EFFECT OF INTERCROPPING ON THE INSECT PEST INFESTATION AND THEIR NATURAL ENEMIES OF CABBAGE

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TO

MY BELOVED PARENTS

CERTIFICATE

This is to certify that the thesis entitled Effect of intercropping on the insect pest infestation and their natural enemies of cabbage submitted to the Department of Entomology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in ENTOMOLOGY embodies the result of a piece of bonafide research work carried out by Md. Shahidur Rahman, Registration No. 03274 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 been duly acknowledged by him.

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The Author

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ABSTRACT

A field experiment was carried out at research farm of Sher-e-Bangla Agricultural University to find out the effect of intercropping on the insect pest infestation of cabbage. The crop combinations were cabbage + garlic, cabbage + radhuni, cabbage + mouri, cabbage + methi, cabbage + kalizira, cabbage + coriander, cabbage + onion and sole cabbage. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The lowest number of insect pest (0.03, 0.12, 0.32, 0.60,1.20, 1.59, 2.15, 2.41 and 3.00 at 15, 22, 29, 36, 43, 50, 57, 64 and 71 DAT, respectively) and highest infestation reduction over control (97.89, 92.28, 83.08, 75.68, 66.40, 62.61, 56.20, 54.75 and 55.40 at 15, 22, 29, 36, 43, 50, 57, 64 and 71 DAT, respectively), The highest number of natural enemy (0.98, 1.41, 1.75 and 2.18 at 50, 57, 64 and 71 DAT, respectively), lowest number of insect pest family (2.21) and highest reduction over control (69.07%), The highest number of natural enemies (2.85) and The highest increase over control (64.29%) were achieved by Cabbage + garlic intercropping system. The highest cabbage yield (63.29 t/ha), relative yield (1.08 t/ha) and cabbage equivalent yield (63.50 t/ha) were obtained in Cabbage + garlic intercropping system. The highest gross return (Tk. 305160.00/ha) was recorded from the Cabbage + garlic intercropping system. Considering the results of the present study, cabbage + garlic intercropping system showed the best performance in respect of reducing insect pest and increasing natural enemies, relative yield, cabbage equivalent yield and gross return.

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CHAPTER I

INTRODUCTION

Cabbage (*Brassica oleracea* L.) is an important cole crop, member of the family Cruciferae. Cole crops, including cabbage are important fresh and processing vegetable crops in most of the countries of the world. Cole crops are biennials, but are generally grown as annuals. They are suited to the climate of many regions.

Cabbage is believed to have originated in Western Europe and it was the first cole crop to be cultivated. Prior to cultivation and use as food, cabbage was mainly used for medicinal purposes (Silva, 1986). In addition to the fresh market, it is now processed into Kraut, egg rolls and cole slaws and there is the potential for other specialed markets for the various types including red, savoy and mini cabbage. Cabbage is an excellent source of Vitamin C. In addition to containing some B vitamins, it supplies some potassium and calcium to the diet.

Cabbage is generally grown in Rabi season in Bangladesh. Proper growth and yield of this vegetable crop remarkably influenced by different insect pest and diseases and their management practices.

However, the productivity of cabbage per unit area is quite low as compared to the developed countries of the world (Anon., 2006). Among the various factors involved, management practices against different insect pests are important operations for higher cabbage yield and its nutrient content.

According to Hamilton (1991) insect causes millions worth of monitory losses annually to food and fiber crops all over the world. Altogether, pests are responsible for the loss of a very significant proportion usually estimated at around 35% of the world's crops. Their ravages starve the people and severely reduce the yield of cash crops. Worldwide expenditure on pesticides is thought to be around US $ 2,000 million annually, but their often-indiscriminate use has led to the build-up of resistance by pests and creates extreme environmental problem. Greater concern for the environment, and a growing awareness of the importance of the complex inter-relationships of organisms within ecosystems, have led to the realization that few pests could be eradicated totally, even if this were considered necessary and desirable. The emphasis is therefore, be given on identifying and understanding all the organisms involved and in keeping the population of potential pests below the level at which they begin to inflict economic damage.

Control measures are now increasingly species-specific and many involved the use of natural enemies or natural plant resistance. The growing awareness of the shortcomings of chemical insecticides has necessitated the exploration for alternative methods of pest control, which is relatively free of adverse side effects.

Cutworms, imported cabbage worm, cabbage lopper, diamondback moth larvae, and cross-striped cabbage worm can be early season pests of cabbage. These pests can cause serious damage to young transplants as well as causing serious leaf feeding damage to older plants. Damage to the head or wrapper leaves often reduces marketability. Because many of these pests are much more difficult to control as mature and large larvae, controls will always be most effective when directed toward young and small larvae. So early detection of economic infestations is critical to the management of these pests. Beet armyworm, flea beetles, cutworms, cabbage aphids and cabbage maggots can also cause serious damage to cabbage crop.

Successful control of cabbage pests, particularly the leaf feeding caterpillars, depends on pest identification, proper timing of applications and insecticide coverage, because caterpillars of different species may be susceptible to different insecticides, it is important to identify the species involved in an infestation.

Among the various alternatives the exploitation of host plant resistance is perhaps the most effective convenient, economical and environmentally acceptable method of insect 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 cabbage through agronomic practices may be considered as one of the possible alternate options.

Agronomic practices like intercropping of crop of diverse growth habit have been found as a very useful technique in controlling a large number of crop pests. Intercropping supports a lower herbivore load than monoculture. One factor explaining this trend is that relatively more stable population of natural enemies can persist in intercropping due to the continuous availability of food sources and microhabitats. The other possibility is that specialized herbivores are more likely to find and remain on pure crop stands that provide concentrated resources and monotonous physical conditions (Altieri, 1995; Altieri and Letourneau, (1984).

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. There is a general agreement that species diversity in multiple cropping reduces the most insect pest problems and the cropping intensity of carefully designed multiple species mixture can successfully out compete weeds. In intercropping, two or more plant species in the field may disrupt the host plant finding behavior of insects. Intercropping can affect the microclimate of the agro-ecosystem, which ultimately produce 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). Many photophilic pests avoid short crops when they are shaded by taller crops. The presence of non host plant between two rows of a host plant may be another factor influencing pest incidence in intercropping system. Perrin and Philips (1979) outlined these effects of intercropping in relation to initial colonization of crops, feeding, reproduction, mortality and dispersal of pests within the crop. The species diversity of population level of the natural enemies may be influenced by the complex environment of intercrop (Prince and Waldbauer, 1975; Coaker, 1981).

Any advantage from intercropping compared with monoculture depends on achieving a relative yield total (RYT)>l. Within insects it is also possible that one plant species may serve as a trap for some 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 spreading of the risk of monocrop failure.

Under the above prospective, intercropping has been thought to be an environment friendly approach for the management of insect pests in cabbage. However, very little work has been done in this area in Bangladesh.

Considering the above factors, the present experiment was undertaken with the following objectives:

Objectives

1. To find out the effect of intercropping on incidence and abundance of insect pests and natural enemies in cabbage,
2. To determine the control efficiency of intercropping for suppressing insect pest in cabbage.
3. To assess the influence of intercropping on the yield performance and productivity of cabbage.

