.i/ha, Advantage 20EC @ 0.5 L. a.i/ha, Talstar 10EC @ 0.0625 L. a.i/ha and Methamidophos 60 SL @ 1.5L. a.i/ha. Seven days after application all the insecticides proved to be similarly toxic to aphids and statistically higher numbers of both aphid species were observed in untreated plots. The lowest numbers of aphids were observed in plots where Talstar was applied as compared to Advantage, Actara and Confidor. However, aphid numbers were too high even after three days of application particularly after first spray. Results of this study suggest that insecticides should not be applied at pod-filling stage to manage aphids.

Amer (2010b) studied the effectiveness of nine insecticides against mustard aphid, *Lipaphis erysimi* (Kalt.) on mustard as foliar spray. Studies revealed that seventh day of spray; imadacloprid 17.8 SL @ 0.0178% gave most effective control. On seventh day after spray, the order of effectiveness was imadacloprid 0.0178%> oxydemeton methyl 0.025%> monocrotophos 0.036%> dimethoate 0.03%> chloropyriphos 0.05%> malathion 0.05%> endosulfan 0.07%> cypermethrin 0.01%> neemarin, respectively.

Said (2005) also reported that after two weeks of spray of insecticides Karate was found best in suppressing of pest population (9.67 aphid per inch of inflorescence), followed by Actara, Ripcord, Bestox, Curacron, Lorsban, Thiodan, Methamidophos, Advantage and Sevin with reduction of aphid population to 14.44, 18.00, 19.78, 20.33,23.22, 24.78, 24.89, 34.11 and 49.11 per inch of inflorescence respectively. All of insecticides were found effective against aphids on canola crop compared to control (130.00 aphids per inch of inflorescence) at 5% level of significance.

Gami (2002) reported the results of 11 different insecticide treatments with methyl-o-demeton 0.025%, carbosulfan 0.04%, methyl parathion 2% dust @ 25kg/ha and monocrotophos 0.04% were found highly effective against mustard aphid, *Lipaphis erysimi* Kaltebach. Profenophos 0.05% and azadirachtin 0.00075% were found less effective against this pest.

Tong (2001) reported the toxicity baselines and efficacies of primicarb (Pirimor, imidacloprid (Provado), thiamethoxam (Actara) and lambda-cyhalothrin (Warrior) were bioassayed in the laboratory and tested in the field against mustard aphid, *Lipaphis erysimi* (Kalt). Results showed that the LC50 and LD50 of the four insecticides for apterous *L. erysimi* adults were comparable with those for other aphid species. Results from field trials showed that primicarb and lambda-cyhalothrin were the most effective among these insecticides, followed by imidacloprid. A field rate (25 gm a.i./ha) of thiamethoxam did not provide satisfactory control of *L. erysimi*, but higher field rate did (50 gm a.i./ha).

Gazi (2001) tested five organophosporus insecticides viz., phosphamdon, quinalphos, malathion, dimethoate and diazinon against mustard aphid, *Lipaphis erysimi* (Kalt) in the field and net house condition. All these insecticides significantly controlled mustard aphid. Quinalphos was comparatively more effective in controlling mustard aphid followed by phosphamidon. Diethoate, diazinon and malathion showed more or less response against the mustard aphid.

Khan and Akber (1999) stated that significantly high grain yield of 1.44, 1.35, 1.20, 1.05 kg /plot (3 x 5m size) was obtained in Tamaron 600 SL, Follidole 50 EC, Ripcord and Nuvacron treated plots, respectively, compared to grain yield of 0.75 kg/plot obtained from untreated plot of the same size.

Phadke (1990) studied that in Bangladesh and other areas of Indo-Pak subcontinent, foliar insecticides generally control insect pest of mustard. Other control methods like cultural, biological are not well known to farmers.

Bhuiyan (1989) conducted an experiment to find out the most effective insecticide (s) for the control of mustard aphid, *Lipaphis erysimi* Kaltenback (Homoptera: Aphididae) in the field. Eight different insecticides, namely, Marshal 20 EC, Dimecron 100 EC, Malathion 57 EC, Zolone 35 EC, Perfekthion 40 EC, Ripcord 10 EC, Diazinon 60 EC, and Elsan 50 EC were applied as general application covering the whole plants. The mortality data recorded 24 and 48 hours after insecticidal treatments were subjected to statistical analysis. Significant difference was observed among the treatments at 1% level of probability. The results indicated that Marshal 20 EC, Zolone 35 EC and Perfekthion 40 EC – 2 ml/L of water were most effective insecticides in reducing aphid population.

Thakur and Kashyap (1989) tested the toxicity and persistence of different compounds on final instar nymphs of mustard aphid (*L. erysimi*). They noted that malathion retained some toxicity 3 days after spraying on sarson leaves. In laboratory ingestion tests, % toxicity LC_{50} values to *Apis mellifera* were determined 0.0615.

Karishniah and Mohan (1983) conducted an experiment on mustard aphids and observed that mustard aphid population on cabbage was in considerable number after third spray in November. Quinalphos, methamidophos, chlorpyrifos (0.5kg ai/ha) monocrotophos (both 0.3 and 0.5 kg ai/ha), endosulfan (0.7 kg ai/ha) gave effective control and suppressed the population for over fortnight. Performance of monocrotophos at 0.3 kg ai/ha was equally good as that at 0.5 kg ai/ha phosphamidon. Phenthoate, methomyl, chlorfenvinphos, malathion, fenitrothion, trichlorfon, garlic oil, carbaryl and dicrotophos were also found ineffective.

Gandhale *et al.* (1983) tested endosulfan, quinalphos, fenitrothion, phosalone and malathion at 0.05% and formothion and thiometon at 0.02% for their effectiveness against the aphid on cabbage in field trials and reported that the highest mortality was caused by thiometon (77.28%), while malathion was least effective (62.48%). The mortalities caused by the remaining treatments ranged from 7.50 to 76.57%.

Ahmad (1970) studied systemic activity of four granular insecticides (phorate 10%, Temik 10%, diazinon 5% and Sevidol [8% carbaryl + 8% gamma-BHC]) for the control of mustard aphid, *Lipaphis erysimi* (Kalt). The granules were applied in the soil to one-month old mustard plants transplanted in pots. Mortality counts were made 24 hours after release. Of the insecticides tested, phorate and Temik at 1 lb a.i./ac proved most effective. Temik had a quick knockdown effect as compared to phorate, as it gave 100% control within 24 hours, while with phorate 100% kill was obtained only after 72 hours. Diazinon at 4 lb a.i./ac gave 83.3% kill after 72 hours. Sevidol proved ineffective as an aphidicide.

2.2.2. Role of ladybird beetle for the management of mustard aphid

Sarwar and Saqib (2010) conducted an experiment with seven-spotted ladybird beetle *Coccinella septempunctata* L., a natural enemy of aphids, had been reared on natural and alternative artificial foods. Both larvae and adults of *C. septempunctata* fed on aphid and artificial diet, the predator normally completed its development from egg to adulthood in 20.6 days on aphid prey, in contrast to 29.0 days, when fed on artificial diet. These results indicated that artificial diet containing important ingredients for adults and larvae of *C. septempunctata* can serve as substitute food for the coccinellids, and reproduction nevertheless can occur in the absence of preferred aphid prey. The present findings can best be utilized for effective mass production of coccinellids species intended for biological control of insect pests.

Pushpendra and Prakash (2010) found that feeding potential of seven spotted lady beetle, *Coccinella septumpunctata* (Linn) was studied under laboratory conditions on mustard aphid, *Lipaphis erysimi* (Kaltenbach) and cotton aphid, *Aphis gossypii* (Glover). *C. septumpunctata* showed high feeding performance on mustard aphids *L. erysimi* than *A. gossypii*. The fourth instar larvae of *C. septumpunctata* consumed the highest number of aphids of *L. erysimi* and the hourly consumption was 6.50±0.80, 6.10±0.73 and 6.40±0.96 for first, second and third hours, respectively in unstarved condition, while in starved condition the hourly consumption was 11.20±0.91, 8.30±0.94 and 8.00±1.05 for first, second and third hours, respectively. The hourly consumption of fourth instar larvae *C. septumpunctata* on aphid, *A. gossypii* was 2.60±0.69, 2.20±0.78 and 2.00±0.66 for first, second and third hours, respectively in unstarved condition, while in starved condition, the hourly consumption was 3.30±0.67, 2.70±0.67 and 2.30±0.67 for first, second and third hours, respectively.

Shelley (2009) conducted an experiment was laid out with 12 treatments including control to find out the persistence of toxicity of insecticides in dust and wettable formulations on mustard crop. The results indicate that, both under field and laboratory conditions, Sumithion 40EC spray and Elsan 2% dust proved most effective. Sevin 50 WP spray proved ineffective. After 10 days of treatment all insecticides of dust and wet table formulations last their toxicity.

The ladybird beetle belongs to the family Coccinellidae of order Coleoptera. The members of the family are exclusively predator on aphids, mealybugs, scale-insects, whiteflies, thrips, leafhoppers, mites and other small soft bodied insect pests (Omkar and Pervez, 2000). It is known to prey on about 39 Arthropod species (Gautam, 1989). The family Coccinellidae comprises 5,200 described species worldwide (Hawkeswood 1987). Pushpendra (2010) have reported 31 species of Lady beetles. Soni *et al.* (2004) conducted a laboratory experiment to determine the feeding potential of *C. septempunctata, Menochilus sexmaculatus, Cheilomenes sexmaculata, and Brumoides suturalis* on mustard aphid *L. erysimi* and they reported that the adult of *C. septempunctata* consumed more mustard aphids.

Singh *et al.* (2003) studied relative abundance of the effective natural enemies of mustard aphid *L. erysimi*, in farmers' fields; the *C. septempunctata* was the highest (41.97%) occurring species. All the natural enemies showed increasing trend till harvest of the crop, whereas, the coccinellids occupied a major share with maximum relative abundance of *C. septempunctata.*

Vandenberg (2000) reported that among the natural enemies' coccinellids are the best known beneficial predatory insects. Coccinellids are commonly known as ladybird, lady beetles or lady bugs. Lady bird belongs to the family Coccinellidae and order Coleoptera. About 6000 species of ladybird beetles found all over the world.

