EFFECT OF INTERCROPPING ON THE INCIDENCE OF APHID POPULATION IN MUSTARD AND ITS IMPACT ON OTHER ARTHROPODS

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CERTIFICATE

This is to certify that thesis entitled, "*EFFECT OF INTERCROPPING ON THE INCIDENCE OF APHID POPULATION IN MUSTARD AND ITS IMPACT ON OTHER ARTHROPODS*" 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 *SAJIB SARKAR, Registration No. 10-4173* under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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DEDICATED TO
MY
BELOVED PARENTS

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ABSTRACT

The experiment was conducted to study the effect of intercropping on the incidence of aphid population in mustard and its impact on pollinators during the period from October, 2017 to February, 2018. The experiment consisted of seven different treatments (each treatment was intercropping with mustard, *Brassica napus*) viz T_1 = Mustard intercropped with cabbage (*Brassica oleracea* var. *capitata*); T_2= Mustard intercropped with onion (*Allium cepa* L.); T_3= Mustard intercropped with garlic (*Allium sativum* L); T_4= Mustard intercropped with black seed (*Nigella sativa*); T_5= Mustard intercropped with coriander (*Coriandrum sativum* L.); T_6= Mustard intercropped with radish (*Raphanus raphanistrum subsp. sativus*) and T_7= Sole mustard as Untreated control. Sole trimming of mustard was additionally developed to think about the adequacy of intercropping framework. The design of experiment was randomized complete block design (RCBD) with three replications. From result it revealed that, when the number of aphid was lower (13.72) at mustard + coriander (T_5) at that time, total number of infested plant/plot (1.48), number of aphid infested branch/plant (1.58), percent of Branch infestation (19.65), percent of Flower infestation(44.38), percent of pod infestation (24.74) were decreased; on the other hand at that time total number of pod/branch (19.45), Number of different pollinators such as honeybee (*Apis indica*)/plant (4.28), wasp (2.26), syrphid fly (2.26); the presence of beneficial insects like lady bird beetle/plot (19.63); Number of healthy pod/plant (82.99) and grain yield per plot (454.74) was increased. The overall result indicates that the intercropping of mustard with onion, garlic, coriander and black seed/black cumin decreased the incidence of aphid population on mustard and increased the abundance of visiting different pollinators and other beneficial insect populations compared to sole cropping of (mustard).

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CHAPTER I
INTRODUCTION

Mustard (*Brassica* spp) is a major oilseed crop which is belongs to the genus *Brassica* of the family Cruciferae symbolized by rapeseed and is one of the leading oilseed crops in Bangladesh and all over the world. It is the most dominant oilseed crop in Bangladesh and covers alone 80% of the total area under oilseed crops. . It is used as a condiment, salad, green manure and fodder crop, and as a leaf and stem vegetable in the various mustard growing countries of the World (FAO, 2004). In Bangladesh, more than 218.47 thousand metric tons of rape and mustard produced from a total of 287.55 thousand hectares of land in the year 2016-2017 (BBS, 2018). Currently, Bangladesh is producing 0.36 million tons of edible oil but total requirement is far from actual demand (1.4 million tons). As a result, Bangladesh needs to invest to import edible oils from other countries for mitigating the demand for additional population and changing of dietary habits and nutritional awareness for total population. This statement indicates that production of mustard crop urgently needs to be increased in Bangladesh. Mustard occupied the top of the list in respect of area and production compare to other oilseed crops grown in Bangladesh (Abraham, 1994). Domestic production of edible oil almost entirely comes from rapeseed and mustard occupying only about 2% area of total cropped area in Bangladesh (BBS, 2002). The annual oil seed production of 0.41 million tons of which the share of rapeseed-mustard was 0.21 million tons, which comes about 52% of the total edible oil seed production (BBS, 2009). Oil cake of mustard is used as fertilizer in the South Asian region for centuries. In combination with cowdung manure and ashes, the oil cakes sustained the fertility levels of marginal farms. Oil cakes render indirect help in promoting the microflora and microfauna of soils providing readily available amino acids and free sugars. It is clear that oil cakes are rich sources of nitrogen, phosphorus and potassium micronutrients (Dhaliwal and Dilawary, 1993). However, increasing of mustard cultivation area is difficult due to several reasons. Among them, climate change and insect pest infestation are the major obstacles to produce mustard crop. There are many insect pests of mustard crop like mustard aphid, sawfly and mustard leaf eating caterpillar. Among them, mustard aphid, *Lipaphis erysimi* (Kalt.) (Homoptera:

Aphididae) is the most destructive one (Das, 2002). Mustard aphid is the most serious and destructive pest and limiting factors for successful cultivation of mustard in South Asia (Bakhetia, 1983; Zaman, 1990). Both nymphs and adults of the mustard aphid infest the leaves, inflorescences and immature resulting poor pod setting and yield reduction, as a result the plant show stunted growth, flowers wither and pod formation is hindered. They also induce growth of fungus that causes dirty and black pods and leaves. Mustard aphid causes 35.4% to 96% yield loss, 30.9% seed weight loss and 2.75% oil loss.

Farmers usually spray chemical pesticides many times during the crop season to control insect pests. This leads to environmental pollution with a consequent of increased health hazard to the growers and consumers. This insecticide has tremendous effects on environment, biodiversity, human and animal health. Moreover, it also leads to the development of resistance to target pests (David and Kumaraswami, 1989) with also a negative effect on natural enemies (Tewari and Moorthy, 1985) and other beneficial and causes disruption of biodiversity. To mitigate these problems, alternative approach is needed. At present, effective control techniques other than insecticide application against insect pests of agricultural crops are highly demanding.

Intercropping is an antiquated conventional agronomic practice, a framework where at least two yield species are developed in a similar field in the meantime during a developing season (Ofori and Stern, 1987). In the event that it is used effectively, it can contribute essentially to decrease bother issues. It is a basic and modest methodology and has been perceived as a conceivably befitted innovation to build crop generation because of its generous yield advantage than sole trimming (Awal *et al*., 2006). The reason for intercropping is to create useful natural communications between the yields. Intercropping can build yields, all the more productively utilize accessible assets, decrease weed, creepy crawly and ailment weights and give more noteworthy natural and financial security (Vandermeer, 1989). Intercropping has been a basic generation strategy in tropical districts for many years (Vandermeer, 1989), and to a lesser degree in mild locales (Li *et al.,* 2001).

Intercropping is an alternative practicable solution that combats crop insect pests. It involves the cultivation of at least two or more then two crop species simultaneously in

the same land. An agronomic practice like intercropping of crop of diverse growth habit has been found as a very useful technique in controlling a large number of crop pests (Singh and Rathi, 2003). If it is utilized correctly, it can contribute significantly to reduce pest problems. It is a simple and inexpensive strategy and has been recognized as a potentially befitted technology to increase crop production due to its substantial yield advantage than sole cropping (Awal *et al.,* 2006). Research findings demonstrate that intercropping saves the target crop using several mechanisms. Non-host crops grown in intercropping can emit organic chemicals which adversely affect the pest insects, providing some degree of protection. Intercropping has been an essential production method in tropical regions for hundreds of years (Vandermeer, 1989), and to a lesser extent in temperate regions (Li *et al.,* 2001). By intercropping it is profitably conceivable those one plant animal types may fill in as a snare for creepy crawlies, lessening invasion of the other or that it might fill in as a rearing spot for predators. When all is said in done the more prominent number of hosts in the intercropping for the most part additionally implies a more prominent decent variety of irritations and maladies. Other advantages of intercropping are more efficient use of field and avoiding the risk of monocrop failure. There is a general agreement that species diversity in multiple cropping reduces the most insect pest problems, increase cropping intensity and can successfully out compete weeds. Sometimes mixed crop acts a barrier crop which hinders the movements of insect pests and thus the susceptible plant will suffer less. Success for intercropping for pest management depends on the choice of associated crops and their additional valuation after harvest, to some extend knowledge of the farmers and mechanization practice used. Intercropping can influence the micro climate atmosphere of the agro-biological system, which at last delivers a troublesome domain for vermin (Singh and Singh, 1978). The olfactory improvement offered by the primary yield could be covered by different intercrops (Aiyer, 1949). Other advantages of intercropping are more efficient use of field and avoiding the risk of monocrop failure. Several field trials on mustard have been conducted till to date using different intercrops such as banana (Rahman *et al.,* 2006), barley (Gangasaran and Giri, 1985), bean (Morse *et al*., 1997); cabbage (Bender *et al*., 1999), chickpea (Singh and Rathi, 2003), chilli (Mamun *et al*,. 2002), coriander (Sing and Kothari, 1997), gram (Tahir *et al.,* 2003), groundnut (Dhyani and Tripathi, 1999), linseed

and lentil (Tahir *et al.,* 2003), oat (Morse *et al.,* 1997), Pea (Banik *et al.,* 2000), wheat (Tahir *et al.,* 2003) etc. and found lower aphid infestation on different intercropped plant than sole crops (Nampala *et al.,* 2002, Ma *et al.,* 2006). With the above prospective, intercropping has been thought to be an environment friendly option for the management of insect pests in mustard.

