INTERCROPPING OF MUSTARD AND ITS EFFECT ON APHID AND HONEYBEE

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*This is to certify that thesis entitled, "**INTERCROPPING OF MUSTARD AND ITS EFFECT ON APHID AND HONEYBEE** 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 **SADIA AFRIN , Registration No. 12-05248** 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.

Dated: DECEMBER, 2013
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DEDICATED TO
MY
BELOVED PARENTS

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INTERCROPPING OF MUSTARD AND ITS EFFECT ON APHID AND HONEYBEE

BY

SADIA AFRIN[1]

THESIS ABSTRACT

A study was conducted in the experimental farm of Sher-e-Bangla Agricultural University during the period from November 2012 to March 2013 to find out the effect of intercropping on the incidence of aphid and its subsequent impact on growth and yield of mustard and its pollinator honeybee population. The intercroppings were mustard (*Brassica napus*, *V*ar. Bari Sarisha-7) with wheat (*Triticum aestivum* L.), onion (*Allium cepa* L.), garlic (*Allium sativum* L), coriander (*Coriandrum sativum* L.), radhuni (*Trachyspermum roxburghianum*) and gram (*Cicer arietinum* L.). Sole cropping of mustard was also grown to compare the effectiveness of intercropping system. The experiment was laid out in randomized complete block design (RCBD) with three replications.The overall result indicates that the intercropping of mustard with onion, garlic, coriander and rahuni decreased the incidence of aphid population on mustard and increased the abundance of visiting honeybee compared to sole cropping of (mustard). When aphid number (3.81) was increased in mustard + gram (T_6) intercropping system, at that time pod formation/plants (24.78) and seed weight/plot (7.63) were decreased. On the other hand, when aphid number (2.99) was decreased, at that time, pod formation and seed weight/plot (9.87) were increased. It was also observed that, when honeybee population (72.65) was increased then pod formation, seed weight/plot was also increased. On the other hand, when honeybee population (47.12) was decreased then pod number/plants, and seed weight/plot were also decreased.

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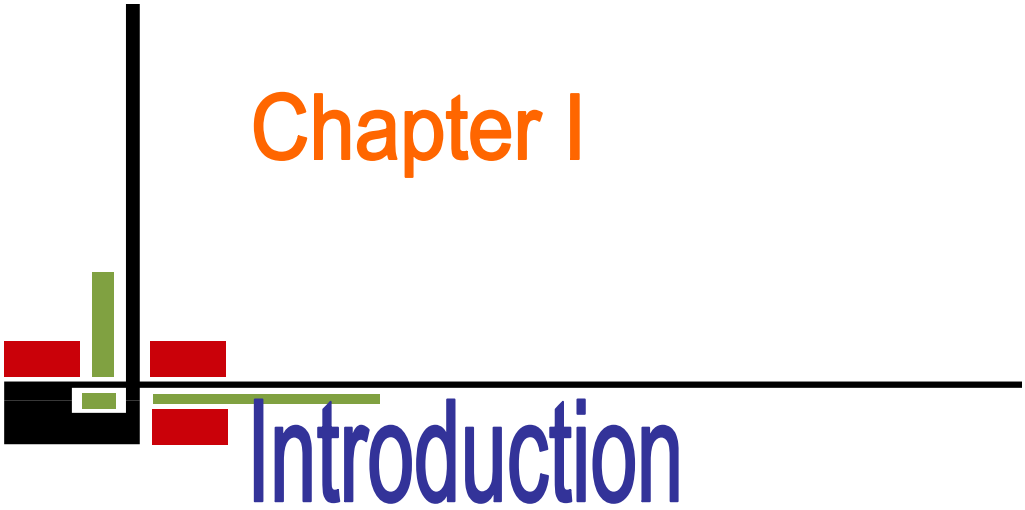

Chapter I
Introduction

CHAPTER I

INTRODUCTION

Mustard belongs to the genus *Brassica* of the family Cruciferae symbolized by rapeseed and is one of the leading oilseed crops in Bangladesh as well as in the World. It plays a vital role in human nutrition. 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 2007-2008 (BBS, 2009). 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).

Bangladesh is running with acute shortage of edible oil and it is about 71% of the total requirement of the country. Annually producing about 0.16 million tons of edible oil as against the requirement of 0.5 million tons. To meet up the demand, the country has to import oil and oilseeds to the tune of about 160 million US $ every year (Wahhab *et al*., 2002). 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).

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). The rate of reproduction varies from 5-9 young in a single day by a single female and the total number of young produced by the female varies from 76-188 (Nair, 1986). Both the nymph and adult aphid suck sap from leaves, stems, inflorescences and pods, as a result the plant show stunted growth, flowers wither and pod formation is hindered (Atwal and Dhaliwal, 1997; Begum, 1995; Butane and Jotwani, 1984).

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. 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 beneficials and causes disruption of biodiversity. Greater concern of the environment and growing awareness of the importance of the complex interrelationship of the organism within the ecosystem have lead to the realization that few pest could be eradicated totally without interfering natural control. The growing awareness of the shortcoming of the chemical insecticides has necessitated for the exploration for alternative methods of pest control, which is relatively free from adverse side effects. Among the various alternatives, the exploitation of host plant resistance is perhaps the most effective, convenient, economical and environmentally acceptable method of insect pest control (Dhaliwal and Dilawary, 1993). At present, effective control techniques other than insecticide application against insect pests of agricultural crops are highly demanding. Considering the above aspects, management of insect pests in mustard through agronomic manipulation that is intercropping may be considered as one of the

possible alternate options. 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).

Intercropping is an ancient traditional agronomic practice, a system where two or more crop species are grown in the same field at the same time during a growing season (Ofori and Stern, 1987). 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). The purpose of intercropping is to generate beneficial biological interactions between the crops. Intercropping can increase yields, more efficiently use available resources, reduce weed, insect and disease pressures and provide greater biological and economic stability (Vandermeer, 1989). 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). Intercropping was once common in temperate regions, but has been largely replaced in the last 150 years by monocultures (Francis, 1986).

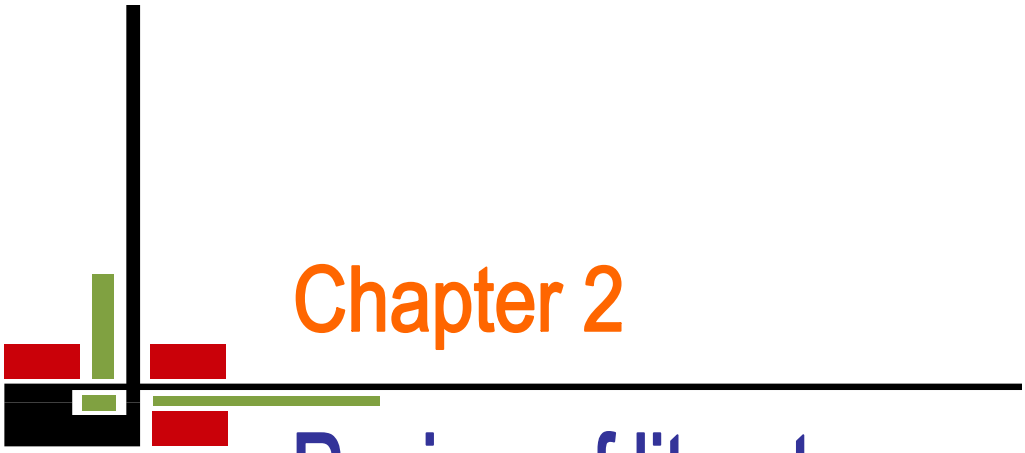
Intercropping offers an excellent opportunity of ecological maneuvering by bringing about changes in crop geometry and cropping system, which may have economically relevant impact on pest damage (Wilken, 1972). There is a general agreement that species diversity in multiple cropping reduces the most insect pest problems, increase cropping intensity and can successfully outcompete weeds. In intercropping, two or more plant species in the field may disrupt the host plant finding behavior of insects. Intercropping can affect the micro climate of the agro-ecosystem, which ultimately produces an unfavorable environment for pest (Singh and Singh, 1978). The olfactory stimulus offered by the main crop could be camouflaged by various intercrops (Aiyer, 1949).