Rafi *et al.* (2005) reported that ladybird beetles generally considered as useful insects as many species feed on soft bodied insects like aphids, jassids, psyllids, whiteflies, scale insects, mealy bugs, insect eggs, small larvae and phytophagus mites which are injurious to agricultural crops and forest plantations.

The success of capturing prey of ladybird beetle depends on abiotic and biotic factor such as plant structure, species of aphid attacked, the predator, in its particular age, level of hunger and genetic characteristics, intra and inter specific competition. (Ferran, 1993).

Agarwala *et al.* (1988) reported that 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 to many injurious insects.

Kalra (1988) reported that, in the field mustard aphid population is naturally controlled to a large extent by its predator, *Coccinella septempunctata* and plays a vital role in lowering the population of mustard aphid in the field.

2.2.3. Effect of insecticides on predatory ladybird beetles during the management of mustard aphid

A research was carried by Sohail *et al.* (2008) to study the effect of different chemical pesticides on mustard aphid (*L. erysimi*) and their adverse effects on Ladybird beetle in field. The experiments were carried out with eight treatments, Actara (low) @ 5 g/100 L water, Actara (medium) @ 10 g/100 L water, Actara (high) @ 15 g/100 L water, Confidor (low) @ 80 ml/100 ml water, Confidor (medium) @100 ml/100 L water, Confidor (high) @ 120 ml/100L water, Fastkil @ 200 ml/100 L of water with a control. Results showed that Fastkil was more toxic to the mustard aphid (*L. erysimi*) population followed by Actara. Fastkil was found most lethal for the ladybird beetle population followed by Confidor and Actara. The study recommends the use of Actara for the safe and effective control of mustard aphid (*L. erysimi*). Farmers should use Actara for the control of Aphids (*L. erysimi*) in the field as it is the least toxic to ladybird beetle population (Sohail *et al.*2008).

Youn *et al.* (2003) reported that some of the lady bird beetles are susceptible to chemical insecticides chlorpyrifos and pirmicarb at the recommended rates. Generally, the 1st and 2nd instars of ladybird beetles were very sensitive to thiamethoxam (aktara) and abamectin but these chemicals are very effective against aphids.

Mannan (2002) conducted an experiment with Malathion 57 EC and Diazinon 60 EC with different doses (1 ml, 2 ml, 3 ml/L water) were tested to evaluate the effect on mustard aphid and their toxicity on the predators and other beneficial insects of mustard aphid. Malathion was more effective then Diazinon for the control of aphids and it was less toxic to the predator and other beneficial insects. The lower dose of insecticides has less adverse effect on the predator and other beneficial insects then the higher dose. Pradhan *et al.* (1995) observed that Malathion, Parathion, Diazinon, and Et- 4P2O7 were 44.0, 16.4, 16.3, and 6.3 times as toxic to *C. septempunctata* grubs as was Systox. Et-6P4O13 and Isodrin were less toxic than was Systox. With the adult beetles, Parathion, Malathion, and Et-6P4O13 were, respectively, 25.6, 9.5, and 8.9 times as toxic as was Systox. All other insecticides used showed a very low toxicity. Generally, the adults were more resistant than the grubs to the insecticides tested. Organophosphorus insecticides were generally very toxic to mustard aphid. Parathion, Malathion, and Diazinon were more toxic to the grubs of *C. septempunctata* than to *L. erysimi*. Systox, Pestox, Et-6P4O13, and the insecticides of the chlorinated hydrocarbon group had a somewhat greater safety margin for *C. septempunctata* grubs. *C. septempunctata* adults were more resistant than aphids to all the insecticides, but the safety margin was rather low for parathion and malathion.

Some of the insecticides are fast killing at all the life stages of coccinellids that feed on the treated aphids. Carbaryl and phosmet are slow acting insecticides that cause the greatest mortality. Methomyl did not cause 100% mortality of ladybird beetle feeding on insecticides treated aphids (Hurej and Dutcher, 1994).

Sing and Sircar (1983) evaluated the toxicity of insecticides against eight species of aphid and predacious *Coccinella septempunctata*. According to them the most toxic compounds against *Aphis cracivora, A. gossypii, B. brassicae, Dactyesotus earthami,* *L. erysimi, Myxus persicae and Rhopalophum maidis* were Phorate, Dimethoate and Carbaryl. Some evidence of the resistance to insecticides was found and susceptibility varied with food plants. Endosulfan, Lindane and Phidan were effective against aphid and relatively safe against *C. septempunctata.*

Tewary and Moorthy (1983) conducted field plot tests in to determine the effectiveness of spray of 10 insecticides for control of *Aphis gossypii*. They noted their effects on predator *Menochilus sexmaculatus* and calculated that endosulfan at 700g was considered to be the best treatment followed by phosphamidon, metasystox and dimethoate at 500, 700 and 700g respectively. Cypermethrin, fenvalerate, permethrin, deltamethrin, malathion and carbaryl were less toxic to aphid than the previous four treatments but gave high mortality of the coccinellids.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The present experiment was conducted in the central farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from November 2014 to February 2015 to explore the efficiency of chemical insecticides on the reduction of infestation level of mustard aphids and their impact on predatory ladybird beetle. The details of different experimental materials and methodologies followed during the course of the investigation are described under the following sub-headings:

3.1. Location and duration of the experimental site

The research work was conducted in the central farm and Laboratory of Sher-e-Bangla Agricultural University, Dhaka-1207 (Plate 1) during the Rabi season of 2014-15 (from November 2014 to February 2015).

3.2. Soil of the experimental site

The soil of the experimental field belongs to the Tejgaon series under the Agro ecological Zone, Madhupur Tract (AEZ- 28) and the general soil type is Shallow Red Brown Terrace Soils. It was medium high land, fertile, well drained, fairly leveled and slightly acidic with pH varying from 5.8 to 6.5, CEC 25-28 (Haider *et al.*, 1991).

3.3. Climate

The experimental area has sub-tropical climate characterized by heavy rainfall during May to September and scantly rainfall during rest of the year. Temperature during the cropping period ranged from 13.32 to 24.12º C.

Plate 1. The experimental field of mustard laid out in the farm of SAU, Dhaka

3.4. Preparation of the field

The plot selected for the experiment was opened by power tiller driven rotovator, afterwards the land was ploughed and cross-ploughed followed by laddering to obtain a good tilth. The corners of the field were spaded, weeds and stubbles were removed and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. The target land was leveled and the experimental field was divided into 18 equal plots with a plot size of 2.0 m x 3.0 m and plot to plot distance 0.5 m; block to block distance 0.75m.

3.5. Application of fertilizers

Recommended doses of N, P, Zn and B (30 kg N from urea, 30 kg P from TSP and 2 kg Zn from ZnO respectively) were applied. The whole amount of TSP and ZnO, half of the urea fertilizer were applied as basal dose during final land preparation. The remaining half of urea was top dressed after 20-22 days of germination.

3.6. Design of the experiment and layout

The experiment was laid out in a Randomized Complete Block Design with three replications. The total numbers of plots were 18 for 6 treatments, each measuring 2 m × 3 m (6 m^2). The adjacent block and neighboring plots were separated by 0.75 m and 0.5 m, respectively.

3.7. Treatments

Five insecticides from four groups and one untreated control were evaluated in this study against mustard aphid. The group wise insecticides with their specific dose applied as treatment are given below:

Treatment	Insecticides ®	Dose	Generic Name	Group
T_1	Morter 48 EC	1 ml/L of water	Chlorpyrifos	Organophosphate
T_2	Imitaf 20 SL	1 ml/L of water	Imidacloprid	Nicotinoid
T_3	Marshal 20 EC	1 ml/L of water	Carbosulfan	Carbamate
T_4	Ripcord 10 EC	1 ml/L of water	Cypermethrin	Pyrithroid
T_5	Diaraz 60 EC	1 ml/L of water	Diazinon	Organophosphate
T_6	Untreated control	-	-	

3.8. Detail procedure of the study

The detail procedure considering the materials used and methodology followed in the study are given below:

3.8.1. Materials

The mustard variety BARI-15 was cultivated in the designed field to investigate the present study according to the objectives mentioned earlier.

3.8.2. Seed sowing

Seeds of the BARI-15 variety of mustard collected from BARI were sown in the selected field on 1th November 2014 in lines following the recommended row to row distance of 75 cm. After germination the seedlings (Plate 2) were sprinkled with water.

Plate 2. Seedlings of mustard in the experimental plot

3.8.3. Intercultural operation

The weeds found in the mustard field were cleaned and removed manually. The thinning of the mustard seedlings was also done as required during the growing season and care was taken to maintain uniform plant population per plot. Three times flood irrigation were given in the field at vegetative stage.

3.8.4. Application of the treatments

The selected treatments comprising different insecticides with their assigned doses were started to apply in the respective plots when the aphids were first appeared in the mustard field. The first appearance or incidence of aphids was determined by visit and daily direct visual observation of mustard plants. Therefore, considering the first appearance of the aphids in the field, treatment applications were started at 45 days after sowing (DAS) of the mustard seeds. The treatments were applied at 2 days interval and continued up to the siliqua were formed.

3.9. Data collection and calculation

Data collection was started at 45 days after sowing when aphids were visible the first time. Randomly 5 plants were selected and number of aphid were counted on level of leaves infestation, level of inflorescence infestation, level of stem infestation and level of pod infestation, incidence of ladybird beetle adult by direct visual count method throughout the growing period of mustard in the field before spraying of insecticides.