Conceiving all thoughts and ideas, the present study has been undertaken with the following objectives:

- To study on the effect of intercropping in mustard due to infestation intensity of aphid
- To find out the effect of intercropping on the other arthropods

CHAPTER II

REVIEW OF LITERATURE

Mustard an important oilseed crops in Bangladesh. A series of studies on intercropping or mixed cropping and their relationship with pest management as an alternative way of using pesticides have been done and reported in Bangladesh and elsewhere in the world. However, studies in this area appeared very limited in Bangladesh. For a better understanding, clear conception and to know the research status on impact of intercropping on insect pest management, But published literature on this pest especially on its infestation status and management are scanty in Bangladesh. Literatures cited below under the following headings and sub-headings reveal some information about the present study.

Relevant hypotheses : Intercropping is a multiple cropping practices involving growing two or more crops in proximity. The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources or ecological processes that would otherwise not be utilized by a single crop**.** According to Van Emden (1965), intercropping or polyculture are ecologically complex because interspecific and intraspecific plant competition occurs simultaneously with herbivores, insect predators, and insect parasitoids. Southwood (1975) stated that elimination of alternate habitats might lead to decrease predator and parasitoid populations and increased insect pest populations.

Singh and Ali (1987) evaluated the effect of mustard on french bean at IIPR, Kanpur under irrigated condition, where one row of mustard was adjusted in place of every 4^{th} and 6^{th} row of french bean the reduction in the grain yield of french bean was calculated @ 27.85% and 32.89% in 3:1 and 5:1 row ratio. Singh and Ali (1988) reported that grain yield of french bean at IIPR, Kanpur, was found to be reduced by 2.29%, when grown in 1:1 row ratio with mustard.

Kushwaha and De (1987) tried mustard + chickpea intercropping and observed that number of branches, pods, seed yield/plant and 1000-seed weight of chickpea decreased

in intercropping than sole chickpea. The intercropping of 66% chickpea + 34% mustard population gave the greatest yield advantage and chickpea in this system had most nodules and dry weight of nodules. This combination also had the highest LAI and removed more nitrogen from the soil. Kumar and Singh (1987) evaluated the effect of mustard on chickpea at Pantnagar where one row of mustard was adjusted on every 4^{th} and 5^{th} row of chickpea. They reported reduction in grain yield of chickpea @ 9.1 and 19.4% in 3:1 and 4:1 row ratio system, respectively. Verma *et al.* (1989) reported that chickpea intercropped with mustard in 4:1 row ratio gave 2.60 t ha^{-1} grain yield against 3.12 t ha^{-1} in pure stand.

Yin-Xin and Thieer (2010) conducted an experiment to study the effect of tomato intercropped with five species: cucumber, maize, vegetable soyabean, okra, sweet potato (with no intercropping serving as control), on tomato yellow leaf curl virus (TYLCV) and whitefly *(Bemisia tabaci*) incidence was studied from November, 2009 to March, 2010 at ARC-AVRDC, Kasetsart University, Kamphaeng Sean, Nakhon Fathom, Thailand. TYLCV incidence and whitefly populations were recorded. The TYLCV incidence on tomato increased rapidly after 58 days after transplanting. Tomato intercropped with vegetable soyabean, maize , sweet potato and cucumber partly reduced the infection of TYCLV. whitefly adults hold the highest population during January 2010 in the field. The population of whitefly nymphs increased sharply from 10 January to 10 February 2010.whitefly larvae population density in the different crops used was highly significant or significant on 37,47, 58, and 78 DAT. Among intercrops cucumber and vegetable soybean were the preferred hosts of whiteflies.

Gangasaran and Giri (1985) evaluated the effect of mustard on chickpea at IARI, New Delhi under dryland conditions where one row of mustard was adjusted in place of every 5^{th}, 7^{th} and 9^{th} row of chickpea. Grain yield of chickpea was found to be reduced by 45.78%, 32.82% and 29.82% in proportion to row number of chickpea and the adverse effect was found to be reduced as the proportionate number of rows of chickpea was increased.

Mandal *et al.* (1985) reported that intercropping of mustard reduced the number of pods and number of seed /pod in chickpea than sole cropping.

According to Bird and Kruger (2009), the behavior of *Bemisia tabaci* females to establish whether this taxon showed reduced feeding and fecundity when exposed to different crops (mixed crops; tomato, bean cucumber) or different tomato cultivar (mixed cultivar) as opposed to the same crop plant (monocrops*). Bemisia tabaci* showed a distinct behavioural preference for cucumber when exposed to the different crops simultaneously. However, when low-ranking host plants giving similar, but not identical, stimuli were present, female whiteflies tended to have difficulty in making a selection, resulting in increased movement and reduced fecundity.

Altieri (1994) stated that a key strategy in sustainable agriculture is to restore functional bio-diversity of the agricultural landscape. Most studies of the effects of biodiversity enhancement on insect populations have been conducted at the field level, rarely considering larger scales such as the landscape level. It is well known that spatial patterns of landscapes influence the biology of arthropods both directly and indirectly. One of the principal distinguishing characteristics of modem agricultural landscape is the large size and homogeneity of crop monocultures, which fragment the natural landscape. This can directly affect abundance and diversity of natural enemies as the larger the area under monoculture the lower the viability of given population. Altieri (1994) opined that the diversity can be enhanced in time through crop rotations and sequences and in space in the form of cover crops, intercropping, agroforestry, crop/livestock mixtures etc. Correct biodiversification results in pest regulation through restoration of natural control of insect pests, diseases and nematodes and also produces optimal nutrient cycling and soil conservation by activating soil biota. All factors leading to sustainable yield, energy conservation and less dependence on external inputs.

According to Dhingra *et al.* (1990), the effect of mustard on chickpea at Ludhiana, Punjab where grain yield of chickpea was found to reduce by 19.73., 21.71, 24.96 and 15.07% when every 2^{nd}, $3^{rd,}$ 5^{th} and 7^{th} row was replaced by mustard in intercropping. In the studies of Mehta *et al.* (1990) chickpea grown in 4:1 row ratio with mustard gave 1.82 t ha^{-1} grain yield , while in pure stand it was 2.42 t ha^{-1}. They also reported that mustard was a better competitor than chickpea in intercropping system. Meena and Lal