By intercropping it is advantageously possible that one plant species may serve as a trap for insects, reducing infestation of the other or that it may serve as a breeding place for predators. In general the greater number of hosts in the intercropping generally also means a greater diversity of pests and diseases. 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). In fact, very little works have been done on intercropping of mustard with other semi season crops in Bangladesh (Samsuzzaman *et al.,* 1995; Mamun *et al.,* 2002). However, no information is available on onion (*Allium cepa L*.) and garlic (*Allium sativum L*.), coriander (*Coriandrum sativum* L) and radhuni intercropped with mustard. With the above prospective, intercropping has been thought to be an environment friendly option for the management of insect pests in mustard. However, very little attention has been given in this area in Bangladesh.

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

- To study on the effect of infestation intensity of aphid on mustard due to intercropping with different crop species.
- To find out the impact of agricultural diversification on aphid and honeybee.
- To find out the effect of intercropping on the management of aphid.



Chapter 2

Review of literature

CHAPTER II

REVIEW OF LITERATURE

A number 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, the relevant available literature have been reviewed and presented below**:-**

Relevant hypotheses

Intercropping (i.e., growing more than one crop simultaneously in the same area) is one way of increasing vegetational diversity. 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.

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.

Bird and Kruger (2009) studied 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.

Risch *el al*. (1983) reported that population density of herbivorous insects are frequently lower in polyculture habitats. Two hypotheses have been proposed to explain this phenomenon, (1) the associational resistance or resource concentration hypotheses (Roots, 1973) which proposes that the specialist herbivores are generally less abundant in vegetationally diverse habitat because their food sources are less concentrated and natural enemies are more abundant and (2) the natural enemies hypothesis (Russell, 1989) which states that a diversity of plant species may provide important resources for natural enemies such as alternate prey, nectar and pollen or breeding sites.

Aiyer (1949) formulated a three part hypothesis (1) host plants are more widely spread in intercrops, meaning they are harder to find by the pest, (2) the species serves as a trap crop to detour the pest from finding the other crop, and (3) one species may serves as a repellent to the pest.

Southwood and Way (1970) cited that the type and abundance of biodiversity in agriculture would differ across agro ecosystems, differ in age, structure and management. In fact there is a great variability in basic ecological and agronomic patterns among the various dominant

agroecosystems. In general, the degree of biodiversity in the agroecosystems depend on four main characteristics of the agro ecosystem : 1) the diversity of vegetation within and around the agroecosystem, (2) the performance of the various crops within the agroecosystem, (3) the intensity of management and (4) the extent of the isolation of the agroecosystem from natural vegetation.

According to Baliddawa (1985), a specialist insect is less likely to find its hosts in diverse plant communities because of the presence of confusing or masking chemical stimuli, physical barriers to movement, and other adverse environmental factors. Consequently, insect survival may be lower.

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.

Saxena (1972) stated that a proper combination of crops is important for the success of inter cropping systems, when two crops are to be grown together. It is imperative that the peak period of growth of the two crop species should not coincide. Crops of varying maturity during need to be chosen so that quick maturing crops complete its life cycle before the grand period of growth of the other crop starts. However, yields of both the crops are reduced when grown as mixed or intercropped, compared with the crops when grown alone but in most cases combined yield per unit area from intercropping are higher.

Relationship between intercropping with insect pests and their natural enemies

Insect pests in intercropping

Intercropping of garlic (Halepyatic *et al*., l987), onion (Johnson and Mau, 1986), ginger (Chowdhury, 1988), and tomato (Roltsch and Gage, 1990) with different crops have been reported to reduce the population of different target pests. Hussain and Samad (1993) reported that intercropping chilli with Brinjal reduces the population of *Aphis gossypii* in brinjal. Simmonds *el al.* (1992) reported plants with antifeedant activities. Among them, *Allium* spp. is reportedly very effective. Kirtikar and Basu (1975) reported that onion, garlic, coriander (*Coriandrum sativum* L.) have also strong pungent repellent action.

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.

Uddin *et al.* (2002) observed that polyculture generally had a greater diversity index and higher equitability of arthropod/insect community. Richness of taxonomic categories was lower in Wheat +chickpea, wheat + potato, chickpea +potato and wheat +chickpea +potato.

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 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 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).

Prasad *et al* (2004) examined the insect pest incidence in linseed (cv. Neelum) intercropped with safflower (cv. A-300), Indian mustard (cv. Varuna) or gram (cv. Pant G-114) at 4:2 or 5:1 linseed-intercrop ratios and the height of linseed plants was reduced by intercropping, especially when safflower was used as the intercrop. The incidence of *Dasineura lini* in 1997-98 (26.0%) and 1998-99 (28.25%) was highest in linseed sole crop, but was significantly reduced under intercropping. The lowest incidence of *D. lini* was observed in linseed intercropped with Indian mustard at 4:2 (19.36% in 1997-98 and 21.67% in 1998-99) and 5:1 (19.99 and 22.50%), and with safflower at 4:2 (19.45 and 21.69%) and 5:1 (20.43 and 23.70%). A higher population of *Helicoverpa armigera* was recorded for linseed intercropped with gram. The lowest incidence of *H. armigera* (0.27 larva/MRL) was recorded in linseed intercropped with Indian mustard at both combinations. The highest linseed equivalent yields in 1997-98 (1071 kg/ha) and 1998-99 (852.46 kg/ha) were obtained with linseed intercropped with Indian mustard and gram at 4:2, respectively.

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.

Goel and Tiwari (2004) intercropped mustard with potato, wheat, gram (*Cicer arietinum*), linseed, fenugreek and coriander or grown as a sole crop in Pantnagar, Uttar Pradesh, India and counted *L. erysimi* nymphs and adults from 10 randomly selected plants in each plot at weekly intervals from 89 to 117 days after sowing and aphid population (per 10 plants) was found lowest 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.

Meena and Lal (2004) reported the effect of cabbage intercropped with lucerne, garlic, mustard, marigold and tomato on mustard aphid, *Lipaphis erysimi* incidence and found that lucerne was the most effective followed by garlic, while mustard was the least effective intercrop in reducing the aphid population.

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 different species of insect pests of which the mustard aphid, *Lipaphis erysimi*, linseed gall midge, *Dasyneura lini*, black aphid, *Aphis craccivora*, and tomato fruit borer, *Helicoverpa*

armigera, showed significant differences in infestation levels in various intercrop situations in Varanasi, Uttar Pradesh, India, during rabi season of 1996-97. However, there was a general downward trend in infestation level of different pests in intercrop combinations compared to their numbers in sole crops of preferred host. The intercrops were thus, found to be more suitable for natural suppression of pest populations.

Casagrade and Haynes (1976) pointed out an interesting potential for integration of plant resistant and polyculture practices. They compared damage by the cereal leaf beetle, *oulema melanopus* L. in mixed and pure strands of resistant and susceptible wheat varieties. They reported that biological control was more effective in the mixed cropping of beetle resistant and beetle susceptible wheat varieties than in a pure strand of either one of those varieties on a region wide basis.

Of the variety of factors that might be involved in the facilitative production principle, the one cited and perhaps the best documented is the reduction in pest attack frequently found in intercrops (Risch *et al.,* 1983). Earlier reviews found similar results (Perkin, 1977; Kvass, 1978; Nickel, 1973; Lit singer and Moody, 1976; Dumpsters and Coaker, 1974) that pests tend to be reduced in intercrops, although not by any means always.while these reviews tend to be concentrate on insects, there is also evidence that intercrops reduce nematode attack (Mc Beth and Taylor, 1944; Khan *et al.,* Awl and Manger, 1967; Catelli *et al.,* 1976; Egunjobi,1984) and diseases (Moreno and Mora, 1984; Rheeneu *et al*., 1981).