3.9.1 Aphid population on leaves

The number of aphid population on five randomly selected plants from each plot was counted at 1, 4and 7 days after spraying. The infested 5 leaves of selected plant were cut and put into the polythene bags separately, and then brought to the laboratory. The aphids were removed from the infested leaves with the help of a soft camel hail brush and placed on a piece of white paper. The numbers of aphids for each leaves were counted visually as well as with the help of a magnifying glass and then recorded the number of each treatment. The percent reduction of aphid population from insecticide treated plot over the untreated control was calculated using the following formula (Khosla, 1997):

$$\% \text{ aphid population reduction over control} = \frac{\text{Mean of untreated plot} - \text{Mean of treated plot}}{\text{Mean of treated plot}} \times 100$$

3.9.2 Aphid population on inflorescence

The population of aphids in the field on the five randomly selected plants from each plot were counted before spraying of insecticides and then 1, 4 and 7 days after first and second spraying of insecticides. The top 5 cm epical 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 in percent reduction of aphid population by using the following formula.

$$\% \text{ aphid population reduction over control} = \frac{\text{Mean of untreated plot} - \text{Mean of treated plot}}{\text{Mean of treated plot}} \times 100$$

3.9.3 Aphid population on stem

The number of aphid population on five randomly selected plants from each plot was counted at 1, 4 and 7 days after spraying. The infested stem of selected plant were cut into 3 cm and put into the polythene bags separately, and then brought to the laboratory. The aphids were removed from the infested stem with the help of a soft camel hail brush and placed on a piece of white paper. The numbers of aphids for each stem were counted visually as well as with the help of a magnifying glass and then recorded the number of each treatment. The percent reduction of aphid population from insecticide treated plot over the untreated control was calculated using the following formula (Khosla, 1997)

$$\% \text{ aphid population reduction over control} = \frac{\text{Mean of untreated plot} - \text{Mean of treated plot}}{\text{Mean of treated plot}} \times 100$$

3.9.4 Aphid population on pod

The number of aphid population on five randomly selected plants from each plot was counted at 1, 4 and 7 days after spraying. The infested 5 pod of selected plant were cut and put into the polythene bags separately, and then brought to the laboratory. The aphids were removed from the infested pod with the help of a soft camel hail brush and placed on a piece of white paper. The numbers of aphids for each stem were counted visually as well as with the help of a magnifying glass and then recorded the number of each treatment. The percent reduction of aphid population from insecticide treated plot over the untreated control was calculated using the following formula (Khosla, 1997)

$$\% \text{ aphid population reduction over control} = \frac{\text{Mean of untreated plot} - \text{Mean of treated plot}}{\text{Mean of treated plot}} \times 100$$

Plate 3: Aphids on inflorescence in mustard plant

Plate 4: Aphids on stem in mustard plant

Plate 5. Severely aphid infested and deformed pods of mustard

3.9.5 Incidence of larvae and adults of ladybird beetle by visual count

The numbers of adults and larvae of ladybird beetles were counted from randomly selected 5 standing mustard plants from each plot through direct visual observation in the afternoon at 2 days interval for each data recording time. The percent reductions of the larvae and adults of ladybird beetles from insecticide treated plots over control were calculated using the following formula:

$$\% \text{ aphid population reduction over control} = \frac{\text{Mean of untreated plot} - \text{Mean of treated plot}}{\text{Mean of treated plot}} \times 100$$

3.9.6 Data under laboratory condition

Eighteen petridish was taken, which were treated with the insecticides. Then the dishes were air dried. 50 aphid and 5 or 10 Lady bird beetle was released each dish for 48 hours. Data collection were

- No of aphid (live) after 12 hours of release.
- No of aphid (live) after 24 hours of release.
- No of aphid (live) after 48 hours of release.
- No of aphid (dead) after 12, 24, 48 hours of release.
- No of LBB after 12, 24, 48 hours of release.
- No of consumed aphid by lady bird beetle.

3.9.7 Data of yield

Maturity of crop was determined when some of 80-90% of the siliqua become golden yellow. Five plants (excluding border plant) were selected randomly from each unit plot and uprooted before harvesting for recording of necessary data. After sampling all the plants in each plot were harvested. The harvested crop of each plot was properly tagged and separately bundled, and brought to the threshing floor. The harvested crop was threshed by hand. The seeds were cleaned and sundried properly. Finally seed yields/plot were recorded and converted to kg/ha.

3.9.8 Statistical analysis

The collected data for various treatments were coded, tabulated and analyzed in accordance with the objective of the study. MSTAT-C computer package program was used for analysis of data.

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISSCUSSION

The results on different parameters of the study have been interpreted and discussed under the following sub-headings:

4.1. Effect of insecticides on the incidence of aphid population on leaves

The number of aphid population was observed before spraying insecticide, The highest population was recorded in T_6 (113.3 aphid/leaves) followed by T_1 (98.33 aphid/leaves) and the lowest aphid population was recorded in T_4 (71.67 aphid/leaves) preceding T_5 (78.33 aphid/leaves) Statistically significant variations were observed among the results of different management practices in terms of number of aphid population in different days after sowing (DAS) of mustard seeds .The highest aphid population (178.33 aphid/leaves) was recorded in untreated control plot T_6, which was statistically different to that of T_3 (48.33 aphid/leaves) i.e., spraying of Marshal 20 EC @ 1 ml/L of water at 2 days interval and T_1 (43.33 aphid/leaves) treated plot (Table 1). On the other hand, the lowest aphid population (33.33 aphid/leaves) was recorded in T_2 i.e., spraying of Imitaf 20 SL@1 ml/L of water at 2 days' interval followed by T_4 (43.33 aphid/leaves) i.e., spraying of Ripcord 10 EC @1 ml/L of water at 2 days interval followed by T_5 (38.33) comprising of Spraying of Diaraz 60 EC @1 ml/L of water at 2 days interval. In case 4 days after spraying (DAS), the highest aphid population (225.00 aphid/leaves) was also recorded in control plot T_6 which was statistically different from all other treatments. It was followed by T_5 (60.00 aphid/leaves) and T_3 (48.33 aphid/leaves). On the other hand, the lowest aphid population (38.33 aphid/leaves) was also recorded in T_2 followed by T_4 (45.00 aphid/leaves) and T_1 (46.33 aphid/leaves) treated plots. In case of 7 days after spraying (DAS), the Highest aphid population of aphid/leaves) was recorded control plot followed by T_6 (380.00aphid/leaves) and T_5 (68.33 aphid/leaves) which is statistically different. On the other hand, the lowest aphid population (50.00 aphid/leaves) was recorded in T_2 followed by T_1 (50.00 aphid/leaves) and T_3 (58.33 aphid/leaves) and T_4 (63.33 aphid/leaves) treated plot. Figure 1 showed that the percent aphid population reduction over control, the highest percent of aphid population reduction (60.00%) was observed in T_2 followed by T_1 (55.93%) and T_5 (51.07%) treated plot. On the other hand, the lowest percent of aphid population reduction over control was observed in T_4 (39.54%) followed by T_3 (39.58%) treated plot.

Table 1. Effect of insecticide on number of aphids on leaves/plant before and after spray

Treatments	Number of aphids			
	DBS	**1 DAS**	**4 DAS**	**7 DAS**
T_1	98.33 ab	43.33 bc	46.67 bc	50.00 b
T_2	83.33 bc	33.33 c	38.33 c	50.00 b
T_3	80.00 bc	48.33 b	48.33 bc	58.33 b
T_4	71.67 c	43.33 bc	45.00 bc	63.33 b
T_5	78.33 bc	38.33 bc	60.00 b	68.33 b
T_6	113.3 a	178.3 a	225.0 a	380.0 a
$LSD_{(0.05)}$	**22.45**	**13.39**	**20.25**	**21.53**
CV (%)	**14.27**	**11.47**	**14.73**	**10.60**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

DBS =Day before spraying

DAS =Day after spraying

[T_1 = Spraying of Morter 48 EC @ 1 ml/ L of water at 2 days interval, T_2 = Spraying of Imitaf 20 SL @ 1 ml/L of water at 2 days' interval, T_3 = Spraying of Marshal 20 EC @ 1 ml/L of water at 2 days interval, T_4 = Spraying of Ripcord 10 EC @ 1 ml/L of water at 2 days interval, T_5 = Spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days' interval, T_6 = Untreated control]

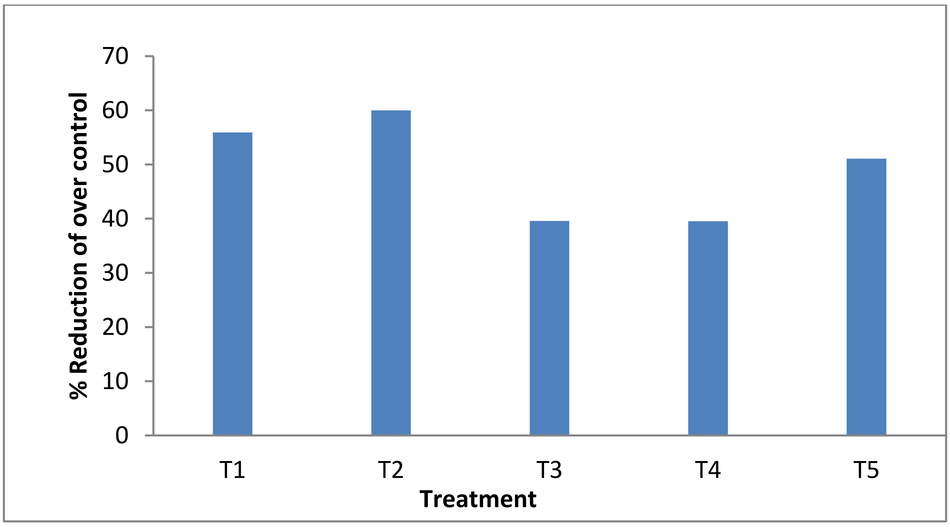

Figure 1. Effect of insecticide on % reduction over control of aphids on leaves plant^{-1}

From the above findings it was revealed that among the five insecticide treatments T_2 comprising insecticide that is spraying of Imitaf 20 SL @ 1 ml/L of water at 2 days interval performed as the best treatment in reducing the highest aphid population by number (60.00%) over control followed by T_1 (55.93%) insecticide that is spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval and T_5 (51.07%) insecticide that is spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days interval. On the other hand, T_4 insecticide that is Ripcord 10 EC @ 1 ml/L of water sprayed at 2 days interval showed the least performance (39.54%) in reducing aphid population followed by T_3 (39.58%) comprising insecticide that is spraying of Marshal 20 EC @ 1 ml/L of water at 2 days interval. As a result, the trend of efficiency among the five insecticides including one untreated control in terms of aphid population reduction ranking was T_2 (Imitaf 20 SL)> T_1 (Morter 48 EC)> T_5 (Diaraz 60 EC)> T_3 (Marshal 20 EC)> T_4 (Ripcord 10 EC)> T_6 (Untreated control). More or less similar findings were also observed by several researchers.