CHAPTER II

REVIEW OF LITERATURE

A number of studies on intercropping or mixed cropping and their relationship with pest management have been done and reported elsewhere in the world. However, studies in this area appeared very limited in Bangladesh. For a better understanding and to know the research status on impact of intercropping on insect pest management, the relevant available literature have been reviewed and presented below.

2.1 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 decreased predator and parasitoid populations and increased insect pest populations.

Risch *et 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 to wit: (1) host plants are more widely spread in intercrops, meaning they are harder to find, (2) the species serves as a trap crop to detour the pest from finding the other crop, and (3) one species serves as a repellent to the pest.

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 modern 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. 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 yields, energy conservation and less dependence on external inputs.

Southwood and Way (1970) cited that the type and abundance of biodiversity in agriculture will differ across agro ecosystems which 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 permanence 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.

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.

The magnitude of yield advantage of intercropping system could be determined by the use of land equivalent ratio (LER) value (Ofori and Stern, 1987). The concept of land equivalent ratio or relative yield total assumed to be an important method in evaluating the benefit of intercropping of two dissimilar crops grown in the same land (Fisher, 1977). If LER is more than 1.00 then intercropping gives agronomic advantages over monoculture practice. The higher is the LER, the more is the agronomic benefits of intercropping systems (Palaniappan, 1988). The land equivalent ratio is the most frequently used index to determine the effectiveness of intercropping relative to growing crops separately (Wil1ey, 1985).

2.2 Relationship between intercropping with insect pests and their natural enemies: Experimental evidences

2.2.1 Insect pests

Intercropping of tomato (AVRDC, 1985; Roltsh and Gage, 1990), garlic (AVRDC, 1985; Halepyatic *et al.*, 1987), onion (Jhons and Mau, 1986) and ginger (Chowdhury, 1988) with different crops have been reported to reduce the population of different target pests. Hussain and Samad (1993) reported that Intercropping chili with Brinjal reduces the population of *Aphis gossypii* in brinjal. Simmonds *et al.* (1992) reported plants with anti-feedant activities. Among them, *Allium* spp. are reportedly very effective. Kirtikar and Basu (1975) reported that onion, garlic, coriander (*Coriandrum sativum* L.) have also strong pungent repellent action.

Letoumeau (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. The total crop yield in intercropping was higher when estimated as a land equivalent ratio.

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 polyculture system compared to the combination of their component sole crops. A combination of pitfall trap and sweeping net methods for the whole crop growth period revealed a highly significant positive relation between richness (x) and diversity index (y), but a negative relationship between richness (x) and equitability (y).

Casagrande 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 verities. They reported that biological control was more effective in the mixed cropping of beetle resistant and beetle susceptible wheat varieties than in a pure stand 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 (Perin, 1977; Kass, 1978; Nickel, 1973; Litsinger and Moody, 1976; Dempster and Coaker, 1974) that pests tend to be reduced in intercrops, although not by any means always. While these reviews tend to concentrate on insects, there is also evidence that intercrops reduce nematode attack (Mc Beth and Taylor, 1944; Khan *et al.*, 1971; Atwal and Manger, 1967; Castillo *et al.*, 1976; Egunjobi, 1984) and diseases (Moreno and Mora, 1984; Rheeneu *et al.*, 1981).

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

In an elegant experiment, Beach (1981) reasoned that 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 that *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 blackgram (*Vigna mungo*).

Ofuya (1991) found that when cowpea was intercropped with tomato, damage caused by *Helicoverpa armigera* was reduced and grain filling was increased compared to monocropped cowpeas.

Prasad and Chand (1989) reported that intercropping of chickpea (*Cicer arietinum*) with barley, mustard and wheat suppressed numbers of *Helicoverpa armigera* by 59.56 and 47%, respectively. They concluded that barley, mustard and wheat are compatible crops for the intercrop 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 pigeonpeas grown adjacent to a strip-intercropped with sorghum suffered less damage by Helicoverpa armigera. Similarly, Patnaik *et al.* (1989) observed the severest attack by *Helicoverpa armigera* on sole cropped pegionpeas, followed by pegionpeas intercropped with groundnuts, mungbeans (*Vigna radiata*), blackgram (*Vigna mungo*) while it was the lowest in pegionpea intercropped with finger millet.

Hossain *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.

Andow (1991) found that polycultures had lower pest populations than monocultures, and even then it occurred intermittently. Severe competition from the other plants in the polyculture might limit the ability of the crop to compensate for pest injury and crop tolerance, or resistance to pest injury might other wise 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 benefits in ployculture 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 the sorghum by the pyralid Chilo partellus in Tamil Nadu, India. On sorghum as a pure crop, 32.6% damage was recorded, as compared with lablab, respectively. The corresponding yields were 3609, 4652 and 4567 kg grain/ha, respectively.

Raymundo and Aclcazar (1983) claimed that potato plants 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 studies in Navgaon, Rajasthan, India during 1984-86. The early maturing pigeonpea cv. UPAS-120 and the mid maturing cv. BDN-1 were intercropped with blackgram (*Vigna mango*) greengram (*V. radiata*), pearl millet and sorghum and the infestation by *Exelastis atomosa* and *Melanagromyza obtusa* was compared with that of pigeonpeas grown as a sole crop. They found no marked 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-l.

Lal (1991) reported that larval infestations of *Phthorimaea operculella* on potatoes were consistently reduced when potatoes were grown with chillies (Capsicum), onoins and peas compared to potato alone. Similarly, tuber damage was significantly lower in plots associated with capsicum, onions, and peas (11, 11 and 13%, respectively) compared to 20% in potato alone.

Manisegaran *et al.* (2001) found that incidence of shoot webber was significantly lower in sesame intercropped with pearl millet 4:1 (11.2%), pearl millet 6:1 (12.2%), blackgram 4:1 (12.5%) and green gram (13.3%) compared with the sole sesame crop (24.9%). In general, the incidence of shoot webber was reduced in sesame when it was intercropped, although incidence increased in the groundnut intercropping system. Sesame yield was the highest as a sole crop (634 kg/ha) followed by intercropping with pearl millet (553-556 kg/ha).

√ Sardana (2001) observed a significantly lower incidence of root borer, Emmaiocera depressella Swinhoe in sugarcane when intercropped with blackgram compared to the sugarcane monocrop. Skovgard and pats (1996) observed the effect of maize-cowpea intercropping on three lepidopteran stem borer and their natural enemies in Kenya. Ovipositon was not affected by inter- cropping but significantly fewer larvae and pupae were found in the intercrop.

2.2.2 Natural enemies

Nampala *et al.* (1999) observed that abundance of coccinellids and syrphid larvae were neither influenced by the cowpea genotype nor cropping systems. Contrastingly, 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 al.* (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 al.* (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 Vandermeer *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 al.* (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 tomotoes and beans from intercrops of the two.

Srikanth *et al.* (2000) examined that the incidence of 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 an another experiment, they also claimed that mean predator number did not differ significantly between intercrop and monocrop.