(2004) revealed the impact of cabbage intercropped with lucerne, garlic, mustard, marigold and tomato on mustard aphid, Lipaphis erysimi frequency and found that lucerne was the best pursued by garlic, while mustard was the least successful intercrop in decreasing the aphid populace. Saha et al. (2000) intercrops of linseed cv. Garima and Indian mustard (Brassica juncea) cv. Varuna and linseed cv. Garima and tomato cv. Pusa Ruby were infested with various types of creepy crawly irritations of which the mustard aphid, Lipaphis erysimi, linseed nerve midge, Dasyneura lini, dark aphid, Aphis craccivora, and tomato organic product borer, armigera, indicated critical contrasts in invasion levels in different intercrop circumstances in Varanasi, Uttar Pradesh, India, during rabi period of 1996-97. Be that as it may, there was a general descending pattern in infestation dimension of various pests in intercrop combinations contrasted with their numbers in sole yields of favored host. The intercrops were along these lines, observed to be progressively appropriate for normal concealment of pest populaces. Casagrade and Haynes (1976) called attention to a fascinating potential for incorporation of plant safe and polyculture rehearses. They thought about harm by the grain leaf bug, oulema melanopus L. in blended and unadulterated strands of safe and helpless wheat assortments. They detailed that natural control was progressively powerful in the blended trimming of scarab safe and bug helpless wheat assortments than in an unadulterated strand of both of those assortments on a locale wide premise Of the assortment of elements that may be engaged with the facilitative creation guideline, the one refered to and maybe the best recorded is the decrease in irritation assault every now and again found in intercrops (Risch et al., 1983). Prior surveys discovered comparable outcomes (Perkin, 1977; Kvass, 1978; Nickel, 1973; Lit vocalist and Moody, 1976; Dumpsters and Coaker, 1974) that irritations will in general be decreased in intercrops, in spite of the fact that not using any and all means always.while these audits will in general be focus on creepy crawlies, there is additionally proof that intercrops diminish nematode assault (Mc Beth and Taylor, 1944; Khan et al., Awl and Manger, 1967; Catelli et al., 1976; Egunjobi,1984) and sicknesses (Moreno and Mora, 1984; Rheeneu et al., 1981).

Relationship between intercropping with insect pests and their natural enemies

Insect pests in intercropping : Tiwari *et al.* (2005) observed the effect of intercropping of mustard with potato, coriander (*Coriandrum sativum*), chickpea, wheat, linseed and fenugreek, on the incidence of themajor insect pests, i.e. mustard aphid (*Lipaphis erysimi*), flea beetle (*Phyllotreta cruciferae*) and saw fly (*Athalia proxima*) and on the yield of mustard as sole crop and intercrops. They found that the lowest aphid population was recorded in mustard grown with coriander and the maximum population was observed on mustard as sole crop. Flea beetle incidence was minimum on mustard intercropped with linseed and maximum when sown with potato. While saw fly population was minimum on mustard sown with potato and maximum on mustard as sole crop and the yield of mustard + linseed was maximum, while a minimum return was recorded for mustard + wheat.

Mishra *et al.* (2001) examined the effects of intercrop (wheat, barley, gram, and fenugreek) on the yield of Indian mustard and the incidence of *L. erysimi*. He found that only Indian mustard + chickpea had lower mean pest incidence (24.61) than the sole Indian mustard (25.50).

Letourneau (1986) examined the effect of crop mixtures on squash herbivore density in the tropical low lands of Mexico. He found that *Diaphania hyalinata* (L.), the most abundant insect in the system, generally had lower population density in intercropping (maize +cowpea + squash) than in monoculture (squash alone) system.

Lasker *et al.* (2004) reported that early sown crop attracted lower number of aphids yet the grain yield was maximum in crop sown during the first week of December. Intercropping of mustard with various other winter season crops (wheat, barley, radish, fenugreek, spinach, coriander , pea and fennel), sown at 2:1 ratio, resulted in lower incidence of the aphid except in mustard-radish combination in which the incidence was with sole crop of mustard; the minimum incidence was found in mustard-wheat, which was with mustard-barley combination. They also reported that economic analysis of the yield data showed that although seed yield was significantly higher in sole crop of mustard yet the sale proceeds of the intercrops gave additional monetary returns which

accounted for 2.39-3.62 times higher return than that from sole crop of mustard, being highest in mustard-spinach intercrop.

Bender *et al.* (1999) claimed that intercropping of cabbage (*Brassica oleracea* var. *capitata*) with Indian mustard (*Brassica juncea*) reduced pesticide applications and was evaluated over three cropping seasons. Insects were monitored in non-intercropped cabbage, cabbage plots surrounded by Indian mustard, and the Indian mustard intercrop. Intercropping had no significant effect on the number of lepidopterous larvae in cabbages. Indian mustard did not appear to preferentially attract lepidopterous insects, but was highly attractive to hemipterans, especially harlequin bugs (*Murgantia histrionica*). In one season with heavy harlequin bug pressure, intercropping with Indian mustard eliminated two insecticide applications to cabbage.

Monika *et al.* (2005) conducted an experiment to determine the effect of intercropping Indian mustard with potato, coriander (*Coriandrum sativum*), chickpea, wheat, linseed and fenugreek, on the incidence of the major insect pests, i.e. mustard aphid (*Lipaphis erysimi*), flea beetle (*Phyllotreta cruciferae*) and saw fly (*Athalia proxima*) and on the yield of mustard as sole crop and with intercrops. The lowest aphid population was recorded in mustard grown with coriander and the maximum population was observed on mustard as sole crop. Flea beetle incidence was minimum on mustard intercropped with linseed and maximum when sown with potato, while saw fly population was minimum on mustard sown with potato and maximum on mustard as sole crop. In monetary terms, the yield of mustard + linseed was maximum, while a minimum return was recorded for mustard + wheat.

Natural enemies

Andow and Risch (1985) observed that predaceous coccinellid beetles, *Coleomegilla maculata* (Dey) and its prey (aphids) were more abundant on sole crops than on mixed maize and beans.

Nampala *et al.* (1999) observed that the abundance of predatory *Orius* sp., spiders and earwigs differed significantly among the cowpea cropping systems, being more common

in the cowpea pure stands and cowpea +green gram than in the cowpea + sorghum intercrops.

In Kenya, Kyamanywa *et at.* (1993) assessed the impact of cowpea + maize intercropping on generalist predators and population thickness of flower thrips Megalurothrips sjostedti Trybom. Strangely, bounty of the Orius sp., lady bird beetles, earwigs and bugs were not upgraded by planting cowpea as a blended yield with maize. In contrast, Ogenga-Latigo *et* ***at.*** (1993) found *Aphis fabae* and coccinellid beetles at higher density on sole crop *Phaseolus* beans than in a mixture with maize.

According to Srikanth *et al*. (2000), the incidence of sugarcane top shoot borer, *Chilo infuscatellus* Snellen (Lepidoptera: Crambidae) did not differ significantly when sugarcane intercropped with blackgram, cowpea, greengram and soybean. The incidence of top borer, *Scircophaga excerptalis* wlk. (Lepidoptera: Pyralidae) was negligible in all combinations. Counts of predators, comprising spiders and coccinellids, showed marginal differences. In another experiment, they also claimed that mean predator number did not differ significantly between intercrop and monocrop.

Mote *el al*. (2001) found that the intercropping of cowpea as well as green gram and cotton proved to be better in suppressing the population of sucking pests. Minimum incidence of bollworm complex was recorded in cotton +cowpea system. Regarding predators and parasitoids, the untreated crops showed maximum number of predators followed by sprays on intercrop only, however, cowpea intercrops system showed maximum number.

Turker *et al*. (2000) studied the effects of intercropping of chickpea (gram) with coriander. They recorded significantly higher parasitoid activity (5.7 cocoons per 5 m row length), low pest activity (2.33larvae per 5 m row length), minimum pod damage (12.7%) and higher grain yield of chickpea (15.5 q/ha) in plots sown with coriander within the rows of gram as compared to the chickpea sole crop. Hansen (1983) clearly demonstrated the increased abundance of several predator species in an intercrop system of maize and cowpea in Southern Mexico, suggesting an explanation for the over yielding of that system as reported by Vandermeet *et al*. (1983). Gavarra and Raros (1975)

detailed spiders to be progressively viable against corn borers in an intercrop of corn and groundnuts than in monoculture of corn.