Franchise *et al.* (1978) found lower attack rates of *Spodoptera frugiperda* in maize + bean intercrop as compared to a maize monoculture. Van Hues (1981) working in Nicaragua found the same pattern with the same pests in the same cropping system.

Andow (1991) found that polycultures had lower populations than monocultures, and even then it occurred intermittently. Severe competitionn from the other plants in the polyculture might limit the ability of crop to compensate for pest injury and crop tolerance, or resistance In an elegant experiment, Beach (1981) reasoned the plant “quality” might be affected by

intercropping to such an extent that the individual host plant intercrops might be less desirable to their pests than individuals in monocultures. He found the *Acalymma vittatum* preferred cucumber leaves taken from monocultures to those taken from cucumber plants intercropped with tomatoes.

Dash *et al*. (1987) observed the highest pod infestation (45.80%) by *Helicoverpa armigera* in monoculture of arhar (*Cajanus cajan*) while the pod damage was the lowest (34.46%) when *C.cajan* was intercropped with black gram (*Vigna mungo*)

Prasad and Chand (1989) reported that intercropping of chickpea (*Cicer arietinum*) with barley, mustard and wheat suppressed number of *Helicoverpa armigera* by 59.56 and 47%, respectively. They concluded that barley, mustard and wheat are compatible crops for the intercrops of *C. aritinum*. In case of severe infestation in one crop, the financial return from the other crop is ensured.

Pawar (1993) showed that short duration pigeonpea grown adjacent to a strip- intercropped with sorghum suffered less damage by *Helicoverpa armigera.* Similarly, Patnaik *et a*l. (1989) observed the severest attack by *Helicoverpa armigera* on sole cropped pegionpeas intercropped with groundnuts, mungbean (*Vigna radiata*), black gram (*Vigna mungo*) while it was the lowest in pegionpea intercropped with finger millet.

Hossian *et al*. (1998) reported that intercropping exhibited a significant effect on pod borer infestation in chickpea in case of mid and late sowing dates. The dates of sowing irrespective of the intercropping displayed a significant effect on pod borer infestation with the early sowing contributing to the significant reduction of pod borer infestation. In case of late sowing, chickpea should be preferably intercropped with wheat to protect it against chickpea pod borer infestation ensuring higher yield.

to pest injury might otherwise limit yield losses in polycultures. In addition, the data suggested that pest injury is likely to exceed economic injury thresholds in polycultures than

in monocultures. Again he claimed that absolute yield benefit in polyculture were higher than yields in monocultures.

Mahadevan and Chelliah (1986) reported that growing sorghum in association with cowpea (*Vigna unguiculata*) or lablab *(Lablab purpureus*) reduced the infestation of sorghum by the pyralid Chilo partellus in Tamil Nadu, India. On sorghum as a pure crop, 32% damage was recorded, as compared with lablab, respectively. The corresponding yields were 3609, 4652 and 4567 kg grain/ha, respectively.

Raymond and Alcazar (1983) claimed that potato plant grown in association with tomato, onion, maize, soybean or bean (*phaseolus*) had significantly less tuber damage from *Phthorimaea operculella* (Zell.) than for potato alone. Sharma and Pandey (1993) carried out field studied in Navgaon, Rajasthan, India during 1984-86. The early maturing pigeonpea cv.UPAS-120 and the mid maturing cv. BDN-1 were intercropped with black gram (*Vigna mungo)* greengram (*V. radiata*), pearl millet and sorghum and the infestation by *Exelastis atomosa* and *Melanagromyza obtuse* was compared with that of pigeonpea grown as a sole crop. They found no market effect of intercropping on pest incidence. In the sole crop, insect infestation ranged between 42.5 to 52.66% in UPS-120 and between 57.0 to 62.16% in BDN-1.

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.

Singh and Kothari (1997) reported that the mustard intercropped with aromatic plant species that could provide an environmentally safe method for aphid control, aphid infestation on a monocrop of *B. juncea* cv. *Rohini* was compared with infestation under intercropping with Artemisia *annua, Coriandrum sativum, Matricaria chamomilla (Chamomilla recutita), Foeniculum vulgare* and *Anethum sowa* and intercropping with *F. vulgare* resulted in a significantly lower aphid infestation.

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.

Sarker *et al.* (2007) found that the intercropped of mustard (*Brassica napus, V*ar. *Bari Sarisha-7*) with onion (*Allium cepa* L.) and garlic (*Allium sativum* L.); these two medicinal as well as spice crops reduced the aphid population significantly. They also found that mustard blocks intercropped with garlic gave highest cost-benefit ratios (1:2.07 and 1: 2.96) than onion intercropped blocks and sole mustard blocks produced lowest cost-benefit ratios (1:1.65 and 1:2.06).

Natural enemies

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. 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. In Kenya, Kyamanywa *et at*. (1993) evaluated the influence of cowpea + maize intercropping on generalist predators and population density of flower thrips *Megalurothrips sjostedti* Trybom. Interestingly, abundance of the *Orius* sp., lady bird beetles, earwigs and spiders were not enhanced by planting cowpea as a mixed crop 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.

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) reported spiders to be more effective against corn borers in an intercrop of corn and groundnuts than in monoculture of corn. Altieri *et at.* (1977), Smith (1969) and Speight and Lawton (1976) reported a higher abundance of predators in a weedy crop than in a comparable monoculture. Perfecto *et al*. (1986) demonstrated that carabid beetles immigrated more rapidly from patches of monoculture of tomatoes and beans from intercrops of the two.

Srikanth *et al*. (2000) examined that 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.

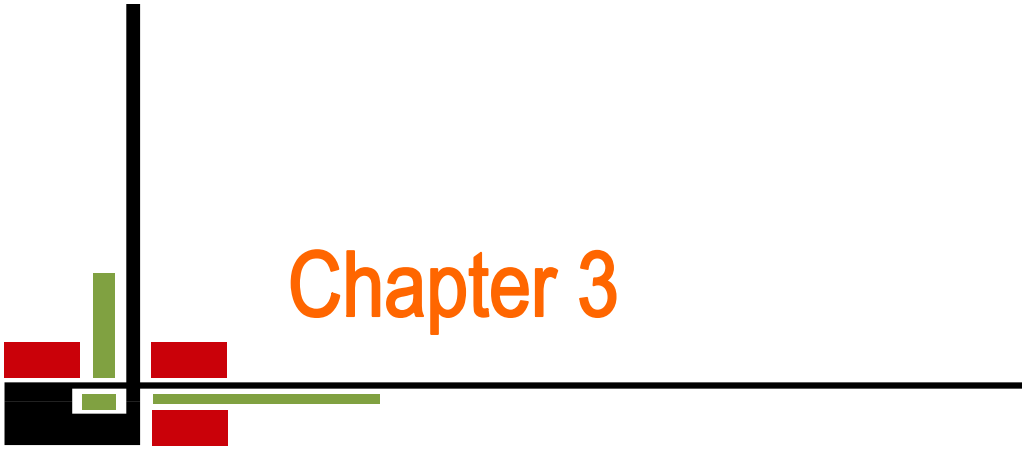
Intercropping and crop yield by suppressing pest

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

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.

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 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2012 to March 2013 to find out the effect of intercropping of mustard and it's effect on mustard aphid and honeybee. The details of the materials and methods that used to conduct the study are presented below:

Location

The study was conducted in the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The location of the experimental site was 24^0 $09^/$ N latitude and 24^0 $26^/$ E longitude and an elevation of 8.2 m from sea level (Anon, 2010).

Climate

The climate of study site was under the subtropical climate, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979).

Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil

series was Tejgaon (Anon, 2010). The soil characterized by poor fertility and impeded by internal drainage. The pH of the experimental soil ranged from 5.5 to 6.2 (Anon, 2010).