Mote *et al.* (2001) found that the population of sucking pests of cotton was minimum when insecticide sprays were imposed on main crop only. Intercropping of cowpea as well as greengram and cotton proved to be better in suppressing the population of sucking pests. The incidence on bollworm complex in fruiting bodies was the lowest in plots in which insecticides were applied but was the highest in untreated plots. 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 intercrop system showed maximum number. Spraying of insecticide on cotton only produced a higher yield. Cotton + greengram produced the same yield of kapas as sole cotton.

Turker *et al.* (2000) studied the effects of intercropping of chickpea (gram) with coriander. They recorded significantly higher parasitic activity (5.7 cocoons per 5 m row length), low pest activity (2.33 larvae 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.

2.3 Intercropping and crop yield

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 (3.8 t/ha), maize +green gram (3.6 t/ha) and maize + pegionpea (3.53 t/ha) 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) gave significantly higher equivalent yield than the other intercropping systems.

Using LER as criteria, Bhuiyan (1981) examined mixed crop combinations of lentil gram and soybean with wheat under different proportion and recorded the highest LER (1.47) in gram and wheat at 100:75 seeding ratio followed by lentil and wheat at 100:75, 100:50 and 100:25 seeding ratio with LER values 1.37, 1.23 and 1.15, respectively.

From the review of literature it was observed that different intercropping systems had lower 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 a 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 in the research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2009 to May 2010 to evaluate the Effect of intercropping on the insect pest infestation and their natural enemies of cabbage. The materials and methods used for conducting the experiment have been described under the following headings:

3.1 Experimental site

The present experiment was conducted in the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^{0}74'$N latitude and $90^{0}35'$E longitude and at an elevation of 8.2 m from sea level (Anon., 1989). The experimental site was represented in Appendix I.

3.2 Climate

The climate is subtropical in nature with low temperature and scanty rainfall. The soil of the experimental land belongs to the Madhupur tract and was silty clay in nature having pH ranging from 5.5 to 6.2. Details of the meteorological data during the study period was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix II.

3.3 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract under AEZ No. 28. It had shallow red brown terrace soil. The selected plot was medium high land and the soil series was Tejgaon. Details of the recorded soil characteristics were presented in Appendix III.

3.4 Treatments

Combination of cabbage *(Brassica oleracea* L.), garlic (*Allium sativum*), radhuni (*Trachyspermum roxburghianum*), mouri (*Fructus foeniculi*), methi (*Trigonella foenumgraecum*), kalizira (Nigella sativa), coriander (*Coriandrum sativum*) and onion *(Allium cepa*) constitute the intercropping systems.

The following system were used as treatments:

(1) Cabbage + garlic
(2) Cabbage + radhuni
(3) Cabbage + mouri
(4) Cabbage + methi
(5) Cabbage + kalizira
(6) Cabbage + coriander
(7) Cabbage + onion and
(8) Sole cabbage

3.5 Design of experiment

The experiment was laid out in a randomized complete block design (RCBD) with three replications. The unit plot size was 3m × 2.5m. The distance between plots and blocks was 1m and 1m, respectively. Plant to plant and row to row distance for cabbage was 75 cm. But for garlic, radhuni, mouri, methi, kalizira, coriander and onion, row to row distance was 30cm and plant to plant distance was 15 cm. In case of intercropping, bulbs of onion and garlic as well as seed of radhuni, mouri, methi, kalizira and coriander were sown in an alternate row arrangement. The layout of the experiment was presented in Appendix IV.

3.6 Land preparation and fertilization

The experimental plot was ploughed thoroughly by a tractor drawn disc plough followed by harrowing. The land was then labeled prior to transplanting. During land preparation, cowdung was incorporated into the soil at the rate of 10 t/ha. Recommended doses of fertilizer comprising urea, TSP and MP at the rate of 330, 200 and 250 kg/ha respectively were applied. TSP and MP were applied as basal dose at the time of transplanting in all the treatments (BARC, 1997). The N in the form of urea was applied in 3 equal splits at basal, 20 days after transplanting (DAT) and 40 DAT.

3.7 Seed source and transplanting

The cabbage seedlings (var. Atlas–70) were collected from Horticulture Development Centre, Bangladesh Agricultural Development Corporation (BADC), Dhaka. Coriander (Var. BARI dahnia-1) was collected from vegetable division of Bangladesh Agricultural Research Institute (BARI), Gazipur. Onion and garlic bulbs, mouri, methi and kalizira seed were collected from local market of Siddique Bazar, Dhaka.

Cabbage seedlings were transplanted in sole and in intercrop on 29 October 2009, coriander, kalizira, methi, mouri and radhuni on 8 November 2009 and onion and garlic on 20 November 2009. After establishment of cabbage, the intercrops were sown/transplanted in between the cabbage lines.

3.8 Cultural practices

Damaged seedlings were replaced immediately by new ones in the experimental field. Weeding and mulching were done at 30, 50, 70 days after transplanting (DAT) to keep the field free from weeds and better establishment of crops. A number of irrigation was applied throughout the whole growing season in all the crop combinations.

3.9 Data collection

1. Presence of insect pests at 7 days interval started at 15 DAT to 71 DAT
2. Presence of natural enemies at 7 days interval started at 15 DAT to 71 DAT
3. Number of families of insect pest during total cropping period
4. Number of families of natural enemies during total cropping period
5. Yield of cabbage
6. Yield of intercropped crops

3.10 Procedure of recording data

1. **Presence of insect pest**

   Number of insect pest was counted from randomly selected five plants at 7 days interval started at 15 DAT to 71 DAT. Number of insect was observed by Pitfall trap method and sweeping net method.

2. **Presence of natural enemy**

   Number of natural enemy was counted from randomly selected five plants at 7 days interval started at 15 DAT to 71 DAT. Number of natural enemy was observed by Pitfall trap and Sweeping net method.

3. **Number of families of insect pest**

   Number of families of insect pest was observed and recorded by the presence of insect pest in crop field from randomly selected five plants during whole cropping season. Number of families of insect pest was observed with the help of Pitfall trap method and Sweeping net method.

4. **Number of families of natural enemies**

   Number of families of natural enemy was observed by the presence of natural enemy in crop field from randomly selected five plants during whole cropping season. Number of families of natural enemy was measured with the help of Pitfall trap method and sweeping net method.

4. **Yield of cabbage**

   Yield/plant was recorded from randomly selected five plants and then averaged to kg/plant. Total yield/plot was also taken and then it was converted to t/ha.

5. **Yield of intercropped crops**

   Total yield/plot was also taken and then it was converted to t/ha.

3.10.1 Pitfall trap method

This method was used for the species that roam in the soil surface such as ground beetles, spiders, collembola etc. Small plastic pots having 6 cm diameter and 8 cm deep were used as pitfall traps each of which was filled with water. Three traps were placed in soil in each of the plots at early, mid and late stage of crops to trap the insects. The trap mouth of the pot was kept with the ground level so as not to obstruct insect movement. After 48 hours of setting traps, insects were collected from each plot/treatment and kept separately.