Said *et al.,* (2005) reported that chemical insecticides reduced aphid population on mustard with application of Curacron (43.45 aphid per inch of inflorescence), followed by Ripcord, Actara, Bestox, Karate, Thiodan, Lorsban, Advantage, Methamidophos and Sevin with 26.31, 26.92, 27.68, 30.45, 31.26, 33.79, 37.32, 42.32 and 43.77 aphid per cm of inflorescence respectively.

Amer *et al., (*2010) reported that the lowest numbers of aphids were observed where Talstar was applied as compared to Advantage, Actara and Confidor. Bakhetia (1984) and Khurana *et al.* (1989) also reported that good control of mustard aphid has been obtained by spraying traditional organic insecticides. Mannan *et al.,* (2002) reported that different doses (1 ml, 2 ml, 3 ml/L water) of Malathion 57 EC were more effective than same doses of Diazinon 60 EC for the control of aphids and it was less toxic to the predator and other beneficial insects. The lower dose of insecticides has less adverse effect on the predator and other beneficial insects than the higher dose. Sing and Sircar (1983) reported that most toxic compounds against eight species of aphids and *C. septempunctata* were Phorate, Dimethoate and Carbaryl, whereas Endosulfan, Lindane and Phidan were effective against aphid and relatively safe against *C. septempunctata.*

4.2. Effect of insecticides on the abundance of aphid inflorescence per plant

Significant variations were observed among different insecticidal treatments in terms of inflorescence infestation due to aphid infestation on mustard (Table 2).

Statistically significant variation was observed among the results of different management practices in terms of total infestation at different days after spraying during the management of mustard. In case of 1 days after spraying (DAS), the highest number of infestation (266.7 aphid/inflorescence) was recorded in T_6 composed which was statistically different from all other treatment followed by T_5 (48.33 aphid/inflorescence) spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days interval and T_4 (43.33 aphid/inflorescence) treated plot (Table 2). On the other hand, the lowest number of infestation (43.33 aphid/inflorescence) was recorded in T_1 comprised of spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval which similar with T_2 (43.33 aphid/inflorescence) comprised of spraying of Imitaf 20 SL @ 1 ml/L of water at 2 days interval, which similar with T_3 (43.33 aphid/inflorescence) comprised of spraying of Marshal 20 EC @ 1ml/L of water at 2 days interval. In case 4 days after spraying (DAS), the highest infestation (340.00 aphid/inflorescence) was recorded in T_6 which was statistically different from all other treatment. This was followed by T_4 (58.33 aphid/inflorescence) and T_5 (55.00 aphid/inflorescence) treated plot. On the other hand, the lowest number of infestation T_1 (43.33 aphid/inflorescence) was recorded in treated control plot followed by T_3 (45.00 aphid/inflorescence) and T_2

(48.33 aphid/inflorescence) treated plot (Table 2). In case of 7 days after spraying (DAS), more or less similar trends were observed among different management practice in terms of number aphid/inflorescence (Table 2). The highest number of infestation (400.0) was recorded in T_6 which was statistically different from all other treatment followed by T_4 (70.00) and T_5 (65.00). On the other hand, the lowest aphid population (58.33) was recorded T_2 in control plot followed by T_1 (58.33) and T_3 (60.00). Figure 2 showed that the percent of inflorescence infestation reduction over control indicate that the highest percent of inflorescence infestation (68.06%) was recorded in T_1 followed by T_4 (58.73%) and T_3 (58.08%) treated plot. On the other hand, the lowest percent of reduction over control (53.57%) was recorded in T_2 followed by T_5 (56.73%).

Table 2. Effect of insecticide on number of aphids per inflorescence/plant before and after spray

Treatments	Number of aphids			
	DBS	1 DAS	4 DAS	7 DAS
T_1	120.0 b	38.33 b	43.33 b	58.33 b
T_2	93.33 b	43.33 b	48.33 b	58.33 b
T_3	103.3 b	43.33 b	45.00 b	60.00 b
T_4	105.0 b	43.33 b	58.33 b	70.00 b
T_5	111.7 b	48.33 b	55.00 b	65.00 b
T_6	206.7 a	266.7 a	340.0 a	400.0 a
$LSD_{(0.05)}$	**46.56**	**22.38**	**25.35**	**12.50**
CV (%)	**20.74**	**15.27**	**14.17**	**5.79**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

DBS = Days before spraying

DAS = Days after spraying

[T_1 = Spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval, T_2 = Spraying of Imitaf 20 SL @ 1 ml/L of water at 2 days interval, T_3 = Spraying of Marshal 20 EC @ 1 ml/L of water at 2 days interval, T_4 = Spraying of Ripcord 10 EC @ 1 ml/L of water at 2 days interval, T_5 = Spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days interval, T_6 = Untreated control]

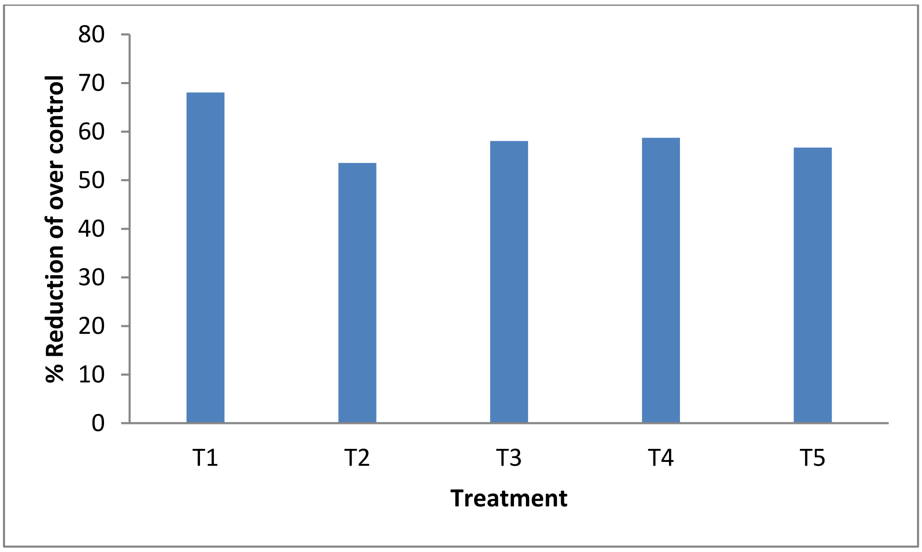

Figure 2. Effect of insecticide on % reduction over control of aphids on inflorescence plant^{-1}

From the above findings it was revealed that among five insecticide treatments applied against mustard aphid, the T_1 insecticide that is spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval performed as the best treatment in reducing the highest aphid population by number (68.06%) over control followed by T_4 (58.73%) that is spraying of Ripcord 10 EC @ 1 ml/L of water at 2 days interval and T_3 (58.08%) that is spraying of Marshal 20 EC @ 1 ml/L of water at 2 days interval. On the other hand, T_2 that is Imitaf 20 SL @ 1 ml/L of water sprayed at 2 days interval showed the least performance (53.57%) in reducing aphid population followed by T_5 (56.73%) comprising insecticide that is spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days interval. As a result, the trend of efficiency among the five insecticides including one untreated control in terms of aphid population reduction ranking was T_1 (Morter 48 EC)> T_4 (Ripcord 10 EC)> T_3 (Marshal 20 EC)> T_2 (Imitaf 20 SL)> T_5 (Diaraz 60 EC)> T_6 (Untreated control). More or less similar findings were also observed by several researchers. Amer *et al.,* (2010b) reported that seventh day of spray; Imidacloprid 17.8 SL @ 0.0178% gave most effective control. Said *et al.*, (2005) also reported that after two weeks of spray of insecticides Karate was found effective in suppressing of pest population (9.67 aphid per inch of inflorescence), followed by Actara, Ripcord, Bestox, Curacron, Lorsban, Thiodan, Methamidophos, Advantage and Sevin with reduction of aphid population to 14.44, 18.00, 19.78, 20.33,23.22, 24.78, 24.89, 34.11 and 49.11 per inch of inflorescence, respectively.

4.3. Effect of insecticides on the number of aphid population per stem per plant

Statistically significant variation was observed among the results of different management practices in terms of total infestation at different days after spraying (DAS) during the management of mustard. In case of 1 days after spraying (DAS), the highest number of infestation (216.7 aphid/stem) was recorded in T_6 which was statistically different from all other treatment followed by T_5 (50.00 aphid/stem) spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days interval and T_3 (43.33 aphid/stem) treated plot (Table 2). On the other hand, the lowest number of infestation (36.67 aphid/stem) was recorded in T_2 comprised of spraying of Imitaf 20 SL @1 ml/L of water at 2 days interval which is similar with T_1 (40.00 aphid/stem) comprised of spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval, which similar with T_4 (41.67 aphid/stem) comprised of spraying of Ripcord 10 EC @ 1 ml/L of water at 2 days interval. In case 4 days after spraying (DAS), the highest infestation (325.0aphid/stem) was recorded in T_6 which was statistically different from all other treatment. This was followed by T_5 (70.00 aphid/stem) and T_3 (65.00 aphid/stem) treated plot. On the other hand, the lowest number of infestation T_1 (51.67 aphid/stem) was recorded in treated control plot followed by T_2 (53.33 aphid/stem) treated plot followed by T_3 (58.33 aphid/stem) treated plot (Table 3). In case of 7 days after spraying (DAS), more or less similar trends were observed among different management practice in terms of number aphid/inflorescence (Table 3). Considering the highest number of infestation (405.0) was recorded in T_6 followed by T_4 (76.67) and T_5 (71.67). On the other hand, the lowest aphid population (65.00) was recorded T_2 in control plot followed by T_3 (65.00) and followed by T_1 (66.67). Figure 3 showed that the percent reduction of stem infestation over control indicate that the highest percent of infestation reduction (62.69%) was recorded in T_4 followed by T_2 (60.71%) and T_1 (59.32%) treated plot. On the other hand, the lowest percent of stem aphid reduction over control (57.73%) was recorded in T_5 followed by T_3 (58.05%).