Mustard variety and its characteristics

Mustard seeds of variety Tori-7 were selected for this experiment. 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.

Treatments

Combination of mustard (*Brassica spp*) with wheat (*Triticum aestivum* L.), onion (*Allium cepa* L.), garlic (*Allium sativum* L.), coriander (*Coriandrum sativum* L.), radhuni (*Trachyspermum roxburghianum* L), gram (*Cicer arietinum* L.) constitute the intercropping systems. The intercropping treatments were as follows:

Treatments	Compositions
T_1	Mustard intercropped with wheat (Figure 2)
T_2	Mustard intercropped with onion (Figure 3)
T_3	Mustard intercropped with garlic (Figure 4)
T_4	Mustard intercropped with radhuni (Figure 5)
T_5	Mustard intercropped with coriander (Figure 6)
T_6	Mustard intercropped with gram (Figure 7)
T_7	Sole mustard (control)

Figure 1. Experimental plot

Figure 2. Intercropping mustard with wheat

Figure 3. Intercropping mustard with onion

Figure 4. Intercropping mustard with garlic

Figure 5. Intercropping mustard with radhuni

Figure 6. Intercropping mustard with coriander

Figure 7. Intercropping mustard with gram

Seed collection for intercropping

The Mustard (*Brassica napus* var. Tori-7) was collected from Oilseed Research Center, Bangladesh Agricultural Research Institute, Gazipur. Wheat, onion (BARI onion-l), garlic (BARI Garlic-l) bulbs and coriander, radhuni, gram, seeds were collected from Spices Research Centre, Bangladesh Agricultural Research Institute, Gazipur.

Land preparation

The experimental plot was opened in the first week of November 2012 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.

Experimental design and layout

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*) wheat, corriender, radhuni, gram were selected for intercropping. Altogether 3 blocks were prepared and 3 replications for each category wheat + mustard, onion + mustard and garlic + mustard, radhuni + mustard, coriander + mustard, gram + 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 24 November 2012.The seeds of wheat, onion (bulb), garlic (bulb), coriander, radhuni, gram was sown on the same date.

Cultural practices

After establishment of seedlings, all other intercultural operations such as, thinning, weeding, irrigation were accomplished as per as when necessary for better growth and development of the mustard crop. Single irrigation was applied just once before flower initiation. Plots were provided with well arranged drainage facilities as prevention process of removing excess rain water if any. Weeding was done twice in the field to keep the plots free from weeds to ensured better growth and development of the crops. The newly emerged weeds were uprooted carefully at flowering stage by mechanical means.

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

1. Total number of infested plants/plot.

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

2. Total number of branch

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

3. Total number of infested branch

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

4. Total number of flower

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

5. Total number of infested flower

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

6. 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.

7. Total number of infested pod

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

8. Total number of Aphid

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

9. Number of honeybee (*Apis florea* & *Apis indica*)

Number of honeybee was counted from randomly selected five plants.

10. Percent reduction over control

The following formula was used to calculate percent reduction over control

Percent reduction over control $= \frac{\text{Value of sole crop} - \text{Value of component crop (Mustard)}}{\text{Value of sole crop (Mustard)}} \times 100$

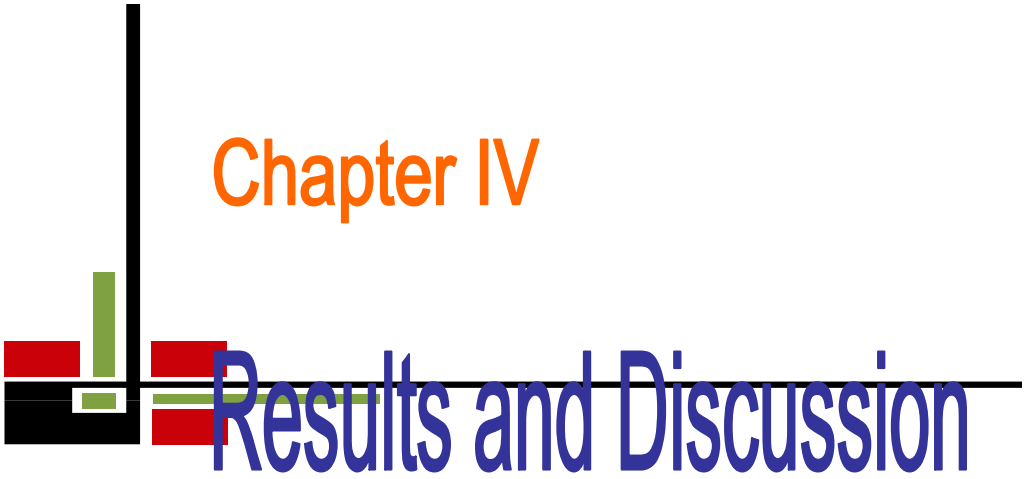
Harvesting, threshing and cleaning

Mustard was harvested at the maturity (93 days of sowing without disturbing the other inter crops) was done manually from each plot. Wheat, Garlic and onion were harvested 102 days after sowing. The radhuni, coriander and gram were harvested at same date respectively. different harvested crops of each plot was bundled separately, properly tagged and brought to laboratory floor. Care was taken for harvesting, threshing and also cleaning of mustard and other intercrop crops. The seeds were cleaned and finally the weight was recorded and converted into per hectare yield. Mustard of each plot was threased separately, cleaned, sun dried, weighed and packed. Radhuni was threased carefully because of it's light and small

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 MSTAT-C 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.


Chapter IV
Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The results on the effect of intercropping systems with mustard + wheat, mustard + onion, mustard + garlic, mustard + radhuni, mustard + coriander and mustard + gram compared to its monoculture on incidence of aphid and honeybee. 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 Incidence of aphid population

4.1.1 Aphid population

Significant variation was found in different treatments in case of number of aphid per plant. Results showed that the lowest number of aphid (14.98) was recorded in mustard + onion (T_2) intercropped combinations which was statistically similar to mustard + coriander (T_5) (15.03/plant), mustard + garlic (T_3) (15.33/plant) and mustard + radhuni (T_4) (15.40/plant). On the other hand, the highest number of aphid per plant (19.07) was recorded in mustard + gram (T_6) 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 radhuni decreased population of aphid on mustard over sole crop but wheat and gram increased aphid population on mustard over sole crop (Table 1).

The result agrees 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 lowest aphid population was recorded in mustard grown with coriander and the maximum population was observed on mustard as sole crop.

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	17.79 b	+ 14.18 a
T_2	14.98 c	- 7.99 c
T_3	15.33 c	- 11.82 b
T_4	15.40 c	- 11.60 b
T_5	15.03 c	- 9.50 c
T_6	19.07 a	+ 13.72 a
T_7	17.42 b	—
CV%	**5.62%**	**8.83%**
$LSD_{0.05}$	**1.68**	**1.76**

Values in the same column accompanied by the same letter(s) are not differ significantly (p = 0.05).

T_1 = Mustard + wheat
T_2 = Mustard + onion
T_3 = Mustard + garlic
T_4 = Mustard + radhuni
T_5 = Mustard + coriander
T_6 = Mustard + gram
T_7 = Mustard (control)

4.1.2 Number of aphid infested plants

Mustard plants with intercropped crops were greatly influenced by the presence of aphid that reduce crop yield. Results under the present study showed that significant variation was observed in terms of affected plants by aphid at different treatments (Table 2). Highest number of aphid infested plants/plot (2.82) was recorded in mustard sole crop (T_7) which was statistically different from all intercropping plots. On the other hand, aphid infested plants/plot was significantly lower in all intercropping plots. The lowest number of affected plants/plot (1.33) was found in mustard + onion (T_2) followed by mustard + radhuni (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 agrees 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 lowest aphid population in mustard grown with coriander and the maximum population on mustard as sole crop.