On the basis of phenotypic similarity, trapped insects were then sorted and further identified to family and order they belong to with the help of identified specimens kept with the museum of the department of Entomology, SAU and other standard taxonomic keys. Data were recorded against each treatment.

3.10.2 Sweeping net method

This method was used for counting flying and stationary insects on host plants to know the abundance pattern of insects in the present study. Five (5) times complete sweeping was done in each plot to make a composite sample by a sweeping net at early, mid and late crop stages. Each sample was examined separately without killing the insects and released then immediately after counting in the same plot. The individuals of each sample were counted by family.

3.11 Harvesting and yield of the crops

Cabbage: Cabbage was harvested when head formation of a plant was completed. At each harvest, data was taken by weight and recorded separately per plot. The cumulative cabbage yield per plot was calculated.

Onion and garlic: Onion and garlic were harvested 123 days after transplanting (DAT). The harvested bulbs of onion and garlic were clean and weighed separately for each plot. The bulb yield thus obtained was converted into per hectare yield.

Radhuni, Mouri, Methi and Coriander: Radhuni, Mouri, Methi and Coriander were harvested after 100, 110, 115 and 125 days after sowing (DAS). The harvested Radhuni, Mouri, Methi and coriander was threshed manually and seeds were separated, clean and sun dried. The dried seed yield thus obtained was converted into per hectare yield.

3.12 Relative yield of cabbage

Relative yield is the ratio between yield of component crops and yield of sole crop.

$$\text{Relative yield} = \frac{\text{Yield of component crop}}{\text{Yield of sole crop}}$$

3.13 Equivalent yield

Yield of an individual crop was converted into equivalent yield by converting yield of intercrops into the yield of the sole crops on the basis of prevailing market price of individual crop (After Anjaneyulu *et al*., 1982) as follows:

i) Cabbage equivalent yield for garlic = $Y_c + \dfrac{Y_g \times P_g}{P_c}$

ii) Garlic equivalent yield for cabbage = $Y_g + \dfrac{Y_c \times P_c}{P_g}$

iii) Cabbage equivalent yield for radhuni = $Y_c + \dfrac{Y_r \times P_r}{P_c}$

iv) Radhuni equivalent yield for cabbage = $Y_r + \dfrac{Y_c \times P_c}{P_r}$

v) Cabbage equivalent yield for mouri = $Y_c + \dfrac{Y_{mo} \times P_{mo}}{P_c}$

vi) Mouri equivalent yield for cabbage = $Y_{mo} + \dfrac{Y_c \times P_c}{P_{mo}}$

$Y_{me} \times P_{me}$

vii) Cabbage equivalent yield for methi = $Y_c + \dfrac{\quad}{P_c}$

viii) Methi equivalent yield for cabbage = $Y_{me} + \dfrac{Y_c \times P_c}{P_{me}}$

ix) Cabbage equivalent yield for kalizira = $Y_c + \dfrac{Y_k \times P_k}{P_c}$

x) Kalizira equivalent yield for cabbage = $Y_k + \dfrac{Y_c \times P_c}{P_k}$

xi) Cabbage equivalent yield for coriander = $Y_c + \dfrac{Y_{co} \times P_{co}}{P_c}$

xii) Coriander equivalent yield for cabbage = $Y_{co} + \dfrac{Y_c \times P_c}{P_{co}}$

xiii) Cabbage equivalent yield for onion = $Y_c + \dfrac{Y_o \times P_o}{P_c}$

xiv) Onion equivalent yield for cabbage = $Y_o + \dfrac{Y_c \times P_c}{P_o}$

Where, Y_c = Yield of cabbage in intercrop (t/ha); Y_r = Yield of radhuni in intercrop (t/ha); Y_{mo} = Yield of mouri in intercrop (t/ha); Y_{me} = Yield of methi in intercrop (t/ha); Y_k = Yield of kalizira in intercrop (t/ha); Y_{co} = Yield of coriander in intercrop (t/ha); Y_o = Yield of onion in intercrop (t/ha); P_c = Price of cabbage in intercrop (Tk./ha); P_g = Price of garlic in intercrop (Tk./ha); P_r = Price of radhuni in intercrop (Tk./ha); P_{mo} = Price of mouri in intercrop (Tk./ha); P_{me} = Price of methi in intercrop (Tk./ha); P_k = Price of kalizira in intercrop (Tk./ha); P_{co} = Price of coriander in intercrop (Tk./ha) and P_o = Price of onion in intercrop (Tk./ha).

3.14 Statistical analysis

Data were analyzed by using MSTAT software. The data recorded on different parameters were subjected to analysis of variance (ANOVA) and the means were compared according to Least Significant Difference (LSD) test at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

The results on the effect of intercropping systems with cabbage + garlic, cabbage + radhuni, cabbage + mouri, cabbage + methi, cabbage + kalizira, cabbage + coriander and cabbage + onion compared to its monoculture on insect pests and their natural enemies complex have been presented and discussed under the following sub headings.

4.1 Incidence of insect pests in intercropping

4.1.1 Incidence of insect pest as infestation by intercropping systems

Productions of cabbage alone and with intercropped crops were significantly influenced by the presence of insects by number that harm cropping system. Significant variation was observed on the incidence of insect at different growth stages of cabbage. The lowest number of insect pests (0.03, 0.12, 0.32, 0.60, 1.20, 1.59, 2.15, 2.41 and 3.00 at 15, 22, 29, 36, 43, 50, 57, 64 and 71 DAT, respectively) from 5 plants of cabbage was recorded in cabbage + garlic (T_1) intercropping system (Table 1). On the other hand, the highest number of insect pests by number (1.45, 1.52, 1.89, 2.48, 3.57, 4.24, 4.91, 5.33 and 6.73 at 15, 22, 29, 36, 43, 50, 57, 64 and 71 DAT, respectively) from 5 plants was recorded in sole cabbage (T_8). Higher number of insect pests (1.10, 1.25, 1.62, 2.17, 3.23,3.94, 4.46, 5.01 and 6.02 at 15, 22, 29, 36, 43, 50, 57, 64 and 71 DAT, respectively) in cabbage was also found in cabbage + mouri (T_3) crop combination system but significantly lower than sole cropping (T_8).