Table 3. Effect of insecticide on number of aphids on stem/plant before and after spray

Treatments	Number of aphids			
	DBS	**1 DAS**	**4 DAS**	**7 DAS**
T_1	98.33 cd	40.00 b	51.67 b	66.67 bc
T_2	93.33 d	36.67 b	53.33 b	65.00 c
T_3	103.3 bd	43.33 b	58.33 b	65.00 c
T_4	111.7 ac	41.67 b	65.00 b	76.67 b
T_5	118.3 ab	50.00 b	70.00 b	71.67 bc
T_6	121.7 a	216.70 a	325.0 a	405.0 a
$LSD_{(0.05)}$	**18.17**	**22.99**	**19.63**	**11.39**
CV (%)	**9.27**	**17.70**	**10.38**	**5.01**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

DBS = Days before spraying

DAS = Days after spraying

[T_1 = Spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval, T_2 = Spraying of Imitaf 20 SL @ 1 ml/L of water at 2 days interval, T_3 = Spraying of Marshal 20 EC @ 1 ml/L of water at 2 days interval, T_4 = Spraying of Ripcord 10 EC @ 1 ml/L of water at 2 days interval, T_5 = Spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days interval, T_6 = Untreated control]

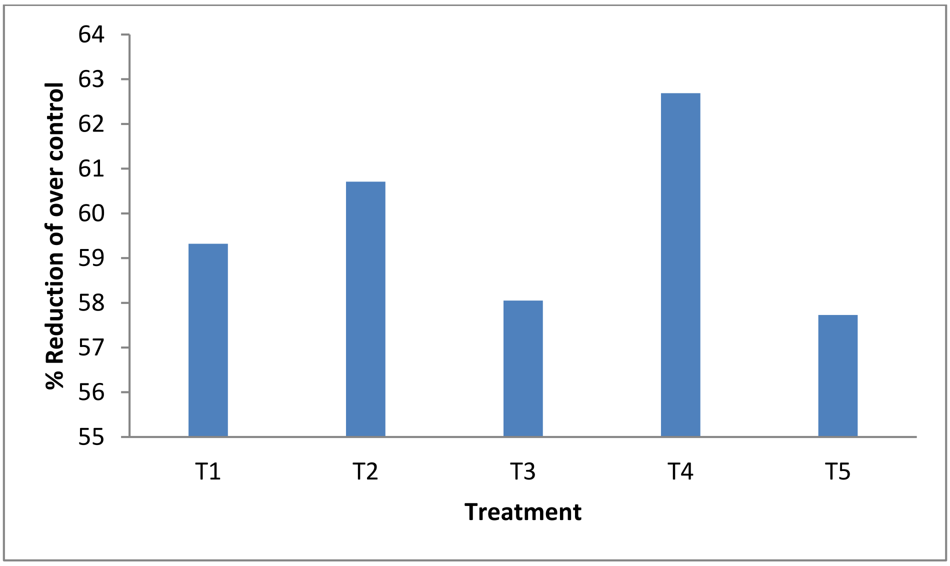

Figure 3. Effect of insecticide on % reduction over control of aphids on stem plant^{-1}

From the above findings it was revealed that among five insecticide treatments applied against mustard aphid, the T_4 comprising insecticide that is spraying of Ripcord 10 EC @ 1 ml/L of water at 2 days interval performed as the best treatment in reducing the highest aphid population by number (62.69%) over control followed by T_2 (60.71%) insecticide that is spraying of Imitaf 20 SL @ 1 ml/L of water at 2 days interval and T_1 (59.32%) insecticide that is spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval. On the other hand, T_5 insecticide that is Diaraz 60 EC @ 1 ml/L of water sprayed at 2 days interval showed the least performance (57.73%) in reducing aphid population followed by T_3 (58.05%) comprising insecticide that is spraying of Marshal 20 EC @ 1 ml/L of water at 2 days interval. As a result, the trend of efficiency among the five insecticides including one untreated control in terms of aphid population reduction ranking was T_4 (Ripcord 10 EC)> T_2 (Imitaf 20 SL)> T_1 (Morter 48 EC)> T_3 (Marshal 20 EC)> T_5 (Diaraz 60 EC)> T_6 (Untreated control). More or less similar findings were also observed by several researchers.

Sarwar *et al.*, (2011) reported that among some new insecticides like Imidacloprid (Confidor 200 EC, Thiamethoxam (Actara 25 WG) and Acetamiprid (Megamos 20 SL) alongwith conventional insecticides such as, Chlorpyrifos (Lorsban 40 EC) and Dimethoate (Systoate 40 EC) belonging to Organophosphate group gave the best results with the application of Imidacloprid by recording the lowest number of aphids (2.2 per plant) than obtained with Thiomethoxam and Acetamiprid (3.22 and 4.66, respectively). Other insecticides, viz., Chlorpyrifos and Dimethoate were also found to be effective in maintaining the aphids' population at lower levels per plant (16.2 and 17.5, respectively) over untreated control (227.7).

4.4. Effect of insecticides on the abundance of aphid per pod

Statistically significant variation was observed among the results of different management practices in terms of total infestation at different days after spraying (DAS) during the management of mustard. In case of 1 days after spraying (DAS), the highest number of infestation (270.0 aphid/pod) was recorded in T_6 composed which was statistically different with T_5 (48.33 aphid/pod) composed of spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days interval and T_4 (46.67 aphid/pod) treated plot (Table 4). On the other hand, the lowest number of infestation (35.00 aphid/pod) was recorded in T_2 comprised of spraying of Imitaf 20 SL @1 ml/L of water at 2 days interval which similar with T_1 (43.33 aphid/pod) comprised of spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval, which similar with T_3 (43.33 aphid/pod) comprised of spraying of Marshal 20 EC @ 1 ml/L of water at 2 days interval. In case 4 days after spraying (DAS), the highest infestation (376.7aphid/pod) was recorded in T_6 which was statistically different from all other treatment. This was followed by T_5 (121.7 aphid/pod) and T_4 (118.3 aphid/pod) treated plot. On the other hand, the lowest number of infestation T_2 (93.33 aphid/pod) was recorded in treated control plot followed by T_3 (101.7 aphid/pod) treated plot followed by T_1 (111.7 aphid/pod) treated plot (Table 4). In case of 7 days after spraying (DAS), more or less similar trends were observed among different management practice in terms of number aphid/pod (Table 4). Considering the highest number of infestation (503.3) was recorded in T_6 followed by T_4 (141.7) and T_1 (141.7). On the other hand, the lowest aphid population (115.0) was recorded T_2 in control plot followed by T_3 (135.0) and followed by T_5 (140.0). Figure 4 showed that the percent reduction of pod infestation over control indicate that the highest percent of reduction (61.11%) was recorded in T_2 followed by T_1 (59.99%) and T_3 (59.39%) treated plot. On the other hand, the lowest percent of reduction over control (58.22%) was recorded in T_4 followed by T_5 (59.15%).

Table 4. Effect of insecticide on number of aphids before and after spray on pod plant^{-1}

Treatments	Number of aphids			
	DBS	**1 DAS**	**4 DAS**	**7 DAS**
T_1	108.3 bc	43.33 bc	111.7 b	141.7 b
T_2	90.00 c	35.00 c	93.33 b	115.0 b
T_3	106.7 bc	43.33 bc	101.7 b	135.0 b
T_4	111.7 bc	46.67 bc	118.3 b	141.7 b
T_5	118.3 b	48.33 b	121.7 b	140.0 b
T_6	216.7 a	270.0 a	376.7 a	503.3 a
$LSD_{(0.05)}$	**28.17**	**13.25**	**28.65**	**30.70**
CV (%)	**12.36**	**8.89**	**10.23**	**8.60**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

DBS = Days before spraying

DAS = Days after spraying

[T_1 = Spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval, T_2 = Spraying of Imitaf 20 SL @ 1 ml/L of water at 2 days interval, T_3 = Spraying of Marshal 20 EC @ 1 ml/L of water at 2 days interval, T_4 = Spraying of Ripcord 10 EC @ 1 ml/L of water at 2 days interval, T_5 = Spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days interval, T_6 = Untreated control]

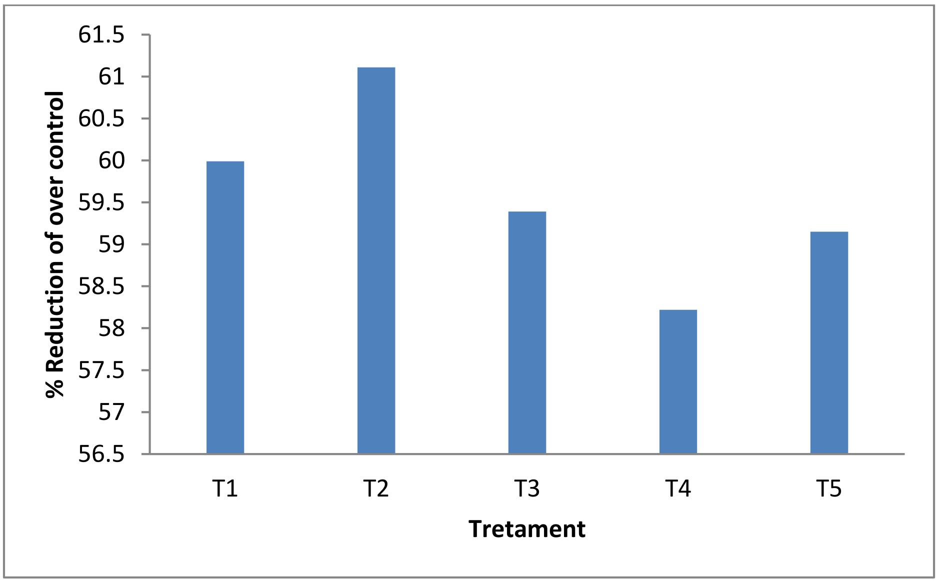

Figure 4. Effect of insecticide on % reduction over control of aphids on pod plant^{-1}

From the above findings it was revealed that among five insecticide treatments applied against mustard aphid, the T_2 comprising insecticide that is spraying of Imitaf 20 SL @ l ml/L of water at 2 days interval performed as the best treatment in reducing the highest aphid population by number (61.11%) over control followed by T_1 (59.99%) insecticide that is spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval and T_3 (59.39%) insecticide that is spraying of Marshal 20 EC @ 1 ml/L of water at 2 days interval. On the other hand, T_4 insecticide that is Ripcord 10 EC @ 1 ml/L of water sprayed at 2 days interval showed the least performance (58.22%) in reducing aphid population followed by T_5 (59.15%) comprising insecticide that is spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days interval. As a result, the trend of efficiency among the five insecticides including one untreated control in terms of aphid population reduction ranking was T_2 (Imitaf 20 SL)> T_1 (Morter 48 EC)> T_3 (Marshal 20 EC)> T_5 (Diaraz 60 EC)> T_4 (Ripcord 10 EC)> T_6 (Untreated control). About similar study was also carried out by Sultana *et al.,* (2009) on the management on mustard aphid (Lipaphis erysimi) using Neem Kernel extract with two chemical insecticides Aktara 25 WG and Diazinon 60 EC. Among the treatments on an average Aktara reduced the highest aphid population (92%) with the highest BCR (4.20) followed by Diazinon (89%) and Neem Kernel extract + Jet powder (65%).