4.1.3 Number of branch/plant

Significant variation was observed in terms of number of branches/plant at different intercroppings (Table 2). The highest number of branches/plant (8.97) was recorded in mustard sole (T_7) followed by T_6 (mustard + gram), T_3 (mustard + garlic) and T_5 (mustard + coriander) intercropping system having no significant difference among them. On the other hand, the lowest number of branch/plant (6.80) was recorded in mustard + onion (T_2) intercropped combinations. Although sole crops had the highest aphid infestation and number of branch was higher due to lack competition with other crops.

Table 2. Effect of intercropping mustard on 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	1.69 b	7.39 cd	1.98 b	26.95 ab
T_2	1.33 d	6.80 d	1.47 b	21.62 b
T_3	1.67 b	8.51 ab	2.03 b	23.15 bc
T_4	1.42 cd	7.77 bc	1.50 b	19.30 c
T_5	1.50 c	8.23 abc	1.64 b	19.92 c
T_6	1.75 b	8.88 a	2.02 b	23.31 bc
T_7	2.82 a	8.97 a	2.68 a	29.88 a
CV%	**5.43%**	**6.57%**	**17.24%**	**14.08%**
LSD $_{0.05}$	**0.15**	**0.94**	**0.56**	**5.75**

Values in the same column accompanied by the same letter(s) are not differ significantly (p = 0.05).

T_1 = Mustard + Wheat
T_2 = Mustard + onion
T_3 = Mustard + garlic
T_4 = Mustard + radhuni
T_5 = Mustard + coriander
T_6 = Mustard + gram
T_7 = Sole mustard

4.1.4 Branch infestation by aphid

The data in 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 (2.68) was recorded from mustard sole plot which significantly higher than all other treatments. However, the lowest number of aphid infested branch per plant (1.47) was recorded from mustard + onion (T_2) crop combination, which was statistically similar to all other intercropping combinations. Similarly the lowest percentage of infested branch was found in (19.30) in mustard + radhuni intercropped system which was statistically similar to T_5, T_3 and T_6 intercropping combinations and that was significantly higher in mustard sole treatment (Table 2). The results agree 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.

4.1.5 Number of flower per plant

Number of Flower infestation of mustard plants with intercropped crops were greatly influenced by the presence of aphid. Results under the present study showed that significant variation was observed in terms of flower at different treatments (Table 3). Results showed that the highest number of flower/branch (7.18) was recorded in mustard + coriander (T_5) which was statistically similar in (6.86) mustard + garlic (T_3) intercropped combination. The lowest number of flower/branch (4.73) was recorded in mustard + wheat (T_1) intercropped combinations. The dissimilar 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-wheat.

4.1.6 Flower infestation

Significant variation was observed in terms of infested flower by aphid at different treatments (Table 3). Results showed that the lowest number of infested flower/branch (39.17) was recorded in mustard + onion (T_2) intercropping system. On the other hand, the highest number of infested flower/plant (96.17) was caused by aphid was recorded in (T_7) mustard (control). 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 dissimilar 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 (96.17) in sole mustard and lowest percentage of flower infestation was found in (39.17) in mustard + onion intercropped system. Incase of percent decrease of flower infestation over sole crop result showed that highest reduction was found (59.27) in mustard + onion (T_2) which was statistically similar (55.26) in mustard + coriander (T_5) crop combination.T_1, T_3, and T_4 gave statistically similar result and the lowest reduction was found (8.10) in mustard + gram (T_6) intercrop combination.

Table 3. Effect of intercropping of mustard 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	4.73 c	3.42 cd	72.30 bc	24.82 b
T_2	5.36 bc	2.10 e	39.17 d	59.27 a
T_3	6.86 ab	4.23 abc	61.66 cd	35.88 b
T_4	6.32 abc	4.15 b	65.66 c	31.73 b
T_5	7.18 a	3.09 d	43.03 d	55.26 a
T_6	5.77 abc	5.10 a	88.38 ab	8.10 c
T_7	5.53 bc	5.03 ab	96.17 a	–
CV%	**16.11%**	**10.48%**	**14.74%**	**16.39%**
$LSD_{0.05}$	**1.70**	**0.93**	**22.49**	**15.17**

Values in the same column accompanied by the same letter(s) are not differ significantly (p = 0.05).

T_1 = Mustard + Wheat
T_2 = Mustard + onion
T_3 = Mustard + garlic
T_4 = Mustard + radhuni
T_5 = Mustard + coriander
T_6 = Mustard + gram
T_7 = Mustard (control)

4.1.7 Number of pod per plant

Mustard plants with intercropped crops were greatly influenced by aphid. The present study showed that significant variation was observed in terms of pod at different treatments (Table 4). Highest number of pod/branch (18.72) was recorded in mustard + gram (T_6) intercropping system which was statistically similar (18.68) in mustard + coriander (T_5). On the other hand, the lowest number of pod/branch (10.87) was recorded

in T_7 mustard (control). The dissimilar result was found by Lasker *et al.* (2004) he reported that intercropping of mustard with various other winter crops like wheat, radish, 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-wheat.

4.1.8 Pod infestation

Results showed that the highest number of infested pod/plant (6.57) was recorded in mustard + gram (T_6) intercropping system. It was also observed that the statistically similar (6.44) result was found in treatments (T_3) which was combined by mustard + garlic crop. Similar trend was observed in percent infested pod. The lowest number of infested pod/plant (4.25) was recorded in mustard + wheat (T_1) intercropping system which was statistically similar to other treatments. Results were found in case of total number of infested pod in lower presence of aphid but significant difference was observed in terms of percent infested pod by aphid in different treatments. Incase of percent decrease of pod infestation over control the highest reduction of infestation was found (53.24) in mustard + coriander (T_5) intercropped combination and lowest number of infestation was also observed (24.25) in mustard + garlic (T_3) intercropped system.

Table 4. Effect of intercropping 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	15.30 c	4.25 b	27.78 cd	45.10 b
T_2	15.54 c	4.33 b	27.86 cd	44.94 b
T_3	16.80 bc	6.44 a	38.33 b	24.25 d
T_4	16.71 bc	4.45 b	26.63 cd	47.37 b
T_5	18.68 a	4.42 b	23.66 d	53.24 a
T_6	18.72 a	6.57 a	35.10 bc	30.63 c
T_7	10.87 d	5.50 ab	50.60 a	_
CV %	**5.31%**	**16.53%**	**15.85%**	**5.19%**
$LSD_{0.05}$	**1.61**	**1.55**	**8.76**	**3.90**

Values in the same column accompanied by the same letter(s) are not differ significantly (p = 0.05).

T_1 = Mustard + Wheat
T_2 = Mustard + onion
T_3 = Mustard + garlic
T_4 = Mustard + radhuni
T_5 = Mustard + coriander
T_6 = Mustard + gram
T_7 = Sole mustard

4.1.9 Number of Honeybee

Mustard plants with intercropped crop were greatly influenced by the presence of honeybee that increase crop yield. Results showed that the highest number of honeybee (4.11) was recorded in mustard + onion (T_2) intercropping system. The second highest

number of honeybee was observed (3.97) in mustard + coriander (T_5). On the other hand, the lowest number of honeybee (3.20) was recorded in mustard + wheat (T_1) intercropped combinations. It was also observed that the result from other treatments gave intermediate results compared to highest and lowest honeybee (Table 5).

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

Treatments	Number of honeybee (*Apis indica*)/plant	Number of honeybee (*Apis florae*)/plant	Total number of honeybees/ plant
T_1	2.56 a	1.54 d	3.20 g
T_2	1.47 de	1.73 c	4.11 a
T_3	1.36 e	1.92 b	3.28 f
T_4	1.57 d	2.19 a	3.76 c
T_5	2.36 b	1.30 e	3.97 b
T_6	1.72 c	1.69 c	3.41 e
T_7	2.26 b	1.71 c	3.66 d
CV	**3.44%**	**2.64%**	**1.28**
$LSD_{0.05}$	**0.11**	**0.08**	**0.08**

Values in the same column accompanied by the same letter(s) are not differ significantly (p = 0.05).