4.1.2 Percent (%) reduction of insect pest by number over control (sole crop)

Intercropping system significantly reduced pest population over sole crop. Results showed that the highest reduction (97.89, 92.28, 83.08, 75.68, 66.40, 62.61, 56.20, 54.75 and 55.40 at 15, 22, 29, 36, 43, 50, 57, 64 and 71 DAT, respectively) was obtained by cabbage + garlic (T_1) intercropping system. But the lowest reduction of insect pest over control (23.83, 17.30, 14.45, 12.62, 9.37, 7.07, 9.16, 6.01 and 10.63 at 15, 22, 29, 36, 43, 50, 57, 64 and 71, DAT respectively) was recorded from cabbage + mouri (T_3) crop combination. The crop combination of cabbage + methi (T_4) also showed lower percent reduction of insect pest but slightly higher than that of cabbage + mouri (T_3) combination (Table 2)

Table 1: Effect of intercropping cabbage with other crops on the incidence of different insect pest at different days after transplanting

Treatments	**Incidence of insect pest by number at**								
	15 DAT	**22 DAT**	**29 DAT**	**36 DAT**	**43 DAT**	**50 DAT**	**57 DAT**	**64 DAT**	**71 DAT**
T_1	0.03 g	0.12 g	0.32 f	0.60 e	1.20 f	1.59 f	2.15 e	2.41 g	3.00 e
T_2	0.16 f	0.36 ef	0.72 e	1.17 d	2.07 e	2.60 e	3.30 d	3.55 ef	4.03 d
T_3	1.10 b	1.25 b	1.62 b	2.17 b	3.23 b	3.94 ab	4.46 ab	5.01 ab	6.02 b
T_4	0.91 c	1.03 c	1.49 bc	2.08 b	3.05 bc	3.62 bc	4.20 bc	4.64 bc	5.49 bc
T_5	0.37 e	0.50 e	0.98 d	1.50 c	2.52 d	3.02 d	3.65 cd	4.02 de	4.39 d
T_6	0.04 g	0.19 fg	0.39 f	0.80 e	1.36 f	1.87 f	2.61 e	3.03 f	3.40 e
T_7	0.60 d	0.72 d	1.28 c	1.93 b	2.88 c	3.30 cd	3.99 bc	4.37 cd	5.04 c
T_8	1.45 a	1.52 a	1.89 a	2.48 a	3.57 a	4.24 a	4.91 a	5.33 a	6.73 a
$LSD_{0.05}$	0.1108	0.2072	0.2349	0.271	0.293	0.3323	0.562	0.5593	0.5939
CV(%)	6.98	8.42	7.54	5.39	9.14	6.25	7.46	5.28	7.14

Figures in the same column accompanied by the same letter(s) are not significantly different at 5% level as per Least Significant Difference test (LSD). Values are mean of three replications.

T_1 = Cabbage + garlic
T_2 = Cabbage + radhuni
T_3 = Cabbage + mouri
T_4 = Cabbage + methi
T_5 = Cabbage + kalizira
T_6 = Cabbage + coriander
T_7 = Cabbage + onion
T_8 = Sole cabbage (Control)

Table 2: Effect of intercropping cabbage with other crops on percent reduction of incidence of different insect pest over control at different days after transplanting (DAT).

Treatments	% reduction of insect pest incidence over control at								
	15 DAT	22 DAT	29 DAT	36 DAT	43 DAT	50 DAT	57 DAT	64 DAT	71 DAT
T_1	97.89 a	92.28 a	83.08 a	75.68 a	66.40 a	62.61 a	56.20 a	54.75 a	55.40 a
T_2	89.14 b	76.46 c	61.74 c	52.82 c	42.00 c	38.64 c	32.79 c	33.29 c	40.14 c
T_3	23.83 f	17.30 g	14.45 g	12.62 g	9.37 g	7.07 g	9.16 g	6.01 g	10.63 g
T_4	37.31 e	32.28 f	21.33 f	16.12 f	14.42 f	14.76 f	14.52 f	12.82 f	18.40 f
T_5	74.17 c	66.79 d	48.17 d	39.52 d	29.29 d	28.82 d	25.52 d	24.46 d	34.74 d
T_6	97.06 a	87.68 b	79.19 b	67.88 b	61.85 b	55.86 b	46.78 b	43.04 b	49.50 b
T_7	58.51 d	52.28 e	32.08 e	22.31 e	19.29 e	22.15 e	18.68 e	17.89 e	25.19 e
T_8	--	--	--	--	--	--	--	--	--
$LSD_{0.05}$	6.824	2.184	3.054	2.138	1.819	1.498	2.235	1.712	1.267
CV(%)	5.65	6.58	6.39	7.48	8.24	6.86	7.49	6.37	7.44

Figures in the same column accompanied by the same letter(s) are not significantly different at 5% level as per Least Significant Difference test (LSD). Values are mean of three replications.

T_1 = Cabbage + garlic
T_2 = Cabbage + radhuni
T_3 = Cabbage + mouri
T_4 = Cabbage + methi
T_5 = Cabbage + kalizira
T_6 = Cabbage + coriander
T_7 = Cabbage + onion
T_8 = Sole cabbage (Control)

In the present study the incidence of insect pest in intercropping of cabbage with different crop combinations, is in conformity with the findings of several studies conducted elsewhere. Andow (1991) and Risch *et al.* (1983) found that intercropping had lower pest infestation than monocultures. In the tropical low lands of Mexico, Letourneau (1986) found the similar results in maize + cowpea + squash intercropping. In a maize + bean intercropping system, Van Huis (1981) and Francis *et al.* (1978) claimed lower attack rates *of Spodoptera frugiperda*in this system as compared to maize monoculture. Dempstar and Coaker (1974) found that the colonization of cabbages by *Erioschia brassicae* and *Pieris rapae* was greatly interfered with when the cabbages were undersown with white and red clover.

In case of fruit infestation in brinjal by brinjal shoot and fruit borer, the study revealed less fruit damage in intercropping brinjal + coriander, brinjal + chilli, brinjal + garlic and brinjal + onion in comparison to that of brinjal alone. Ali *et al.* (1996) evaluated the effect of intercropping onion, garlic and coriander with brinjal where brinjal + coriander intercropping performed the best in reducing the fruit infestation by brinjal shoot and fruit borer among other intercrop treatments.

In all the studied crops of the present study, the abundance of insect pests in intercropping was lower as compared to monoculture which might be due to physical barriers to insect movement, chemical composition of plants in intercropping may have affected the incidence of insect pest populations, adverse environmental factors or low availability of food sources etc.

4.2 Effect of intercropping on the abundance of natural enemies

Significant influence of intercropping was observed on presence of natural enemies by number at different days after transplanting (Table 3). Results indicated that at 15, 22, 29, 36 and 43 DAT, there was no significant variation was found in respect of presence of natural enemies. Among the five observations (15 – 43 DAT) no natural enemy was recorded from first 3 observations and second two observations, natural enemy was very poor. But at 50, 57, 64 and 71 DAT, the presence of natural enemy was significant compared to all treatments along with sole cropping. Results showed that the highest natural enemies (0.98, 1.41, 1.75 and 2.18 at 50, 57, 64 and 71 DAT, respectively) were found from cabbage + garlic (T_1) intercropping combination. On the other hand the lowest number of natural enemy was observed (0.08, 0.13, 0.21 and 0.41 at 50, 57, 64 and 71 DAT, respectively) in sole cabbage (T_8) which was significantly similar with cabbage + mouri (T_3) intercropping combination (0.11, 0.18, 0.42 and 0.84 at 50, 57, 64 and 71 DAT, respectively).

Table 3: Effect of intercropping cabbage with other crops on the incidence of natural enemies at different days after transplanting (DAT).