4.5. Effect of insecticides on number of lady bird beetles

Statistically significant variation was observed among the results of different management practices in terms of total reduction of lady bird beetles at different days after spraying (DAS) during the management of mustard. In case of 1 DAS, the highest number of reduction (9.67 lady beetle/plot) was recorded in T_4 composed which was statistically similar with T_5 (9.33 lady beetle /plot) composed of spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days interval and T_3 (8.33 lady beetle/plot) treated plot

(Table 5). On the other hand, the lowest number of reduction (7.33 lady beetle/plot) was recorded in T_1 comprised of spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval which similar with T_2 (8.00 lady beetle/plot) comprised of spraying of Imitaf 20 SL @ 1 ml/L of water at 2 days interval. In case 4 days after spraying (DAS), the highest reduction (14.00 lady bird beetle/plot) was recorded in T_5 which was statistically different from all other treatment. This was followed by T_3 (13.67 lady bird beetle/plot) and T_4 (13.33 lady beetle/plot) treated plot. On the other hand, the lowest number of reduction T_2 (11.67 lady beetle/plot) was recorded in treated control plot followed by T_1 (13.33 lady beetle/plot) treated plot (Table 5). In case of 7 days after spraying (DAS), more or less similar trends were observed among different management practice in terms of number lady beetle/plot (Table 5). Considering the highest number of reduction (22.00) was recorded in T_4 followed by T_5 (22.00) and T_3 (20.00). On the other hand, the lowest reduction (19.00) was recorded T_2 in control plot followed by T_1 (19.00). Figure 5 showed that the percent reduction of lady bird over control indicate that the highest percent of reduction (63.74%) was recorded in T_4 followed by T_3 (57.65%) and T_1 (56.88%) treated plot. On the other hand, the lowest percent of reduction over control (55.56%) was recorded in T_2 followed by T_5 (56.26%) treated plot.

Table 5. Effect of insecticide on number of lady bird beetles on plant/plot before and after spray

Treatments	Number of lady bird beetles			
	DBS	1 DAS	4 DAS	7 DAS
T_1	17.00 b	7.33 b	13.33 b	19.00 c
T_2	18.00 b	8.00 b	11.67 b	19.00 c
T_3	19.67 ab	8.33 b	13.67 ab	20.00 bc
T_4	26.67 ab	9.67 ab	13.33 b	22.00 b
T_5	21.33 ab	9.33 ab	14.00 ab	22.00 b
T_6	29.67 a	12.67 a	19.33 a	28.00 a
$LSD_{(0.05)}$	**11.37**	**3.57**	**5.93**	**2.94**
CV (%)	**28.34**	**21.29**	**22.93**	**7.29**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

DBS = Days before spraying

DAS = Days after spraying

[T_1 = Spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval, T_2 = Spraying of Imitaf 20 SL @ 1 ml/L of water at 2 days interval, T_3 = Spraying of Marshal 20 EC @ 1 ml/L of water at 2 days interval, T_4 = Spraying of Ripcord 10 EC @ 1 ml/L of water at 2 days interval, T_5 = Spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days interval, T_6 = Untreated control]

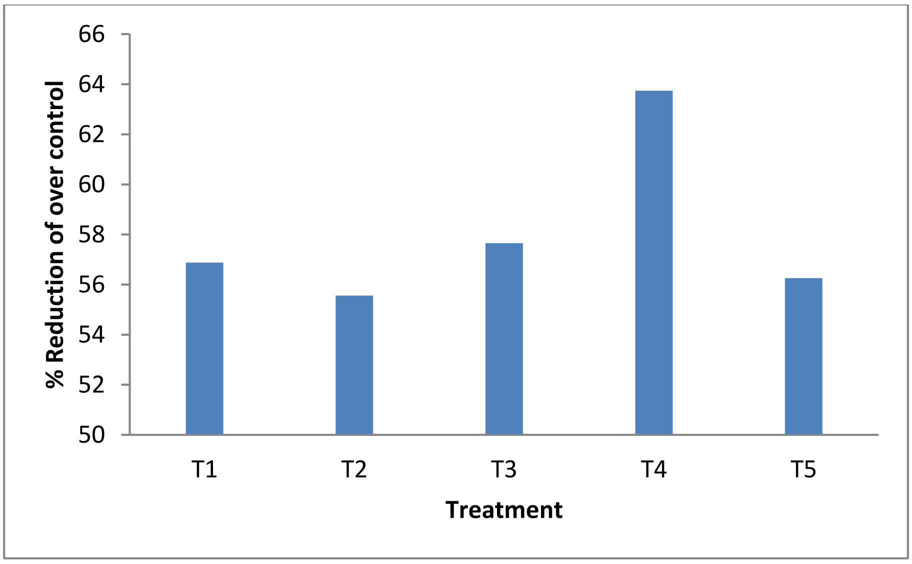

Figure 5. Effect of insecticide on % reduction over control of lady bird beetles on plant plot^{-1}

From the above findings it was revealed that among five insecticide treatments applied against lady bird beetle, the T_4 comprising insecticide that is spraying of Ripcord 10 EC @1 ml/L of water at 2 days interval performed in reducing the highest lady bird beetle population by number (63.74%) over control followed by T_3 (57.65%) insecticide that is spraying of Marshal 20 EC @ 1 ml/L of water at 2 days interval and T_1 (56.88%) insecticide that is spraying of Morter 48 EC @ 1 ml/L of water at 2 days interval. On the other hand, T_2 insecticide that is Imitaf 20 SL @ 1 ml/L of water sprayed at 2 days interval showed the least performance (55.56%) in reducing lady bird beetle population followed by T_5 (56.26%) comprising insecticide that is spraying of Diaraz 60 EC @ 1 ml/L of water at 2 days interval. As a result, the trend of efficiency among the five insecticides excluding one untreated control in terms of lady bird beetle population reduction ranking was T_4 (Ripcord 10 EC)> T_3 (Marshal 20 EC)> T_1 (Morter 48 EC)> T_5 (Diaraz 60 EC)> T_2 (Imitaf 20 SL).

Youn *et al.* (2003) reported that some of the ladybird beetles are susceptible to chemical insecticides chlorpyrifos and pirmicarb at the recommended rates. Generally, the first and second instars of ladybird beetles were very sensitive to thiamethoxam (Aktara) and Abamectin but these chemicals are very effective against aphids. Tewary and Moorthy (1983) reported that Cypermethrin, Malathion and Carbaryl were less toxic to aphid but gave high mortality of the ladybird beetle.

4.6. Effect of insecticides on number of survival of aphids in laboratory condition

Statistically significant variation was observed among the results of different management practices in terms of reduction of lady bird beetles at different hours after spraying (HAS) during the management of aphid in lab condition. In case of 12 hours after spraying (HAS), the highest number of reduction (31.67 aphid/dish) was recorded in T_2 composed which was statistically different with T_1 (25.00 aphid/dish) composed of spraying of Morter 48 EC @ 0.1 ml/100 ml of water at 12h interval and T_3 (20.00 aphid/dish) treated petridish (Table 6). On the other hand, the lowest number of reduction (11.67 aphid/dish) was recorded in T_6 which is untreated control with 12h interval which different with T_3 (20.00 aphid/dish) comprised of spraying of Marshal 20 EC @ 0.1ml/100 ml of water at 12h days interval. In case 24 hours after spraying (HAS), the highest reduction (40.00 aphid/dish) was recorded in T_2 which was statistically different from all other treatment. This was followed by T_1 (33.33 aphid/dish) and T_5 (25.00 aphid/dish) treated petridish. On the other hand, the lowest number of reduction T_6 (18.33 aphid/dish) was recorded in untreated control dish followed by T_4 (24.00 aphid/dish) treated dish (Table 6). In case of 48 hours after spraying (HAS), more or less similar trends were observed among different management practice in terms of number aphid/dish (Table 6). Considering the highest number of reduction (45.00) was recorded in T_2 followed by T_1 (40.00) and T4(35.00). On the other hand, the lowest reduction (23.33) was recorded T_6 in untreated control dish followed by T_5 (33.33) treated control followed by T_3 (33.33). Figure 6 showed that the percent mortality of aphid under lab condition over control indicate that the highest percent of mortality (90.00%) was recorded in T_2 followed by T_1 (80.00%) and T_4 (70.00%) treated petridish. On the other hand, the lowest percent of mortality Over control (46.67%) was recorded in T_6 which was untreated dish followed by T_3 (66.67%) which was treated dish and followed by T_5 (66.67%) followed by treated petridish.