Intercropping and crop yield by suppressing pest

Khehra *et al*. (1979) in an experiment found that blackgram consistently gave higher yield when intercropped with maize, although the blackgram as intercropped depressed the maize yield. Study of Krishna and Raikhelkar (1997) in maize- legumes intercropping systems found that maize + blackgram (3.8t ha^{-l}), maize + green gram (3.6 t ha^{-l}) and maize pegionpea (3.53 t ha^{-l}) gave significantly higher seed yield than other systems. Considering maize equivalent yield, maize + pegionpea (4.88 t/ha) and maize + blackgram (4.66 t ha^{-l}), gave significantly higher equivalent yield than the other intercropping systems. Using land equivalent ratio (LER) as criteria, Bhuiyan (1981) examined mixed crop combinations of lentil, gram and soybean with wheat under different proportion and recorded the highest LER (l.47) in gram and wheat followed by lentil and wheat at 100:75, 100:50 and 100:25 values 1.37, 1.23 and 1.15, respectively.

Rathore *et al.* (1980) conducted an intercropping experiment of maize with pulses and found that maize + blackgram combination produced the highest grain yield.

These reviews of the literature represent that different intercropping systems had lowered insect infestation and higher abundance of natural enemies. Intercropping system has proven to show greater productivity and higher economic return than monocropping system. It can also reduce dependency on chemical insecticides and ensure a greater environmental protection. As intercropping has great scope in managing insect pests, it is therefore necessary to speculate the lower incidence of insect pests, abundance of natural enemies, and productivity and economics of intercropping systems.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study the effect of intercropping on the incidence of aphid population in mustard and its impact on other arthropods during the period from mid October, 2017 to February, 2018. The subtleties of the materials and techniques that used to direct the investigation are exhibited underneath:

3.1 Location of the experimental field

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from mid October, 2017 to February. The location of the experimental site was at 23^0 46' N latitude and 90^0 22' E longitudes with an elevation of 8.24 meter from sea level (Khan, 1997).

3.2 Climate condition during the experiment

The experimental area is characterized by subtropical rainfall during the month of April to September and scattered rainfall during the rest of the year. Information regarding average monthly temperature as recorded by Bangladesh Meteorological Department (climate division) during the period of study has been presented in Appendix I.

3.3 Soil of the experimental field

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) (UNDP and FAO, 1988) with pH 5.8-6.5, ECE-25.28 (Haider, 1991). The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.4 Planting material and its characteristics

The variety of Mustard Tori-7 was selected for the experiment during Rabi season 2017-2018. The seed of this variety was collected from Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

The variety was local one and improved by the Bangladesh Agricultural Research Institute (BARI) in the year of 2004. The plant height of this variety ranges 60-75cm and the life cycle is 75 -75 days when cultivated in robi season.

3.5 Treatments

Combination of mustard (*Brassica spp*) with cabbage (*Brassica oleracea* var. *capitata*), onion (*Allium cepa* L.), garlic (*Allium sativum* L.), black seed/black cumin (*Nigella sativa* L), coriander (*Coriandrum sativum* L.), radish (*Raphanus raphanistrum* subsp. *sativus*) constitute the intercropping systems. The intercropping treatments were as follows:

Treatments	**Compositions**
T_1	Mustard intercropped with cabbage
T_2	Mustard intercropped with onion
T_3	Mustard intercropped with garlic
T_4	Mustard intercropped with black seed
T_5	Mustard intercropped with coriander
T_6	Mustard intercropped with radish
T_7	Sole mustard (control)

Plate 1: Mustard seedling at the early vegetative stage

Plate 2: Experimental plot at the flowering stage (A) and fruiting stage (B) during the study period

Plate 3: Experimental plot intercropping with cabbage during the study period

Plate 4: Experimental plot intercropping with onion during the study period

Plate 5: Experimental plot intercropping with garlic during the study period

Plate 6: Experimental plot intercropping with coriander during the study period

3.5.1 Seed collection for intercropping crops

Cabbage, onion (BARI onion-l), garlic (BARI Garlic-l) bulbs and coriander, black seed, radish, seeds were collected from Spices Research Centre, Bangladesh Agricultural Research Institute, Gazipur.

Land preparation

The experimental plot was opened in the 2nd week of October 2017 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for sowing of mustard Seeds.

The experiment was conducted considering seven treatments and laid out in a Randomized Complete Block Design (RCBD). Each treatment was replicated three times. Field trials were conducted during the winter season in the research field of Entomology Department, Sher-e-Bangla Agricultural University Campus. Mustard (*Brassica napus var*. Bari Sarisha-7 with local varieties of onion *(A. cepa*) and garlic (*A. sativum*) cabbage, corriender, black seed, radish were selected for intercropping. Altogether 3 blocks were prepared and 3 replications for each category cabbage + mustard, onion + mustard and garlic + mustard, black seed + mustard, coriander + mustard, radish + mustard & only mustard were cultivated for this experiment. The unit plot size was 25 m x 12m. The distance between plots and blocks were 0.75 m and 1.0m, respectively. Row to row distance for mustard was 50 cm. Similar distance was maintained when every seeds were sown, respectively.

Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of Urea, TSP, MP, Gypsum, Zinc sulphate and borax, respectively were applied. The entire amount of TSP, MP, Gypsum, Zinc sulphate and borax were applied during the final preparation of land. Urea was applied in two equal installments at final land preparation and at 30 days of seed sowing. The dose and method of application of fertilizers are shown in Table 1 (Anon., 2005).

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

Fertilizers	Dose (kg/ha)	Application (%)	
		Basal	Top dressing
Urea	300	50	50
TSP	180	100	--
MP	100	100	--
Gypsum	180	100	--
Znic sulphate	07	100	
Borax	15	100	--

Date of sowing

The seeds of mustard were sown in sole and in intercrop plot on November 2017.The seeds of cabbage, onion (bulb), garlic (bulb), coriander, black seed, radish was sown on the same date.

Cultural practices

After foundation of seedlings, all other intercultural activities, for example, diminishing, weeding, water system were cultivated according to as when fundamental for better development and advancement of the mustard crop. Single water system was connected only once before blossom commencement. Plots were furnished with all around masterminded seepage offices as anticipation procedure of expelling overabundance downpour water assuming any. Weeding was done twice in the field to keep the plots free from weeds to guaranteed better development and advancement of the yields. The recently risen weeds were evacuated cautiously at blossoming stage by mechanical methods.

Plate 7: Aphid infested radish plant during study period

Plate 8: Aphid infested mustard plant with pods during study period

Data collection

The data on the following parameters were recorded at different time intervals as given below:

- Total number of infested plants/plot.
- Total number of branch/plant
- Total number of infested branch/plant
- Total number of Pod/plant
- No of infested Pod/plant
- Total number of flower/plant
- No. of infested flower/plant
- Total number of Aphid (Per/cm)
- Number of honey bee (*Aphis florae* & *Aphis indica*).
- Total number of seeds five selected plants/plot
- Weight of total number of seeds/5 selected plot
- Total number of pods/5 selected plants
- Weight of pods/5 selected plants

Procedure of recording data

Total number of infested plants/plot: Total number of infested plant was counted from each replication from randomly selected five plants.

Total number of branch: Total number of branch was counted from each replication from randomly selected five plants also.

Total number of infested branch: Total number of infested branch was counted from total number of branch among selected five plants.

Total number of flower: Total number of flower was counted from each replication from randomly selected five plants.