Treatments	Presence of natural enemy by number at								
	15 DAT	22 DAT	29 DAT	36 DAT	43 DAT	50 DAT	57 DAT	64 DAT	71 DAT
T_1	0.00	0.00	0.00	0.38	0.52	0.98 a	1.41 a	1.75 a	2.18 a
T_2	0.00	0.00	0.00	0.07	0.23	0.49 c	1.02 bc	1.37 ab	1.72 bc
T_3	0.00	0.00	0.00	0.00	0.00	0.11 e	0.18 e	0.42 c	0.84 f
T_4	0.00	0.00	0.00	0.00	0.05	0.16 de	0.26 e	0.54 c	1.07 ef
T_5	0.00	0.00	0.00	0.05	0.13	0.33 cd	0.73 cd	1.18 b	1.46 cd
T_6	0.00	0.00	0.00	0.22	0.40	0.75 b	1.21 ab	1.56 ab	2.00 ab
T_7	0.00	0.00	0.00	0.00	0.06	0.23 de	0.45 de	1.07 b	1.28 de
T_8	0.00	0.00	0.00	0.00	0.00	0.08 e	0.13 e	0.21 c	0.41 g
$LSD_{0.05}$	Ns	Ns	Ns	Ns	Ns	0.1837	0.3673	0.4567	0.3414
CV (%)	--	--	--	1.25	3.46	4.57	6.12	5.24	6.78

Figures in the same column accompanied by the same letter(s) are not significantly different at 5% level as per Least Significant Difference test (LSD). Values are mean of three replications.

NS = Non Significant

DAT= Days after transplanting (DAT).

T_1 = Cabbage + garlic
T_2 = Cabbage + radhuni
T_3 = Cabbage + mouri
T_4 = Cabbage + methi
T_5 = Cabbage + kalizira
T_6 = Cabbage + coriander
T_7 = Cabbage + onion
T_8 = Sole cabbage (Control)

Results of the present study are in general conformity with that reported by Nampala *et al.* (1999) and Hansen (1983). Nampala *et al.* (1999) found 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 + greengram than in the cowpea+ sorghum intercrops. This reflects a difference between intercrop combinations. Hansen (1983) observed an increased abundance of several predator species in an intercrop system of maize and cowpea in Southern Mexico.

In several other studies, however, it has been shown that higher density of natural enemies occurred in sole crop than in mixed crops, which appeared opposit to the general prediction. Kyamanywa *et al.* (1993) worked with cowpea +maize intercropping and found that the abundance of *Orius*species, lady bird beetles, earwigs and spiders were not enhanced by planting cowpea as a mixed crop with maize. This trend has been partially reflected for spider population in brinjal+garlic and brinjal+chili and for lady bird beetle population in brinjal +onion systems in the present study. Similarly, Andow and Risch (1985) observed that predaceous coccinellid beetles, *Coleomegilla maculata* (Dey) and its prey (aphids) were both more abundant on sole crops than on mixed maize and beans.

4.3 Effect of intercropping on the abundance of family of insect pest and natural enemies

4.3.1 Family of insect pest

The major insect families observed in whole cropping period were cabbage looper (noctuidae), Diamond back moth (Plutellidae), Army warm (noctuidae), Army cut warm (noctuidae), Cabbage aphid(aphidodae), Leaf feeding caterpillar(noctuidae), Flea beetle (chrysomelidae),Cabbage maggots (anthomyiidae), Significant variation was observed in terms of insect pest family presence during whole cropping period (Table 4). It was measured that the lowest number of insect pest families (2.21) was recorded in cabbage + garlic (T_1) intercropping combination while the highest (7.15) was observed with control treatment (sole cabbage, T_8). On the other hand, within intercropping treatments the highest number of insect pest (5.87) was obtained by cabbage + mouri (T_3) intercropping system.

intercropping treatments the highest number of insect pest (5.87) was obtained by cabbage + mouri (T_3) intercropping system.

✓ Another considering fact was that the highest percent (%) reduction over control of insect pest families by number (69.07%) was achieved by cabbage + garlic (T_1) intercropping method while the lowest percent (%) reduction over control of insect pest families by number (17.78%) was obtained by cabbage + mouri (T_3) intercropping treatment.

4.3.2 Family of natural enemy

The major natural enemies observer in whole cropping season were ant (Formicidae), Ladybird beetle (coccinellidae), Wolf spider (lycosidae) and earwig. Significant variation was recorded in terms of family of natural enemy presence during whole cropping period (Table 4). It was measured that the highest number of natural enemy families (2.85) was recorded in cabbage + garlic (T_1) intercropping combination where the lowest (1.05) was observed with control treatment (sole cabbage, T_8). On the other hand, within intercropping treatments the lowest number of natural enemy (1.46) was obtained by cabbage + mouri (T_3) intercropping system.

✓ Another considering fact was that the highest percent (%) increase over control of natural enemy families by number (64.29 %) was achieved by cabbage + garlic (T_1) intercropping method where the lowest percent (14.64 %) increase over control of natural enemy families by number (%) was obtained by cabbage + mouri (T_3) intercropping treatment.

Table 4: Effect of intercropping cabbage with other crops on the number of insect families recorded from whole plants during whole cropping season

Treatments	Family of insect pest and natural enemy by number			
	Insect pest	% Reduction of insect over control	Natural enemy of insect	% increase of natural enemy over control
T_1	2.21 d	69.07 a	2.85 a	64.29 a
T_2	3.09 d	56.85 b	2.39 bc	47.62 c
T_3	5.87 b	17.78 e	1.46 e	14.64 g
T_4	5.13 bc	28.25 d	1.68 d	22.50 f
T_5	4.54 c	36.51 c	2.19 c	40.71 d
T_6	3.10 d	56.66 b	2.53 b	52.74 b
T_7	4.88 bc	31.69 d	1.81 d	27.02 e
T_8	7.15 a	--	1.05 f	--
$LSD_{0.05}$	1.038	4.226	0.2072	2.489
CV(%)	5.82	6.38	5.42	7.36

Figures in the same column accompanied by the same letter(s) are not significantly different at 5% level as per Least Significant Difference test (LSD). Values are mean of three replications.

T_1 = Cabbage + garlic
T_2 = Cabbage + radhuni
T_3 = Cabbage + mouri
T_4 = Cabbage + methi
T_5 = Cabbage + kalizira
T_6 = Cabbage + coriander
T_7 = Cabbage + onion
T_8 = Sole cabbage (Control)

4.4 Effect of intercropping on the yield performance of cabbage

Effects of intercropping treatments against the presence of insect pest and its subsequent impacts on yield performance of cabbage by its weight are presented in Table 5.

4.4.1 Yield performance of cabbage

Significant variation was observed on cabbage yield as influenced by intercropping treatments (Table 5). It was observed that highest yield/plant (3.98 kg) was performed by cabbage + garlic (T_1) intercropping system which was statistically identical with sole cabbage (3.91 kg) treatment (T_8) and statistically similar with cabbage + radhuni (T_2) (3.67 kg) and cabbage + kalizira (T_6) (3.87 kg). On the other hand the lowest yield/plant (2.47 kg) was obtained by cabbage + mouri (T_3) intercropping system which was significantly different from all other treatments.