Table 6. Effect of insecticide on number of survival of aphids in laboratory condition

Treatments	Number of aphids		
	12 HAS	24 HAS	48 HAS
T_1	25.00 b	33.33 b	40.00 b
T_2	31.67 a	40.00 a	45.00 a
T_3	20.00 bc	25.00 c	33.33 c
T_4	20.00 bc	24.00 c	35.00 c
T_5	16.67 cd	25.00 c	33.33 c
T_6	11.67 d	18.33 d	23.33 d
$LSD_{(0.05)}$	**6.43**	**4.54**	**4.70**
CV (%)	**16.97**	**9.03**	**7.38**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability

HAS = Hours after spraying

[T_1 = Spraying of Morter 48 EC @ 0.1 ml/100 ml of water at 12 hours interval, T_2 = Spraying of Imitaf 20 SL @ 0.1 ml/100 ml of water at 12 hours interval, T_3 = Spraying of Marshal 20 EC @ 0.1 ml/100 ml of water at 12 hours interval, T_4 = Spraying of Ripcord 10 EC @ 0.1 ml/100 ml of water at 12 hours interval, T_5 = Spraying of Diaraz 60 EC @ 0.1 ml/100 ml of water at 12 hours interval, T_6 = Untreated control]

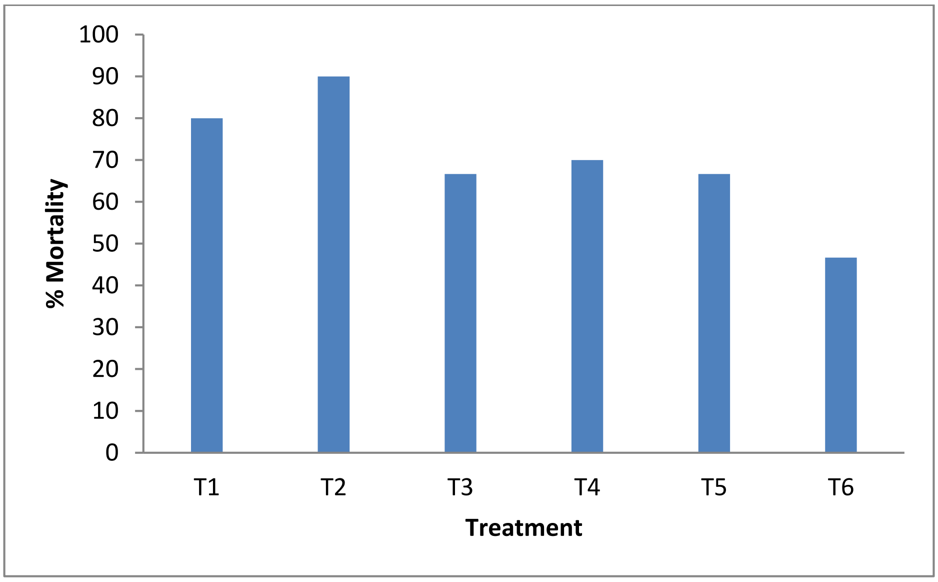

Figure 6. Percent mortality of aphids against treatments under laboratory condition

From the above findings it was revealed that among five insecticide treatments applied against aphid in lab condition, the T_2 comprising insecticide that is spraying of Imitaf 20 SL @ 0.1 ml/100 ml of water at 12h interval performed in reducing the highest aphid population by number (90.00%) over control followed by T_1 (80.00%) insecticide that is spraying of Morter 48 EC @ 0.1 ml/100 ml of water at 12h interval and T_4 (70.00%) insecticide that is spraying of Ripcord 10 EC @ 0. 1ml/100 ml of water at 12h interval. On the other hand, T_3 insecticide that is Marshal 20 EC @ 0.1 ml/100 ml of water sprayed at 12h interval showed the least performance (66.67%) in reducing aphid population followed by T_5 (66.67%) comprising insecticide that is spraying of Diaraz 60 EC @ 0.1 ml/100 ml of water at 12h interval. As a result, the trend of efficiency among the five insecticides excluding one untreated control in terms of LBB population reduction ranking was T_2 (Imitaf 20 SL)> T_1 (Morter 48 EC)> T_4 (Ripcord 10 EC)> T_5 (Diaraz 60 EC)> T_3 (Marshal 20 EC)> T_6 (Untreated control).

4.7. Effect of insecticides on the number of survival of lady bird beetle in laboratory condition

Statistically significant variation was observed among the results of different management practices in terms of reduction of lady bird beetles at different hours after spraying (HAS) during the management of lady bird beetle in lab condition. In case of 12 hours after spraying (HAS), the highest number of reduction (13.33 lady beetle/dish) was recorded in T_2 composed which was statistically similar with T_5 (9.33 lady beetle/dish) composed of spraying of Diaraz 60 EC @0.1ml/100 ml of water at 12h interval and T_4 (9.00 lady beetle/dish) treated petridish (Table 7). On the other hand, the lowest number of reduction (0.67 lady beetle/dish) was recorded in T_6 which is untreated control with 12h interval which similar with T_1 (8.33 lady beetle/dish) comprised of spraying of Morter 48 EC @0.1ml/100 ml of water at 12h days interval.

In case 24 HAS, the highest reduction (18.33 lady beetle/dish) was recorded in T_2 which was statistically different from all other treatment. This was followed by T_1 (12.33 LBB/dish) and T_5 (11.67 lady beetle/dish) treated petridish similar with T_3 (11.67) and T_4 (11.67). On the other hand, the lowest number of reduction T_6 (5.00 lady beetle/dish) was recorded in untreated control dish (Table 7). In case of 48 HAS, more or less similar trends were observed among different management practice in terms of number lady beetle/dish (Table 7). Considering the highest number of reduction (22.00) was recorded in T_2 followed by T_1 (18.33) and T_5 (15.33). On the other hand, the lowest reduction (8.67) was recorded T_6 in untreated control dish followed by T_4 (15.33) treated control followed by T_3 (15.33). Figure 7 showed that the percent mortality of lady bird over control indicate that the highest percent of mortality (44.00%) was recorded in T_2 followed by T_1 (36.67%) and T_5 (30.67%) treated dish. On the other hand, the lowest percent of mortality over control (17.33%) was recorded in T_6 which was untreated dish followed by T_4 (28.67%) which was treated dish and followed by T_3 (30.67) treated petridish.

Table 7. Effect of insecticide on the number of survival of lady bird beetles in laboratory condition

Treatments	Number of lady bird beetles		
	12 HAS	**24 HAS**	**48 HAS**
T_1	8.33 b	12.33 b	18.33 ab
T_2	13.33 a	18.33 a	22.00 a
T_3	8.33 b	11.67 b	15.33 b
T_4	9.00 b	11.67 b	14.33 b
T_5	9.33 b	11.67 b	15.33 b
T_6	0.67 c	5.00 c	8.67 c
$LSD_{(0.05)}$	**3.45**	**2.77**	**4.19**
CV (%)	**23.23**	**12.94**	**14.69**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability.

HAS= Hours after spraying

[T_1 = Spraying of Morter 48 EC @ 0.1ml/100 ml of water at 12 hours interval, T_2 = Spraying of Imitaf 20 SL @ 0.1ml/100 ml of water at 12 hours interval, T_3 = Spraying of Marshal 20 EC @ 0.1ml/100 ml of water at 12 hours interval, T_4 = Spraying of Ripcord 10 EC @ 0.1ml/100 ml of water at 12 hours interval, T_5 = Spraying of Diaraz 60 EC @ 0.1ml/100 ml of water at 12 hours interval, T_6 = Untreated control]

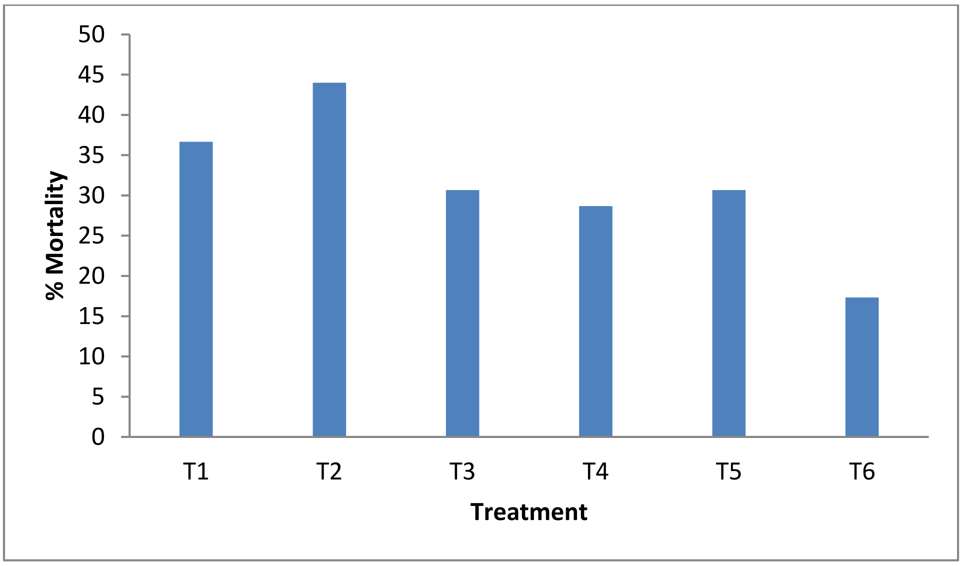

Figure 7. Percent mortality of lady bird beetles in relation to treatments under laboratory condition

From the above findings it was revealed that among five insecticide treatments applied against lady bird in lab condition, the T_2 comprising insecticide that is spraying of Imitaf 20 SL @ 0.1 ml/100 ml of water at 12h interval performed in reducing the highest aphid population by number (44.00%) over control followed by T_1 (36.67%) insecticide that is spraying of Morter 48 EC @ 0.1 ml/100ml of water at 12h interval and T_5 (30.67%) insecticide that is spraying of Diaraz 60 EC @ 0.1ml/100ml of water at 12h interval. On the other hand, T_4 insecticide that is Ripcord 10 EC @ 0.1 ml/100 ml of water sprayed at 12h interval showed the least performance (28.67%) in reducing aphid population followed by T_3 (30.67%) comprising insecticide that is spraying of Marshal 20 EC @ 0.1 ml/100 ml of water at 12h interval. As a result, the trend of efficiency among the five insecticides excluding one untreated control in terms of lady bird beetle population reduction ranking was T_2 (Imitaf 20 SL)> T_1 (Morter 48 EC)> T_5 (Diaraz 60 EC)> T_3 (Marshal 20 EC)> T_4 (Ripcord 10 EC).