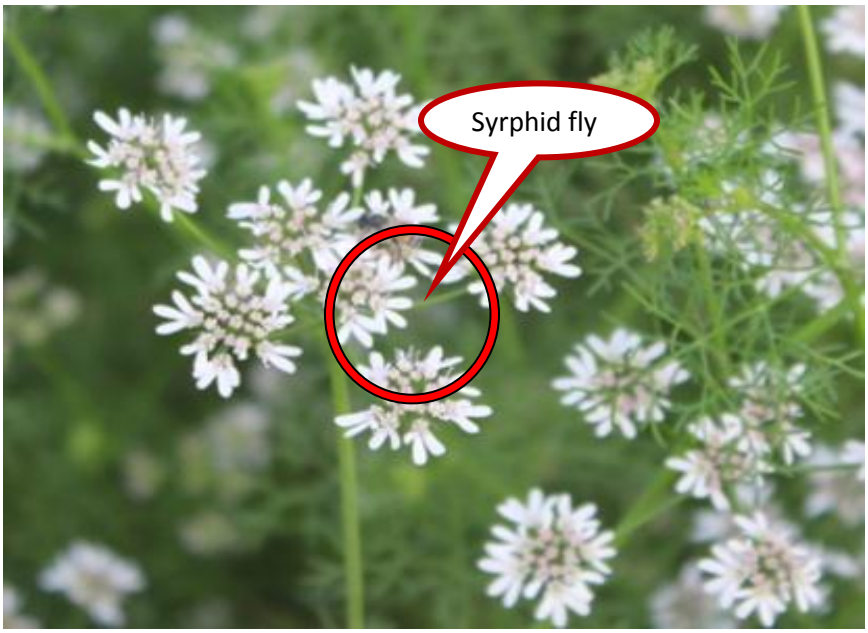

Plate 9: Syrphid fly on coriander flowers during study period in the experimental plot

Plate 10: Syrphid fly on mustard flowers during study period in the experimental plot

Total number of infested flower: Total number of infested flower was counted from total number of flower among selected five plants.

Total number of pod: Total number of pod was counted from each replication from randomly selected five plants, then average number of pod/plant was counted. Average number of seed per plant was also counted and total seed weight was measured.

Total number of infested pod: Total number of infested pod was counted from total number of pod among selected five plants.

Total number of Aphid: Total number of aphid was counted between 1cm from the inflorescense plant from each replication from randomly selected five plants.

Number of honeybee (*Apis indica*)

Number of honeybee was counted from randomly selected five plants.

Harvesting, threshing and cleaning

Mustard was collected at the development (93 days of sowing without exasperating the other inter crops) was done physically from each plot. Cabbage, Garlic and onion were reaped 102 days in the wake of sowing. The black seed, coriander and radish were gathered at same date separately. Distinctive collected harvests of each plot was packaged independently, appropriately labeled and brought to research facility floor. Care was taken for reaping, sifting and furthermore cleaning of mustard and other inters crops. The seeds were cleaned lastly the weight was recorded and changed over into per hectare yield. Mustard of each plot was threased independently, cleaned, sun dried, gauged and pressed. Black seed was threased cautiously in view of its light and little grain. Threased mechanically, cleaned, sun dried and weighed on those by mustard. Mature onion and garlic bulbs were separated from the stem using sickle manually.

Statistical analysis

Data were analyzed by Statistis10 software for proper interpretation. The data recorded on different parameters were subjected to analysis of variance (ANOVA) and means were compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance.

Plate 11: Honey bee on mustard flowers during study period in the experimental plot

Plate 12: Healthy mustard with flowers and pods during study period in the experimental plot

CHAPTER IV

RESULTS AND DISCUSSION

The results on the effect of intercropping systems with mustard + cabbage, mustard + onion, mustard + garlic, mustard + black seed, mustard + coriander and mustard + radish compared to its monoculture on incidence of aphid and its impact on other arthropods. The results of the present study have been discussed and possible interpretations are furnished and presented in this chapter under the following sub headings:

4.1 Number of aphid population on mustard due to intercropping

In case of number of aphid per plant, significant variation was found in different treatments. There were showed that the lowest number of aphid (13.72) was recorded in T_5 (mustard + coriander intercropped combinations) treatment which was statistically similar to T_2 (mustard + onion) that is 15.51 /plant and 14.46 /plant in T_3 (mustard + garlic) treatment respectively. On the other hand, the highest number of aphid per plant (20.05) was recorded in T_6 (mustard + radish intercropping system) which was statistically different from all other treatments. In case of percent increase or decrease of aphid population on mustard over sole crop, onion, coriander, garlic and black seed decreased population of aphid on mustard over sole crop but cabbage and radish increased aphid population on mustard over sole crop were observed in Table 1.

The result were more or less similar with the findings of Halepyatic *et al*. (1987) who observed that intercropping of garlic with different crops reduced the population of different target pests. The result partially contradicts with the findings of Tiwari *et al.* (2005). They studied the effect of intercropping of mustard with potato, coriander (*Coriandrum* (*sativu*), chickpea, wheat, linseed and fenugreek, on the incidence of the major insect pests, i.e. mustard aphid (*Lipaphis erysimi*), flea beetle (*Phyllotreta cruciferae*) and saw fly (*Athalia proxima*) and on the yield of mustard as sole crop and intercrops. They found that the maximum population was observed on mustard as sole crop and the lowest aphid population was recorded in mustard grown with coriander.

Table 1. Effect of intercropping of mustard with other crops on aphid population

Treatments	Number of aphid/plant	% increase (+) or decrease (-) over sole crop
T_1	18.52 ab	+ 14.417 a
T_2	15.51 cd	- 8.4400 c
T_3	14.46 cd	- 11.290 b
T_4	16.86 bc	- 12.157 ab
T_5	13.72 d	- 8.3433 c
T_6	20.05 a	+ 13.583 ab
T_7	18.82 ab	0
CV%	5.82%	8.56%
LSD0.05	2.79	2.38

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

[T_1= Mustard intercropped with cabbage; T_2= Mustard intercropped with onion; T_3= Mustard intercropped with garlic; T_4= Mustard intercropped with black seed; T_5= Mustard intercropped with coriander; T_6= Mustard intercropped with radish and T_7= Sole mustard as Untreated control]

4. 2 Number of aphid infested plants of mustard

From Table 2, it was observed that mustard plants with intercropped crops were greatly influenced by the presence of aphid that reduce crop yield. Results illustrated that significant variation was observed in terms of affected plants by aphid at different treatments. The highest number of aphid infested plants/plot (2.87) was recorded in mustard sole crop (T_7) which was statistically different from all intercropping plots. Conversely, aphid infested plants/plot was significantly lower in all intercropping plots. The lowest number of affected plants/plot (1.45) was recorded in mustard + onion (T_2) followed by mustard + black seed (T_4) and mustard + coriander (T_5) having no significant difference among them. The result indicates that intercropping of mustard with spices reduced aphid infestation over sole crops in the field. This result were more or less similar with the findings of Singh and Kothari (1997) who observed that intercropping mustard with aromatic plants like coriander reduced aphid infestation on

mustard over monocrop. It also supports the report of Monika *et al.* (2005) who recorded the maximum population on mustard as sole crop and the lowest aphid population in mustard grown with coriander.

4.3 Number of branch/plant of mustard due to intercropping with other crops

In Table 2, it was revealed that significant variation was observed in terms of number of branches/plant at different intercropping with other crops. The lowest number of branch/plant (7.19) was recorded in mustard sole (T_7) intercropped combinations. Although sole crops had the highest aphid infestation and number of branch was higher due to lack competition with other crops. On the other hand, the highest number of branches/plant (9.28) was recorded in mustard + onion (T_2) followed by T_6 (mustard + radish) and T_4 (mustard + black seed), intercropping system having no significant difference among them

Table 2. Effect of intercropping on mustard plant and branch infestation by aphid

Treatments	Total number of infested plant/plot	Total number of branch/plant	Number of aphid infested branch/plant	Branch infestation (%)
T_1	1.77 ab	7.66 bc	1.80 bc	27.21 a
T_2	1.45 b	9.28 a	1.50 c	22.58 b
T_3	1.74 ab	7.65 bc	2.66 ab	22.57 b
T_4	1.65 b	8.01 abc	1.66 c	20.15 bc
T_5	1.48 b	7.67 bc	1.58 c	19.65 c
T_6	1.70 ab	8.75 ab	2.38 abc	22.51 b
T_7	2.87 a	7.19 c	2.92 a	28.73 a
CV%	22.91**%**	6.40**%**	16.42**%**	3.68**%**
LSD 0.05	1.18	1.46	0.97	2.45