T_1 = Mustard + Wheat
T_2 = Mustard + onion
T_3 = Mustard + garlic
T_4 = Mustard + radhuni
T_5 = Mustard + coriander
T_6 = Mustard + gram
T_7 = Sole mustard

4.2.1 Relationship between number of aphid and number of pod/plant

Highest number of aphid (3.81) was found in mustard + gram (T_6) intercropping system. Which was statistically different than all others treatment. The second highest number of aphid (3.59) was found in mustard + radhuni (T_4). On the other hand, the lowest number of aphid (2.99) was recorded in mustard + onion (T_2) intercropping system. It was also observed that the highest number of pod formation (39.34) was observed in mustard + onion (T_2) intercropping system. Lowest number of pod (24.78) was found in mustard + gram (T_6) intercrop system. Which was statistically different to others treatment. This figure also showed that aphid number was highest in intercropping mustard + gram (T_6) than control (Figure 1).

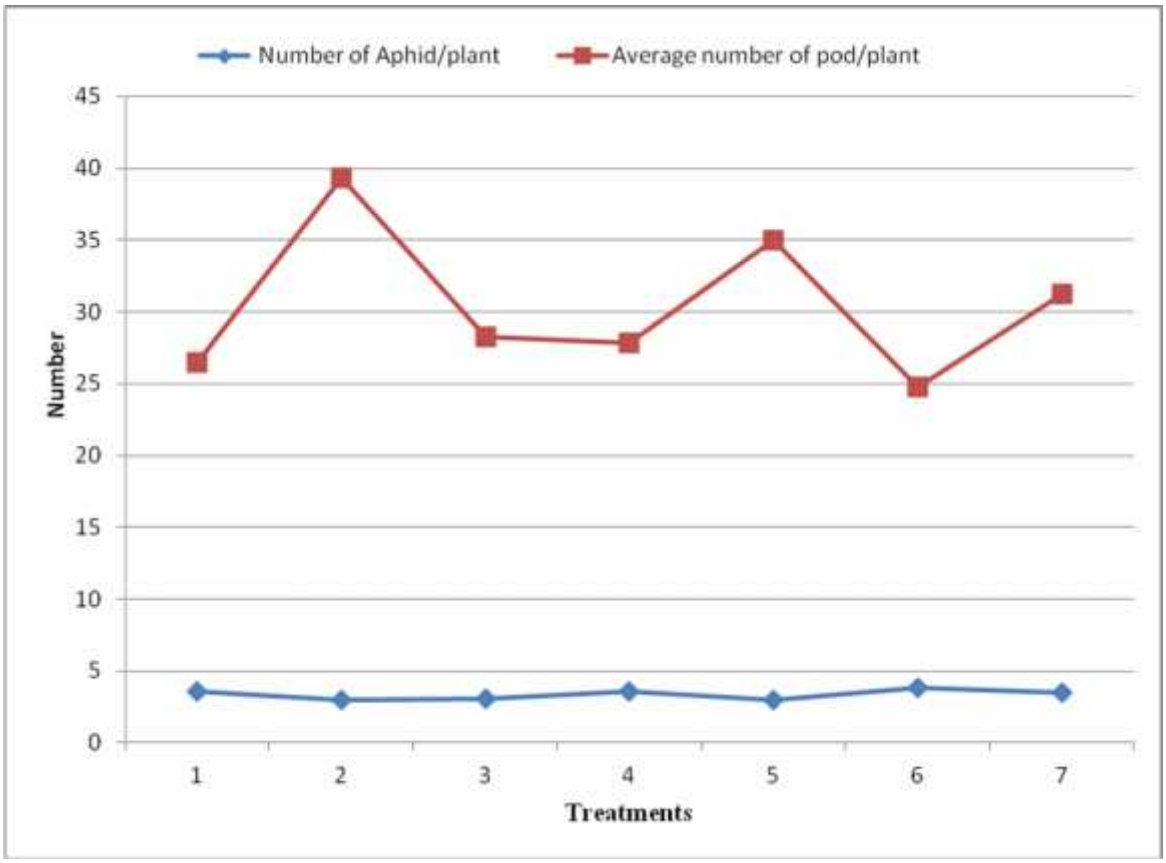


Figure 1: Relationship between total number of aphid and number of pod.

T_1 = Mustard + Wheat
T_2 = Mustard + onion
T_3 = Mustard + garlic
T_4 = Mustard + radhuni
T_5 = Mustard + coriander
T_6 = Mustard + gram
T_7 = Sole mustard

4.2.2 Relationship between honeybee and number of pod/plant

Highest number of honeybee (72.65) was found in mustard + onion (T_2) intercropping system. Which was statistically different than all others treatment. Second highest number of honeybee was found (71.97) in mustard + coriander. Lowest number of honeybee (47.12) was recorded in mustard + gram (T_6) intercropping system. Which was statistically different than all others treatment. It was also observed that the, highest number of pod formation (39.34) was observed in mustard + onion (T_2) intercropping system. Lowest number of pod (24.78) was found in mustard + gram (T_6) intercrop system (Figure 2).

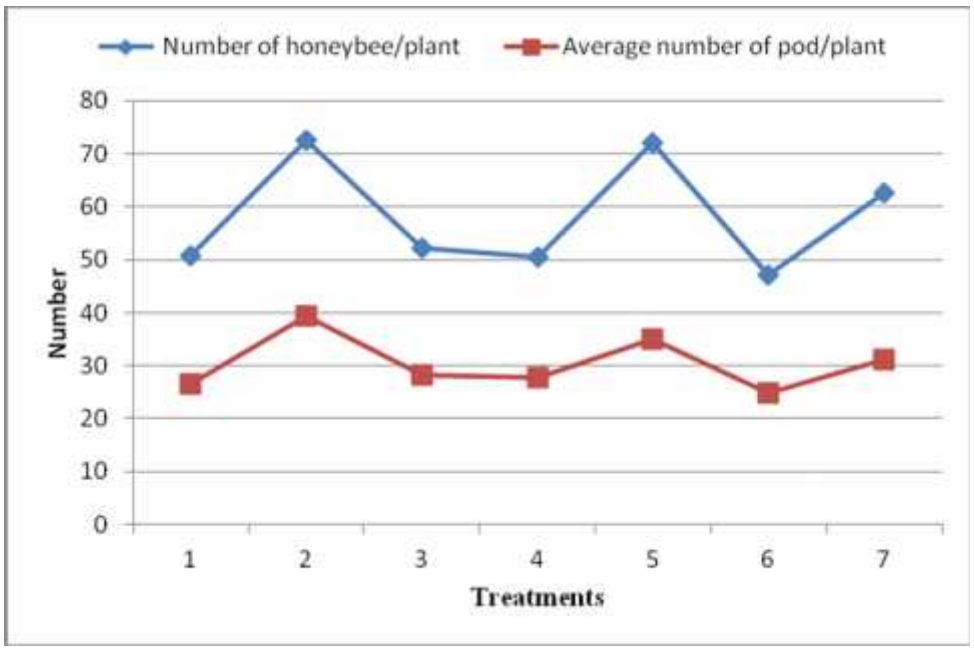


Figure 2: Relationship between number of honeybee and number of pod.

T_1 = Mustard + Wheat
T_2 = Mustard + onion
T_3 = Mustard + garlic
T_4 = Mustard + radhuni
T_5 = Mustard + coriander
T_6 = Mustard + gram
T_7 = Mustard (control)

4.2.3 Relationship between number of aphid and number of seed/plot

Highest number of aphid (3.81) was found in mustard + gram (T_6) intercropping system. Which was statistically different than all others treatment. The second highest number of aphid (3.59) was found in mustard + radhuni (T_4). On the other hand, the lowest number of aphid (2.99) was recorded in mustard + onion (T_2) intercropping system. It was also observed that highest number of seed/plot was found (920.0) in mustard + onion (T_2). Which was statistically different than all others treatment. Lowest number of seed/plot was found (647.8) in mustard + gram (T_6) which was statistically similar (657) in mustard + coriander (T_5) and (668) in mustard + wheat (T_1) crop combination. This figure also showed that aphid number was highest in intercropping mustard + gram (T_6) than control (Figure3).