In terms of yield/plot, the highest performance (47.47 kg) was achieved by cabbage + garlic (T_1) intercropping system which was significantly different from all other treatments. On the other hand, the lowest yield/plot (40.82 kg) was obtained by cabbage + mouri (T_3) intercropping system which was statistically similar (40.75 kg) with cabbage + mehti (T_4) intercropping treatments. The yield performance expressed in t/ha, the highest yield (63.29 t/ha) was performed by cabbage + garlic (T_1) intercropping system which was significantly different from all other treatments even it was the better performer than sole treatment (58.76 t/ha). On the other hand, the lowest yield/ha (54.42 t/ha) was obtained by cabbage + mouri (T_3) intercropping system which was significantly same (54.33 t/ha) with cabbage + mehti (T_4) intercropping treatments.

4.4.2 Yield performance of intercropped crops

Yield performance of intercropped crops was also significantly influenced by different intercropping systems. Results showed that the highest yield of different intercropped crops by weight was achieved from garlic (0.87 t/ha) and onion (0.89 t/ha) by cabbage + garlic (T_1) and cabbage + onion (T_7) respectively while the lowest yield/ha by weight was from kalizira (0.27 t/ha) and coriander (0.29 t/ha) by cabbage + kalizira (T_5) and cabbage + coriander (T_1) respectively. But in terms of economic return the best performance was recorded from mouri (Tk. 76,800.00/ha) and methi (Tk. 75,833.00/ha) by cabbage + mouri (T_3) and cabbage + methi (T_4) intercropping system, respectively.

Table 5: Effect of intercropping cabbage with other crops on cabbage and intercropped yield performance by weight regarding pest infestation

Treatments	Yield performance of cabbage			Yield performance of intercropped crops			
	Yield/plant (kg)	Yield/plot (7.5 m^2) (kg)	Yield/ha (ton)	Name of component crops	Yield/plot (7.5 m^2) (kg)	Yield/ha (ton)	Economic return from intercropped crops (Tk./ha)
T_1	3.98 a	47.47 a	63.29 a	Garlic	0.65 a	0.87 a	52000
T_2	3.67 ab	44.33 c	59.10 c	Radhuni	0.35 b	0.47 b	56000
T_3	2.47 d	40.82 e	54.42 e	Mouri	0.36 b	0.48 b	76800
T_4	2.94 c	40.75 e	54.33 e	Methi	0.44 b	0.58 b	75833
T_5	3.57 b	43.46 d	57.95 d	Kalizira	0.20 c	0.27 c	45333
T_6	3.87 ab	45.09 b	60.11 b	Coriander	0.22 c	0.29 c	43500
T_7	3.18 c	43.31 d	57.75 d	Onion	0.67 a	0.89 a	16020
T_8	4.07 a	44.07 c	58.76 c	--	---	--	--
$LSD_{0.05}$	0.3797	0.4922	0.6576	--	0.1125	0.1488	--
CV (%)	6.35	7.48	8.21	5.96	7.24	7.14	--

Figures in the same column accompanied by the same letter(s) are not significantly different at 5% level as per Least Significant Difference test (LSD). Values are mean of three replications.

T_1 = Cabbage + garlic
T_2 = Cabbage + radhuni
T_3 = Cabbage + mouri
T_4 = Cabbage + methi
T_5 = Cabbage + kalizira
T_6 = Cabbage + coriander
T_7 = Cabbage + onion
T_8 = Sole cabbage (Control)

Price of garlic, radhuni, mouri, methi, kalizira, coriander and onion was Tk. 60.00/kg, Tk. 120.00/kg, Tk. 160.00/kg, Tk. 130.00/kg, Tk. 170.00/kg, Tk. 150.00/kg and Tk. 18.00/kg respectively.

4.5 Yield and economics

In the present study, relative yield, equivalent yield and gross return were measured to evaluate the effectiveness of intercropping treatments that were used in the experiment.

4.5.1 Relative yield of cabbage

Relative yield indicates the competitive ability of component crops in an intercropping system (Wahua and Miller, 1778). The results on relative yield of cabbage were significantly influenced by different intercropping system under the present study (Table 6). The highest relative yield of cabbage (1.08 t/ha) was recorded from cabbage + garlic (T_1) which was statistically similar with cabbage + radhuni (T_2), cabbage + kalizira (T_5), cabbage + coriander (T_6), cabbage + onion (T_7) and sole cabbage (T_8). But the lowest relative yield of cabbage (0.92 t/ha) was found from cabbage + mouri (T_3) which was statistically identical with cabbage + methi (T_4). Among the component crops cabbage was found to be more competitive (1.08 t/ha) than the other crops. Higher competitive ability of cabbage may be attributed to its bushy and leafy structures which dominated over the understoried crops. Similar result was also reported by the Haque and Hamid (2001) in maize + sweet potato intercropping system where tall maize were more competitive than the shorter sweet potato

4.5.2 Cabbage equivalent yield with intercropped crops

Cabbage equivalent yield with intercropped crops was significantly influenced by different intercropping system (Table 6). Results showed that the highest cabbage equivalent yield with intercropped crops (63.40 t/ha) was recorded from cabbage + garlic (T_1) intercropping system, which was significantly different from all other treatments. On the other hand the lowest cabbage equivalent yield with intercropped crops (54.68 t/ha) was recorded from cabbage + methi (T_4) intercropping system which was statistically identical with cabbage + mouri (T_3) intercropping system. Yield advantage or yield reduction of intercropping system depends on complementary or competitive behavior of component crops (Spitters, 1983).

In the present study, cabbage have failed to get any complementary effects from radhuni, mouri, methi, kalizira and coriander and reduced the equivalent yield.

4.5.3 Intercropped crops equivalent yield with cabbage

Intercropped crops equivalent yield with cabbage was significantly influenced by different intercropping system (Table 6). Results showed that the highest intercropped crops equivalent yield with cabbage(15.31 t/ha) was recorded from cabbage + onion (T_7) treatment which was significantly different from all other treatments. On the other hand the lowest cabbage equivalent yield with intercropped crops (3.31 t/ha) was recorded from cabbage + mouri (T_3) intercropping system which was statistically identical with cabbage + methi (T_4) intercropping system.

4.5.4 Gross return

From the economic point of view, it was observed that intercropping of different combinations gave higher economic return than monoculture (Table 6). In the studied intercropping systems, cabbage + garlic (T_1) were more compatible than other intercropping system. It was observed that the highest gross return (Tk. 305160.00/ha) was achieved by cabbage + garlic (T_1) intercropping system. The second, third and fourth highest gross return were more or less same and that were Tk. 294480.00/ha, Tk. 293167.00/ha and Tk. 292400.00/ha obtained by cabbage + mouri (T_3), cabbage + methi (T_4) and cabbage + radhumi (T_2) intercropping system, respectively.On the other hand, the lowest gross return (Tk. 235053.00/ha) was achieved from sole treatment. But in intercropping treatment, the lowest (Tk. 247007.00/ha) was achieved in cabbage + onion intercropping system. These results agreed well with the findings of Haque*et al.* (2001) and Shah *et al.* (1991) where they found a higher gross return from intercropping systems than their corresponding sole crops.