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

[T_1= Mustard intercropped with cabbage; T_2= Mustard intercropped with onion; T_3= Mustard intercropped with garlic; T_4= Mustard intercropped with black seed; T_5= Mustard intercropped with coriander; T_6= Mustard intercropped with radish and T_7= Sole mustard as Untreated control]

4.4 Branch of mustard infestation by aphid

From table 2 demonstrated that significant variation was existed in case of aphid infested branch per plant under different treatments. The highest number of aphid infested branches/plant (2.92) was recorded from mustard sole plot which significantly higher than all other treatments. However, the lowest number of aphid infested branch per plant (1.50) was recorded from mustard + onion (T_2) crop combination, which was statistically analogous to all other intercropping combinations. Similarly the lowest percentage of infested branch was found in (1.66) in mustard + black seed intercropped system which was statistically similar to T_5, T_1 and T_6 intercropping combinations and that was significantly higher in mustard sole treatment in table 2. The results were more or less similar with the findings of Monika *et al.* (2005) who studied the effect of intercropping of Indian mustard with coriander and other crops and the incidence of the major insect pest, i.e. mustard aphid and found the lowest aphid population in mustard grown with coriander and the maximum population was observed on mustard as sole crops. The result partially contradicts with the findings of Goel and Tiwari (2004) and they reported that aphid population was lowest when mustard was intercropped with coriander followed by gram and other intercrops and the maximum aphid population was recorded when mustard was grown as a sole crop.

4.5 Number of flower per plant

From table 3, it was observed that numbers of flower infestation of mustard plants with intercropped crops were greatly influenced by the presence of aphid. Results illustrated that significant variation was observed in terms of flower at different treatments. Results showed that the highest number of flower/branch (7.48) was recorded in T_5 (mustard +coriander) treatment which was statistically similar in (7.24) mustard + garlic (T_3) intercropped combination. The lowest number of flower/branch (5.37) was recorded in mustard + cabbage (T_1) intercropped combinations. The contradictory result was found

by Lasker *et al.* (2004) reported that intercropping of mustard with various crops like wheat, radish, barley, resulted in lower incidence of the aphid except in mustard–radish combination in which the incidence was highest with sole crop of mustard; the minimum incidence was found in mustard-cabbage.

4. 6 Flower infestation by aphid

In terms of infested flower by aphid at different treatments in Table 3 were significantly different. Results revealed that the highest number of infested flower/plant (97.96) was caused by aphid was recorded in (T_7) mustard (control). On the other hand, the lowest number of infested flower/branch (40.49) was recorded in mustard + onion (T_2) intercropping system. Statistically similar results were found in case of total number of infested flower but significant difference was observed in terms of present infested flower by aphid in different treatments. The contradictory result was found by Goel and Tiwari (2004) who worked on mustard with potato, wheat, gram (*Cicer arietinum*), linseed, fenugreek and coriander and counted aphid population. He found the lowest aphid number when mustard was intercropped with coriander, followed by linseed, fenugreek, gram, wheat and potato and the maximum aphid population was recorded when mustard was grown as a sole crop. On the other hand, highest percentage of infested flower was found in (97.96) in sole mustard and lowest percentage of flower infestation was found in (40.49) in mustard + onion intercropped system. Incase of percent decrease of flower infestation over sole crop result showed that highest reduction was found (57.91) in mustard + onion (T_2) which was statistically similar (57.46) in mustard + coriander (T_5) crop combination. The lowest reduction was found (8.43) in mustard + gram (T_6) intercrop combination.

Table 3. Effect of intercropping of mustard with other crops on flower infestation by aphid

Treatments	Number of flowers/ infested branch	Number of aphid infested flower/ infested branch	Flower infestation (%)	% decrease of flower infestation over sole crop
T_1	5.37 b	4.07 bc	72.71 c	25.37 d
T_2	5.80 ab	3.10 c	40.49 f	57.91 a
T_3	7.24 a	4.31 abc	63.24 d	36.72 b
T_4	6.60 ab	4.79 abc	65.11 d	32.70 c
T_5	7.48 a	4.61 abc	44.38 e	57.46 a
T_6	6.41 ab	5.33 ab	89.55 b	8.43 e
T_7	6.71 ab	6.24 a	97.96 a	0
CV%	9.53%	14.64%	1.34%	3.76%
LSD0.05	1.77	1.93	2.58	3.35

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

[T_1= Mustard intercropped with cabbage; T_2= Mustard intercropped with onion; T_3= Mustard intercropped with garlic; T_4= Mustard intercropped with black seed; T_5= Mustard intercropped with coriander; T_6= Mustard intercropped with radish and T_7= Sole mustard as Untreated control]

4.7 Number of pod per branch of plant

In terms of pod per branch of mustard plant with intercropped crops were greatly influenced by aphid. At the different treatments there were significant variation was observed in table 4. The highest number of pod/branch (19.45) was recorded in T_5 (mustard + coriander intercropping system) treatment, which was statistically similar (17.74) in T_2 (mustard +onion) treatment. On the other hand, the lowest number of pod/branch (10.52) was recorded in T_7 mustard (untreated control). The divergent result was found by Lasker *et al.* (2004). He reported that intercropping of mustard with various other winter crops like wheat, radish, and barley, resulted in lower incidence of the aphid except in mustard –radish combination in which the incidence was highest in sole crop of mustard; the minimum incidence was highest in mustard-cabbage.

4.8 Pod infestation by aphid

From table 4, it was observed that the highest number of infested pod/plant (8.11) was recorded in T_6 (mustard + radish intercropping system) treatment, which was statistically similar with T_3 (7.42) treatment (mustard + garlic crop). Similar trend was also observed in percent infested pod at the different treatment. On the other hand the lowest number of infested pod/plant (4.78) was recorded in T_1 (mustard + cabbage intercropping system) treatment, which was closely statistically similar to other treatments. In case of percent of pod infestation by aphid in table 4, there were significant difference was observed in different treatments. Incase of percent decrease of pod infestation over control the highest reduction of infestation was found (53.60) in mustard + coriander (T_5) intercropped combination, so the lowest number of infestation was also observed (24.74) in T_5 (mustard + coriander intercropped system) treatment.

Table 4. Effect of intercropping of mustard with other crops on pod infestation by aphid

Treatments	Total number of pod/branch	Total number of infested pod/branch	Pod infestation (%)	% decrease of pod infestation over sole crop
T_1	15.95 b	4.78 d	27.19 cd	45.37 c
T_2	17.74 ab	6.36 bc	28.99 c	43.87 c
T_3	16.67 b	7.42 ab	38.41 b	47.75 b
T_4	16.13 b	5.24 cd	27.05 d	47.37 b
T_5	19.45 a	5.79 cd	24.74 e	53.60 a
T_6	16.68 b	8.11 a	36.55 b	32.25 d
T_7	10.52 c	5.46 cd	51.97 a	0
CV %	5.06%	8.32%	1.94%	2.30%
LSD0.05	2.336	1.46	1.86	2.32

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

[T_1= Mustard intercropped with cabbage; T_2= Mustard intercropped with onion; T_3= Mustard intercropped with garlic; T_4= Mustard intercropped with black seed; T_5= Mustard intercropped with coriander; T_6= Mustard intercropped with radish and T_7= Sole mustard as Untreated control]

4. 9 Number of different pollinators per plant due to intercropping

From table 5, it was revealed that mustard plants with intercropped crop were greatly influenced by the presence of different pollinators which increase crop yield. Results illustrated that the highest number of honeybee (4.28) was recorded in T_5 treated plot (Mustard intercropped with coriander). The second highest number of honeybee was observed (3.16) in T_4 (mustard+ black seed intercropped combinations) treated plot. On the other hand, the lowest number of honeybee (1.86) was recorded in T_3 (mustard +

garlic) treatment. It was also observed that the result from other treatments gave intermediary results compared to the highest and the lowest honeybee in table 5. Similar way it was showed that the highest number of wasp (4.29) was recorded in T_6 treated plot (mustard + radish intercropping system) and the lowest was recorded (1.83) in T_4 (mustard+ black seed intercropped combinations) treated plot. In case of other pollinators like syrphid fly, the highest number (4.26) was recorded in mustard + radish (T_6) intercropping system which was statistically similar to T_1 (3.02) treatment (Mustard + cabbage) and T_3 (3.10) treatment (Mustard + garlic). The lowest recorded in T_4 (1.94) treatment (Mustard + black seed) in table 5.