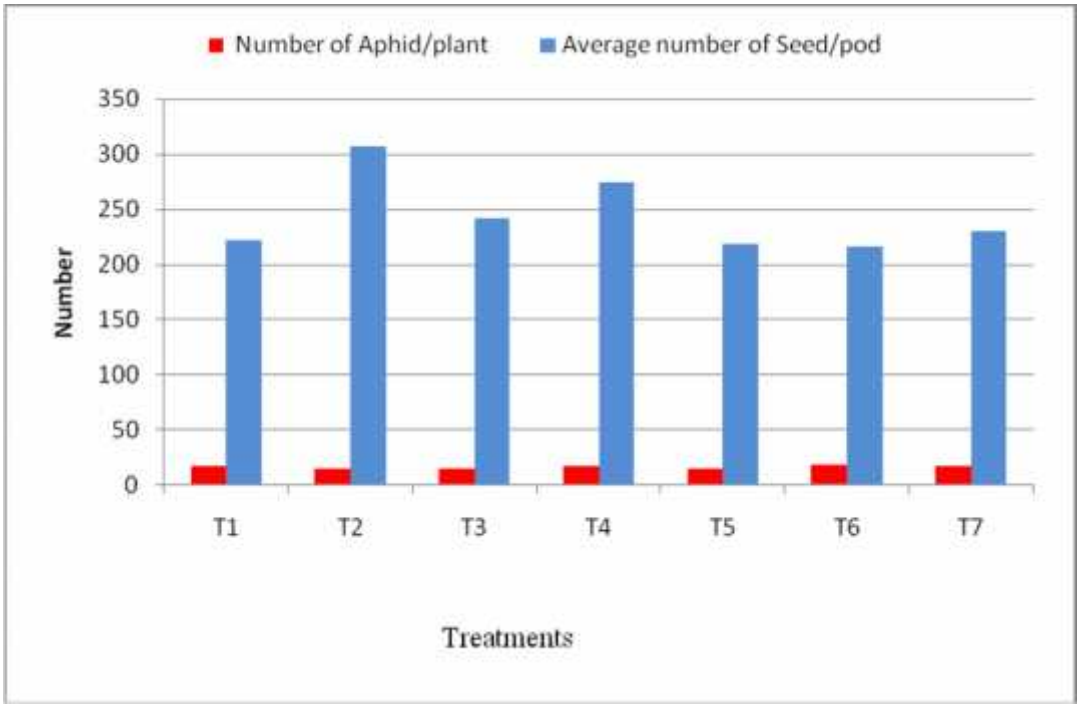


Figure 3: Relationship between number of aphid and number of seed/plot

T_1 = Mustard + Wheat
T_2 = Mustard + onion
T_3 = Mustard + garlic
T_4 = Mustard + radhuni
T_5 = Mustard + coriander
T_6 = Mustard + gram
T_7 = Mustard (control)

4.2.4 Relationship between honeybee and number of seed/plot

Highest number of honeybee (72.65) was found in mustard + onion (T_2) intercropping system. Which was statistically different than all others treatment. Second highest number of honeybee was found (71.97) in mustard + coriander. Lowest number of honeybee (47.12) was recorded in mustard + gram (T_6) intercropping system. Which was statistically different than all others treatment. It was also observed that highest number of seed/plot was found (920.0) in mustard + onion. Which was statistically different than all others treatment. Lowest number of seed/plot was found (647.8) in mustard + gram (T_6) which was statistically similar (657) in mustard + coriander (T_5) and (668) in mustard + wheat (T_1) crop combination (Figure 4).

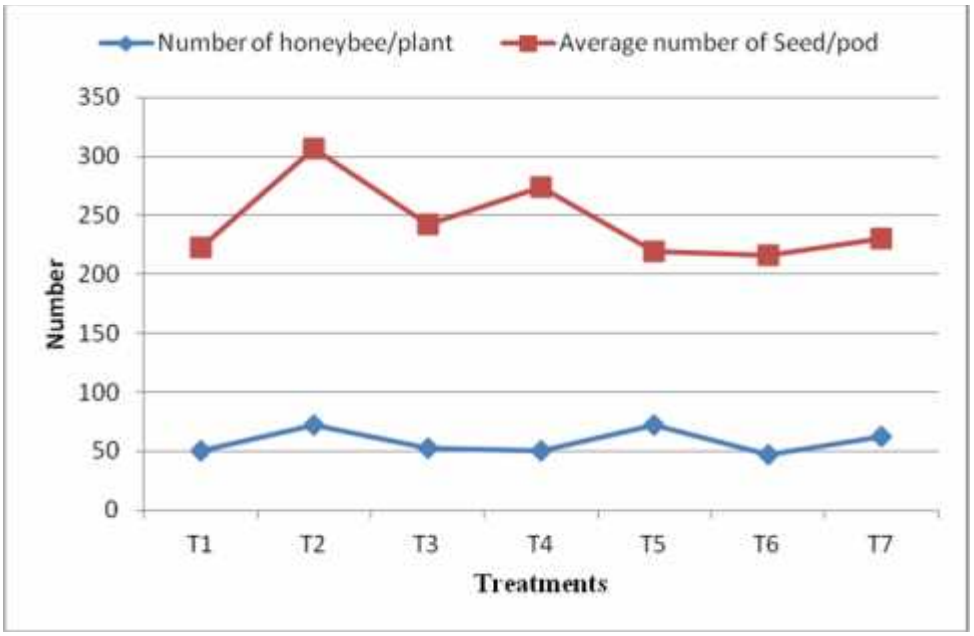


Figure 4: Relationship between number of honeybee and number of seed.

T_1 = Mustard + Wheat
T_2 = Mustard + onion
T_3 = Mustard + garlic
T_4 = Mustard + radhuni
T_5 = Mustard + coriander
T_6 = Mustard + gram
T_7 = Mustard (control)

4.2.5 Relationship between number of aphid and seed weight/plot

Highest number of aphid (3.81) was found in mustard + gram (T_6) intercropping system. Which was statistically different than all others treatment. The second highest number of aphid (3.59) was found in mustard + radhuni (T_4). On the other hand, the lowest number of aphid (2.99) was recorded in mustard + onion (T_2) intercropping system. It was also observed that highest number of seed weight/plot (9.87) was found in mustard + onion (T_2) which was statistically different to others treatment. Lowest number of seed weight (7.63) was found in mustard + gram (T_6) crop combination which was statistically similar to mustard + coriander (T_5) treatment (Figure 5).

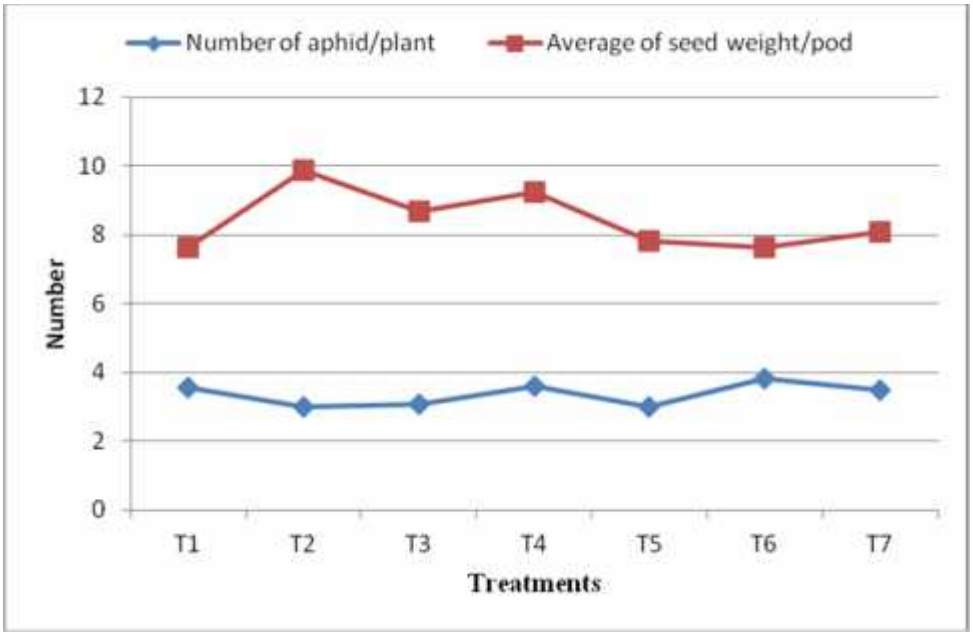


Figure 5: Relationship between number of aphid and seed weight.