4.2. Yield performance under insecticide application

Figure 8. showed the yield contributing character according to the insecticide application in (kg/ha). The maximum yield was found in that treatment T_2 (812 kg/ha) followed by T_3 (794 kg/ha) and T_1 (792 kg/ha). On the other hand, lowest yield was found in the T_6 treatment (310.2 kg/ha)

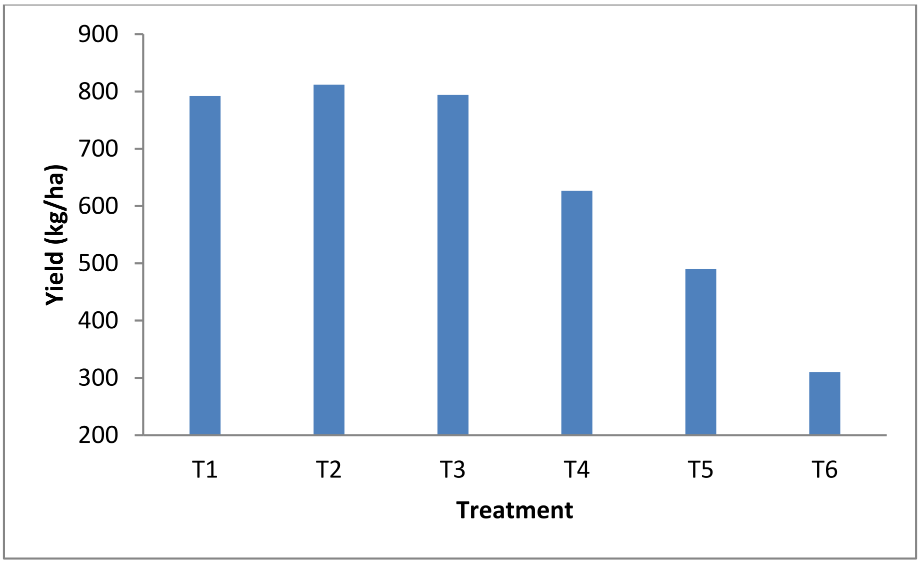

Figure 8. Effect of insecticides on aphid and lady bird beetle in contributing yield of mustard.

CHAPTER V

SUMMARY AND CONCLUSION

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SUMMARY

In terms of the abundance of aphid population into leaves, among five insecticides, T_2 comprising Imitaf 20 SL @ 1 ml/L of water performed as the most effective insecticide in reducing the highest percent of aphid population (60.00%) over control. Whereas, Ripcord 10 EC @ 1 ml/L of water showed the least performance in reducing the aphid population (39.54%). As a result, the order of trend of efficiency of five insecticides along with untreated control in terms of reducing the aphid population was T_2 (Imitaf 20 SL)> T_1 (Morter 48 EC)> T_5 (Diaraz 60 EC)> T_3 (Marshal 20 EC)> T_4 (Ripcord 10 EC)> T_6 (Untreated control).

In respect of inflorescence infestation, Morter 48 EC @ l ml/L water performed as the most effective insecticide in reducing the highest percent of aphid population (68.08%) over control. Whereas, Imitaf 20 SL showed the least performance in reducing the inflorescence infestation (53.57%) over control. As a result, the order of trend of efficiency of five insecticides along with untreated control in terms of reducing aphid population was T_1 (Morter 48 EC)> T_4 (Ripcord 10 EC)> T_3 (Marshal 20 EC)> T_2 (Imitaf 20SL)>T_5 (Diaraz 60 EC)> T_6 (Untreated control).

In terms of stem infestation, Ripcord 10 EC @ 1 ml/L of water also performed as the most effective insecticide in reducing the highest percent of stem infestation (62.67%) over control. Whereas, Diaraz 60 EC showed the least performance in reducing the stem infestation (57.73%) over control. As a result, the order of trend of efficiency of five insecticides along with untreated control in terms of reducing the number of aphid on stem was T_4 (Ripcord 10 EC)> T_2 (Imitaf 20 SL)> T_1 (Morter 48 EC)> T_3 (Marshal 20 EC)> T_5 (Diaraz 60 EC)> T_6 Untreated control).

Similarly, in terms of pod infestation, Imitaf 20 SL @ 1 ml/L of water performed as the most effective insecticide in reducing the highest percent of pod infestation (61.11%) over control. Whereas, Ripcord 10 EC showed the least performance in reducing the pod infestation (58.22%) over control. As a result, the order of trend of efficiency of five insecticides along with untreated control in terms of reducing the number of aphid per pod was T_2 (Imitaf 20 SL)> T_1 (Morter 48 EC)> T_3 (Marshal 20 EC)> T_5 (Diaraz 60 EC)> T_4 (Ripcord 10 EC)>T_6 (Untreated control).

Similarly, in terms of reduction of Lady bird beetle, Ripcord 10 EC @ 1 ml/L of water performed as insecticide in reducing the highest percent of lady bird beetle reduction (63.74%) over control. Whereas, Imitaf 20 SL showed the least performance in reducing the lady bird beetle infestation (55.56%) over control. As a result, the order of trend of efficiency of five insecticides along with untreated control in terms of reducing the lady bird beetle infestation was T_4 (Ripcord 10 EC)> T_3 (Marshal 20 EC)> T_1 (Morter 48 EC)> T_5 (Diaraz 60 EC)> T_2 (Imitaf 20 SL)> T_6 (untreated control).

Similarly, in terms of efficiency of insecticide sprayed on aphid under laboratory condition, Imitaf 20 SL @ 0.1 ml/100 ml water performed as insecticide in reducing the highest percent of aphid population (90.00%) over control. Whereas, Marshal and Diaraz 60 showed the least performance in reducing the aphid population (55.56%) over control. As a result, the order of trend of efficiency of five insecticides along with untreated control in terms of reducing the aphid population was T_2 (Imitaf 20 SL)> T_1 (Morter 48 EC)> T_4 (Ripcord 10 EC)> T_5 (Diaraz 60 EC)> T_3 (Marshal 20 EC)> T_6 (Untreated control).

Similarly, in terms of efficiency of insecticide sprayed on lady bird beetle under lab condition, Imitaf 20 SL @ 0.1 ml/100 ml water performed as insecticide in reducing the highest percent of aphid population (44.00%) over control. Whereas, Rapid showed the least performance in reducing the lady bird beetle population (28.67%) over control. As a result, the order of trend of efficiency of five insecticides along with untreated control in terms of reducing the lady bird beetle population was T_2 (Imitaf 20 SL)> T_1 (Morter 48 EC)> T_5 (Diaraz 60 EC)> T_3 (Marshal 20 EC)> T_4 (Ripcord 10 EC)> T_6 (Untreated control).

Similarly, in case of yield of mustard, Imitaf 20 SL @ 1 ml/L of water performed as the most effective insecticide in increasing the yield (812 kg/ha) over control. Whereas, Diaraz 60 EC showed the least performance in increasing the yield (490 kg/ha) over control. As a result, the order of trend of efficiency of five insecticides along with untreated control in terms of increasing the yield of mustard in ton/ha was T_2 (Imitaf 20 SL)> T_1 (Morter 48 EC)> T_3 (Marshal 20 EC)> T_4 (Ripcord 10 EC)> T_5 (Diaraz 60 EC)> T_6 (Untreated control).

CONCLUSION

Based on the above findings of the study, the following conclusions have been drawn:

In case of efficacy of insecticides on aphid infestation and yield of mustard

- In case of percent leaves aphid population reduction over control, the highest percent of aphid population reduction (60.00%) was observed in $T_{2.}$ while the lowest percent of aphid population reduction over control was observed in T_4 (39.54%).
- The percent of inflorescence infestation reduction over control indicate that the highest percent of inflorescence infestation reduction (68.06%) was recorded in T_1. while, the lowest percent of reduction over control (53.57%) was recorded in T_2.
- The percent reduction of stem infestation over control indicate that the highest percent of infestation reduction (62.69%) was recorded in $T_{4.}$ while, the lowest percent of stem aphid reduction over control (57.73%) was recorded in T_5.
- The percent reduction of pod infestation over control indicate that the highest percent of reduction (61.11%) was recorded in T_2. while, the lowest percent of reduction over control (58.22%) was recorded in T_4.
- The percent mortality of aphid under lab condition over control indicate that the highest percent of mortality (90.00%) was recorded in T_2 followed by T_1 (80.00%) and T_4 (70.00%) treated petridish. On the other hand, the lowest percent of mortality over control (46.67%) was recorded in T_6 which was untreated dish.
- The maximum yield found in the treatment T_2 (812 kg/ha) because of low aphid infestation followed by T_3 (794 kg/ha) and T_1 (792 kg/ha). while low yield performance found in the T_6 treatment was untreated control (310.2 kg/ha).

Impact of insecticides on the population of ladybird beetle

- The percent reduction of lady bird over control indicate that the highest percent of reduction (63.74%) was recorded in T_4 followed by T_3 (57.65%) and T_1 (56.88%) treated plot. while, the lowest percent of reduction over control (55.56%) was recorded in T_2 treated plot.
- The percent mortality of lady bird over control indicate that the highest percent of mortality (44.00%) was recorded in T_2 followed by T_1 (36.67%) T_3 (30.67) and T_4 (28.67 T_5 (30.67%), treated dish. On the other hand, the lowest percent of mortality over control (17.33%) was recorded in T_6 which was untreated dish.

RECOMMENDATIONS

Considering the findings of the study following recommendations may be drawn:

Imitaf 20 SL and Ripcord 10 EC may be recommended as effective insecticides for the management of mustard aphid as compared with Morter 48 EC, Marshal 20 EC and Diaraz 60 EC;

- Imitaf 20 SL may be recommended as least hazardous insecticides for predatory ladybird beetle.
- Further intensive studies based on different doses of Ripcord 10 EC, Morter 48 EC, Marshal 20 EC and Diaraz 60 EC should be done.
- More chemical insecticides should be included in further research for controlling mustard aphid in different agro-ecological zones of Bangladesh.

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