Table 5. Effect of intercropping mustard with other crops on visiting pollinators

Treatments	Number of honeybee (*Apis indica*)/plant	Number of Wasp/plant	Number of Syrphid fly/ plant
T1	2.95 bc	3.07 bc	3.02 ab
T_2	1.89 c	1.94 cd	2.11 b
T_3	1.86 c	3.14 ab	3.10 ab
T_4	3.16 ab	1.83 d	1.94 b
T_5	4.28 a	2.26 bcd	2.26 b
T_6	2.16 bc	4.29 a	4.26 a
T_7	1.93 c	2.10 bcd	2.02 b
CV	16.62**%**	15.47**%**	17.34%
LSD0.05	1.23	1.17	1.32

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

[T_1= Mustard intercropped with cabbage; T_2= Mustard intercropped with onion; T_3= Mustard intercropped with garlic; T_4= Mustard intercropped with black seed; T_5= Mustard intercropped with coriander; T_6= Mustard intercropped with radish and T_7= Sole mustard as Untreated control]

4. 10 Number of beneficial insects during study period in the experimental field

From table 6, it was observed that mustard plant with intercropped other crops were greatly influenced by the presence of beneficial insects like lady bird beetle, dragon fly, damsel fly. Results showed that the highest number of lady bird beetle observed in T_1 (21.52) treatment **(**Mustard + cabbage intercropping system) and the lowest in T_7 (14.70)

treatment Sole mustard. Statistically similar results were observed in T_5 (Mustard + coriander), T_6 (Mustard + radish), T_3 (Mustard + garlic) and T_4 (Mustard + black seed) treatments (19.63, 18.37, 18.41and 18.14) respectively.

Similar trends of result also observed in case number of dragon fly and damsel fly per plot during the study period in the experimental field.

Table 6. Effect of intercropping mustard with other crops on visiting beneficial insects during study period in the experimental field

Treatments	Number of lady bird beetle/plot	Number of dragon fly/plot	Number of damsel fly/plot
T_1	21.52 a	8.78 bc	6.03 bc
T_2	16.17 cd	9.73 b	9.73 a
T_3	18.41 bc	7.22 cd	6.41 bc
T_4	18.14 bc	12.88 a	7.33 ab
T_5	19.63 ab	7.55 bcd	6.71 bc
T_6	18.37 ab	6.25 d	6.70 bc
T_7	14.70 d	5.51 d	4.54 c
CV	5.97%	9.69%	12.54%
LSD0.05	3.08	2.29	2.42

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

[T_1= Mustard intercropped with cabbage; T_2= Mustard intercropped with onion; T_3= Mustard intercropped with garlic; T_4= Mustard intercropped with black seed; T_5= Mustard intercropped with coriander; T_6= Mustard intercropped with radish and T_7= Sole mustard as Untreated control]

4.1.11 Effect of intercropping on grain yield of mustard during the study period

From table 7, it was revealed that mustard plants with intercropped crop were greatly influenced increase crop yield. Results illustrated that the highest number of healthy pod/plant (82.99) was recorded in T_5 (mustard + coriander intercropping system)

treatment, which was statistically similar (69.08) in T_4 (Mustard intercropped with black seed), T_1 (Mustard intercropped with cabbage), T_3 (Mustard + garlic) and T_2 (Mustard + onion) intercropped combinations treatment. On the other hand, the lowest number of pod/plant (32.23) was recorded in T_7 sole mustard (untreated control) crop.

Significant variation was found in different treatments in case of grain yield per plot. Results showed that the lower grain yield per plot (315.84) were recorded in T_7 (Sole mustard), which was statistically similar with (358.25) at T_3 (Mustard + garlic) and 374.05 gm at T_6 (Mustard + radish). On the other hand the highest grain yield per plot (454.74) were recorded in T_5 (mustard + coriander), which was statistically similar with (432.95) gm at T_4 (Mustard + onion) intercropped combinations, 430.82 gm at T_2 (Mustard + onion) and T_1 (Mustard + cabbage) treatments respectively in table-7.

Table 7. Effect of intercropping on grain yield of mustard during the study period

Treatments	Number of healthy pod/plant	grain yield/plot(gm)
T_1	65.60 ab	428.15 b
T_2	64.54 ab	430.82 b
T_3	47.08 bc	358.25 d
T_4	69.08 ab	432.95 b
T_5	82.99 a	454.74 a
T_6	55.01 bc	374.05 c
T_7	32.23 c	315.84 e
CV	14.61%	0.89%
LSD0.05	24.80	10.14

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

[T_1= Mustard intercropped with cabbage; T_2= Mustard intercropped with onion; T_3= Mustard intercropped with garlic; T_4= Mustard intercropped with black seed; T_5= Mustard intercropped with coriander; T_6= Mustard intercropped with radish and T_7= Sole mustard as Untreated control]

4.2.1 Relationship between number of aphid and percent of pod infestation per plot:

Correlation study was done to establish the relationship between number of aphid / plant and percent of pod infestation per plot among different treatments. From the Figure 1, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = 0.648x + 28.21 gave a good fit to the data and the co-efficient of determination (R^2 = 0.046) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that the percent of pod infestation was strongly as well as positively correlated with number of aphid/plant. Percent of pod infestation /treated plot was increased due to increase of the number of aphid/plant.

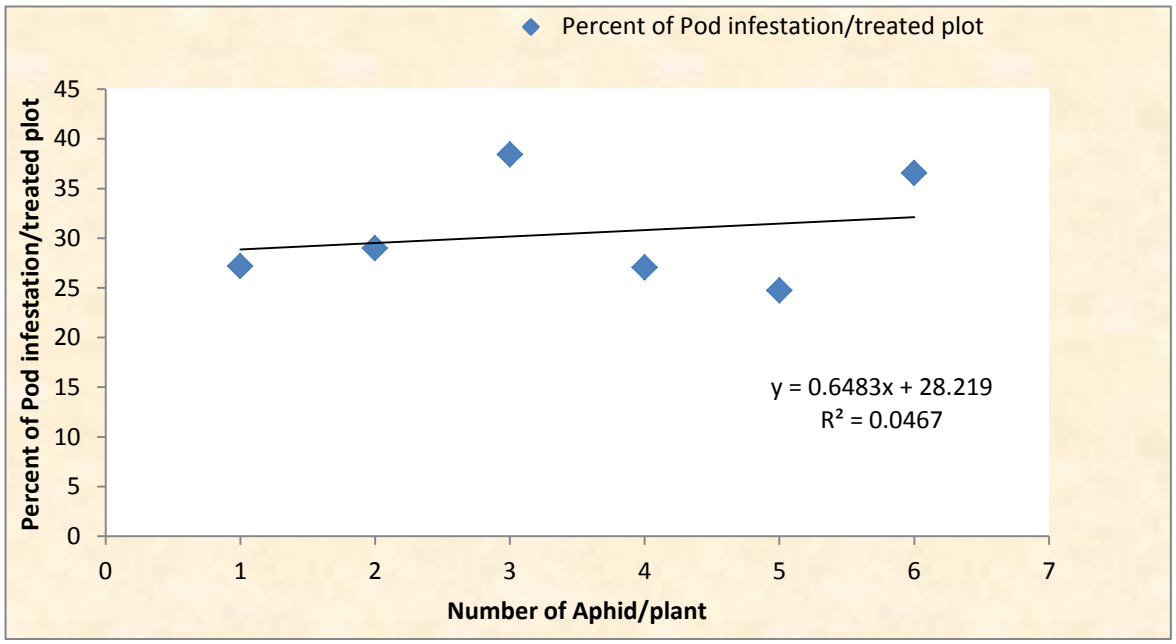

Figure 1: Relationship between number of aphid and percent of pod infestation per plot

4.2.2 Relationship between percent of fruit infestation per plot and grain yield

Correlation study was done to establish the relationship between percent of pod infestation per plot and grain yield of mustard per plot among different treatments. From the Figure 1, it was revealed that negative correlation was observed between the parameters. It was evident that the equation y = -12.64x + 449.8 gave a good fit to the data and the co-efficient of determination (R^2 = 0.046) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that the grain yield of mustard per plot was strongly as well as negatively correlated with percent of pod infestation. Grain yield of mustard per plot was decreased due to increase of the Percent of pod infestation /treated plot.