T_1 = Mustard + Wheat
T_2 = Mustard + onion
T_3 = Mustard + garlic
T_4 = Mustard + radhuni
T_5 = Mustard + coriander
T_6 = Mustard + gram
T_7 = Mustard (control)

4.2.6 Relationship between number of honeybee and seed weight/plot

Highest number of honeybee (72.65) was found in mustard + onion (T_2) intercropping system. Which was statistically different than all others treatment. Second highest number of honeybee was found (71.97) in mustard + coriander. Lowest number of honeybee (47.12) was recorded in mustard + gram (T_6) intercropping system. Which was statistically different than all others treatment. It was also observed that highest number of seed weight (9.87) was found in mustard + onion (T_2) which was statistically different to others treatment. Lowest number of seed weight (7.63) was found in mustard + gram (T_6) crop combination which was statistically similar to mustard + coriander (T_5) treatment (Figure6).

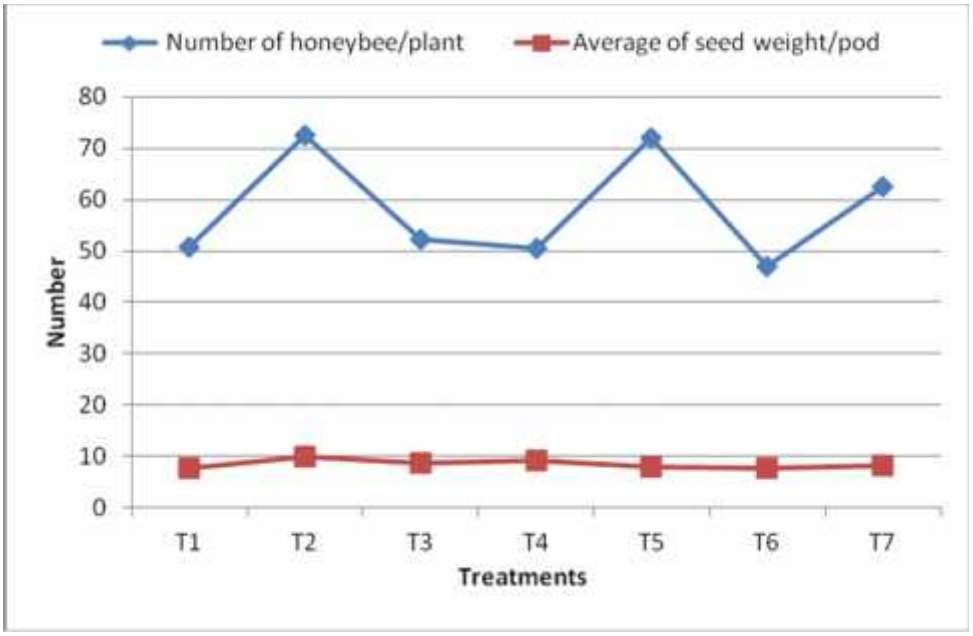


Figure 6: Relationship between number of honeybee seed weight.

T_1 = Mustard + Wheat
T_2 = Mustard + onion
T_3 = Mustard + garlic
T_4 = Mustard + radhuni
T_5 = Mustard + coriander
T_6 = Mustard + gram
T_7 = Mustard (control)

CHAPTER V
SUMMARY AND CONCLUSION

SUMMARY

A field experiment was carried out in the experimental farm of Sher-e-Bangla Agricultural University, to investigate the effect of intercropping mustard on aphid and honeybee during the period from November 2012 to March 2013. The crop combinations were mustard + wheat, mustard + onion, mustard + garlic, mustard + coriander, mustard + radhuni, mustard + gram and sole mustard (control). The experiment was laid out in a Randomized Complete Block Design with three replications.

Data was collected on the 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 honeybee, number of pod/plants, number of seeds/pod, and weight of total seeds/plot.

Significantly lowest number of infested plant/plot affected by aphid was found (1.33) in mustard + onion (T_2) crop combination and Highest number of affected plants/plot (2.82) was recorded in mustard control (T_7) intercropping system. It was also observed that the highest number of branches/plant (8.97) was recorded in sole mustard (T_7) intercropping system, & lowest number of branches/plant (6.80) was recorded in mustard + Onion (T_2) intercropped combinations. At that time, results showed that the highest number of infested branches/plant (2.68) caused by aphid was recorded in sole mustard (T_7) & lowest percentage of infested branch was found in (1.47) in mustard + onion (T_2) intercropped. On the other hand, highest number of flower/branch (7.18) was recorded in mustard + coriander (T_5) intercropping system, and lowest number of flower/branch (4.73) was recorded in mustard + wheat (T_1) intercropped combinations. Results showed

that the highest number of infested flower/branch (96.17) was recorded in sole mustard (T_7), lowest number of infested flower/branch (39.17) was recorded in mustard + onion (T_2) intercropping system. It was also observed, highest number of pod/branch (18.72) was recorded in mustard + gram (T_6) and lowest number of pod/branch (10.87) was recorded in sole mustard (T_7). At that time lowest number of infested pod/branch (4.25) was recorded in mustard + wheat (T_1) intercropping system, & the highest number of infested pod/branch (6.75) was caused by aphid was recorded in mustard + gram (T_6). When aphid number (3.81) was highest in mustard + gram (T_6) intercropping system. Then it was also found that pod number (24.78) was lowest in mustard + gram (T_6) intercrop system, number of seed/plot were lowest (647.8) in mustard + gram (T_6), and seed weight (7.63) were also lowest in mustard + gram (T_6) crop combination. On the other hand, When aphid number (2.99) was lowest in mustard + onion (T_2) intercropping system. At that time, pod formation (39.34) was highest in mustard + onion (T_2) intercropping system, seed/plot number were highest (920.0) in mustard + onion (T_2), and seed weight (9.87) were also highest in mustard + onion (T_2). It was also observed that, when honeybee number (72.65) was increase in mustard + onion (T_2) intercropping system, Pod formation (39.34) were increase in mustard + onion (T_2) intercropping system, seed/plot number were increase (920.0) in mustard + onion (T_2) and seed weight (9.87) were also increase in mustard + onion (T_2). On the other hand, that lowest number of honeybee (47.12) was recorded in mustard + gram (T_6) intercropping system at that time, pod number (24.78) were decrease in mustard + gram (T_6) intercrop system, seed/plot number were decrease (647.8) in mustard + gram (T_6), and seed weight/plot (7.63) were also decrease in mustard + gram (T_6) crop combination system.

CONCLUSION

From the study, it may be concluded that incidence of mustard aphid infestation was less in intercropping system & the abundance of honeybee was 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 population was increase, pod formation & seed yield were also increase. At that time, when honeybee population was decrease then, pod formation & seed yield also decrease in intercrop combination. The overall study revealed that intercropping may be considered as an ecofriendly pest management practice for mustard by which it could reduce the pest infestation without use of any chemical insecticide. Among them intercropping system, sole mustard showed more infestation & mustard intercropped with onion 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 agoecosystems of Bangladesh.

CHAPTER VI

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