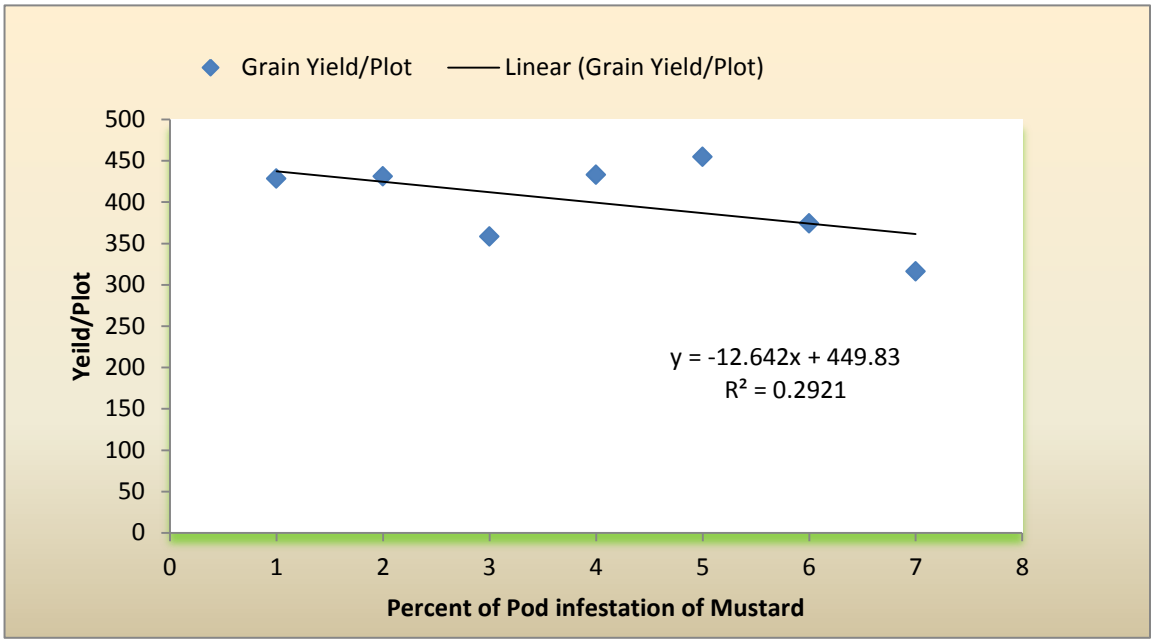

Figure 2: Relationship between percent of pod infestation per plot and grain yield of mustard

CHAPTER V

SUMMARY AND CONCLUSION

The research experiment was carried out in the experimental farm of Sher-e-Bangla Agricultural University, to investigate the effect of intercropping mustard on aphid and other arthropods during the period from mid October, 2017 to February 2018. The crop combinations were mustard + cabbage, mustard + onion, mustard + garlic, mustard + coriander; mustard + black seed mustard + radish and sole mustard (control). The experiment was laid out in a Randomized Complete Block Design with three replications.

In the experiment data were collected on the different parameters such as number of infested plants/plot, number of branch/plants, number of infested branch/plants, number of pod/plants, number of infested pod/plants, number of flower/plants, number of infested flower/plants, number of aphid (per/cm), number of different pollinators such as honeybee, wasp, syrphid fly; number of pod/plants, number of seeds/pod, and weight of total seeds/plot.

Significantly the lowest number of infested plant/plot affected by aphid was found (1.45) in mustard + onion (T_2) crop combination and the highest number of infested plants/plot (2.87) was recorded in mustard control (T_7) intercropping system. In term of branches/plant, It was also observed that the highest number of branches/plant (9.28) was recorded in mustard+ Onion (T_2) intercropping system, and the lowest number of branches/plant (7.19) was recorded in sole mustard (T_7) intercropped combinations. At the same time, results demonstrated that the highest number of infested branches/plant (2.87) caused by aphid was recorded in sole mustard (T_7) and the lowest percentage of infested branch/plant was found in (1.45) in mustard + onion (T_2) intercropped.

In the term of flower/branch, the highest number of flower/branch (7.48) was recorded in mustard + coriander (T_5) intercropping system, and lowest number of flower/branch (5.37) was recorded in mustard + cabbage (T_1) intercropped combinations. Results showed that the highest number of infested flowers/branch (97.96) was recorded in sole mustard (T_7), the lowest number of infested flower/branch (40.49) was recorded in mustard + onion (T_2) intercropping system. It was also observed, the highest number of pod/branch (19.45) was recorded in mustard + coriander (T_5) and the lowest number of

pod/branch (10.52) was recorded in sole mustard (T_7). At that time the lowest number of infested pod/branch (4.78) was recorded in mustard + cabbage (T_1) intercropping system, and the highest number of infested pod/branch (8.11) was caused by aphid was recorded in mustard + radish (T_6), Whereas, aphid number (20.05) was the highest in mustard + radish (T_6) intercropping system.

In term of beneficial insects, results showed that the highest number of lady bird beetle observed in T_1 (21.52) treatment **(**Mustard + cabbage intercropping system) and the lowest in T_7 (14.70) treatment Sole mustard. Statistically similar results were observed in T_5 (Mustard + coriander), T_6 (Mustard + radish), T_3 (Mustard + garlic) and T_4 (Mustard + black seed) treatments (19.63, 18.37, 18.41and 18.14) respectively. Similar trends of result also observed in case number of dragon fly and damsel fly per plot during the study period in the experimental field.

Incase of pollinators, results illustrated that the highest number of honeybee (4.28) was recorded in T_5 treated plot (Mustard intercropped with coriander). The second highest number of honeybee was observed (3.16) in T_4 (mustard+ black seed intercropped combinations) treated plot. On the other hand, the lowest number of honeybee (1.86) was recorded in T_3 (mustard + garlic) treatment. Similar way it was showed that the highest number of wasp (4.29) was recorded in T_6 treated plot (mustard + radish intercropping system) and the lowest was recorded (1.83) in T_4 (mustard+ black seed intercropped combinations) treated plot. In case of other pollinators like syrphid fly, the highest number (4.26) was recorded in mustard + radish (T_6) and the lowest recorded in T_4 (1.94) treatment (Mustard + black seed) intercropping system.

At last it was also found that the highest number of pod (82.99) and grain yield (454.74) were recorded in mustard + coriander (T_5) intercropping system and the lowest number of pod/plant (32.23) and grain yield (315.84) was recorded in sole mustard (T_7) intercropping system respectively.

CONCLUSION

From the study, it may be concluded that incidence of mustard aphid infestation was less in intercropping system and the abundance of different pollinators and other beneficial insects were also higher in intercropping system. When aphid infestation was higher in intercropping system then it was observed that pod formation was lower and seed yield also lower. At that time, when aphid infestation was lower in intercropping system then, pod formation and seed yield were higher. On the other hand, when honeybee and other pollinator's populations were increased, pod formation and seed yield were also increase. The overall study revealed that intercropping may be considered as tools of an eco-friendly pest management practice for mustard by which it could reduce the pest infestation without use of any chemical insecticide and also benefits on pollination. Among them intercropping system, sole mustard showed more infestation and mustard intercropped with coriander showed less infestation in intercropping system.

RECOMMENDATION

However, further study is recommended to assess the environment friendly management practices of mustard aphid in various intercropping systems prevailing in different agro eco-systems of Bangladesh.

CHAPTER VI

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