Table 6: Effect of intercropping cabbage with other crops on intercropped yield performance by weight regarding pest infestation

Treatments	Relative yield of cabbage(t/ha)	Cabbage equivalent yield with intercropped crops	Intercropped equivalent yield with cabbage	Gross return(tk/ha)
T_1	1.08 a	63.50 a	5.74 b	305160
T_2	1.01 ab	59.34 c	4.69 c	292400
T_3	0.92 c	54.77 f	3.31 d	294480
T_4	0.93 c	54.68 f	3.45 d	293167
T_5	0.99 ab	58.15 d	5.38 b	277120
T_6	1.02 ab	60.29 b	5.82 b	283953
T_7	0.98 ab	57.82 e	15.31 a	247007
T_8	1.00 ab	--	--	235053
$LSD_{0.05}$	0.0682	1.037	1.009	--
CV(%)	6.34	7.28	6.55	

Figures in the same column accompanied by the same letter(s) are not significantly different at 5% level as per Least Significant Difference Test (LSD). Values are mean of three replications.

T_1 = Cabbage + garlic
T_2 = Cabbage + radhuni
T_3 = Cabbage + mouri
T_4 = Cabbage + methi
T_5 = Cabbage + kalizira
T_6 = Cabbage + coriander
T_7 = Cabbage + onion
T_8 = Sole cabbage (Control)

Price of cabbage, garlic, radhuni, mouri, methi, kalizira, coriander and onion was Tk. 4.00/kg, Tk. 60.00/kg, Tk. 120.00/kg, Tk. 160.00/kg, Tk. 130.00/kg, Tk. 170.00/kg, Tk. 150.00/kg and Tk. 18.00/kg respectively.

CHAPTER V

SUMMARY

A field experiment was carried out in the research farm of Sher-e-Bangla Agricultural University to find out the effect of intercropping on the insect pest infestation and their natural enemies of cabbage. The crop combinations were cabbage + garlic, cabbage + radhuni, cabbage + mouri, cabbage + methi, cabbage + kalizira, cabbage + coriander, cabbage + onion and sole cabbage. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications.

Significantly, the lowest number of insect pest was present (0.03, 0.12, 0.32, 0.60,1.20, 1.59, 2.15, 2.41 and 3.00 at 15, 22, 29, 36, 43, 50, 57, 64 and 71 DAT respectively) in cabbage with cabbage + garlic intercropping system. On the other hand, the highest number of insect pest (1.45, 1.52, 1.89, 2.48, 3.57, 4.24, 4.91, 5.33 and 6.73 at 15, 22, 29, 36, 43, 50, 57, 64 and 71 DAT respectively) was recorded in sole cabbag intercropping system the highest infestation was observed in Cabbage + mouri intercropping system.

In terms of percent reduction of infestation or presence of insect pest over control, the highest reduction of insect pest over control(97.89, 92.28, 83.08, 75.68, 66.40, 62.61, 56.20, 54.75 and 55.40 at 15, 22, 29, 36, 43, 50, 57, 64 and 71 DAT, respectively) was observed by Cabbage + garlic intercropping system where the lowest (23.83, 17.30, 14.45, 12.62, 9.37, 7.07, 9.16, 6.01 and 10.63 at 15, 22, 29, 36, 43, 50, 57, 64 and 71 DAT, respectively) was in Cabbage + mouri intercropping system.

Incidence of natural enemies by number, the highest result (0.98, 1.41, 1.75 and 2.18 at 50, 57, 64 and 71 DAT respectively) was obtained by Cabbage + garlic intercropping system. On the other hand, the lowest number of natural enemy (0.08, 0.13, 0.21 and 0.41 at 50, 57, 64 and 71 DAT, respectively) was present in cabbage + mouri intercropping system.

Significantly the lowest number of family of insect pest (2.21) was present in Cabbage + garlic intercropping system where the highest (7.15) was in sole cropping system. But in intercropping system Cabbage + mouri showed the highest number of insect pest family (5.87). However, the highest reduction on number of insect pest over control

(69.07%) was achieved by Cabbage + garlic intercropping system. On the other hand, the lowest reduction on number of insect pest over control (17.78%) was achieved by cabbage + mouri intercropping system.

Presence of family of natural enemy, the highest result (2.85) was obtained in Cabbage + garlic intercropping system where the lowest (1.05) was in sole cropping. But in intercropping treatments, Cabbage + mouri intercropping system showed the lowest result (1.46). However, the highest increase on number of family of natural enemy over control (64.29%) was achieved by Cabbage + garlic intercropping system where the lowest increase over control (14.64%) was achieved by Cabbage + mouri intercropping system.

In terms of yield performance, the highest cabbage yield (63.29 t/ha) was obtained in Cabbage + garlic intercropping system where the lowest cabbage yield (54.33 t/ha) was achieved by Cabbage + methi intercropping system. But in terms of intercropped crop yield the highest return (Tk. 76800.00/ha) was observed from mouri in Cabbage + mouri intercropping system where the lowest return (Tk. 16020.00/ha) was from onion in Cabbage + onion intercropping system.

Again, the highest relative yield (1.08 t/ha) was gained in Cabbage + garlic intercropping system where the lowest (0.93 t/ha) was in Cabbage + mouri intercropping system. The highest cabbage equivalent yield with intercropped crops (63.50 t/ha) was also obtained in Cabbage + garlic intercropping system but the lowest (54.68 t/ha) was found in Cabbage + methi intercropping system. In case of intercropped equivalent yield with cabbage, the highest performance (15.31 t/ha) was observed in Cabbage + onion intercropping system but the lowest (3.31 t/ha) was obtained in Cabbage + mouri intercropping system.

The highest gross return (Tk.305160.00/ha) was recorded from the Cabbage + garlic intercropping system followed by cabbage + mouri (Tk.294480.00/ha), cabbage + methi (Tk. 293167.00/ha) and cabbage + radhuni (Tk. 292400.00/ha). In sole cropping, the lowest gross return (Tk. 253053.00/ha) was observed followed by Cabbage + onion (gross return = Tk. 247007.00/ha) intercropping system.

CONCLUSION AND RECOMMENDATION

From the study, it may be concluded that incidence of insect pests of cabbage was less in intercropping. The abundance of natural enemies was also higher in intercropping systems. The total yield, relative yield, equivalent yield and gross return were higher in intercropping than sole cropping. The overall study revealed intercropping as an eco-friendly pest management practice for cabbage by which insect pest infestation may be reduced without use of any chemical insecticide. Considering the results of the present study, it also may be concluded that cabbage + garlic intercropping system was the best as compared to other intercropped combinations in reducing insect pests of cabbage and in increasing natural enemies, relative yield, cabbage equivalent yield and gross return.

Further study is recommended to assess the environment friendly management practices of important agricultural insect pests in various intercropping systems prevailing in different agro-ecosystem of Bangladesh.

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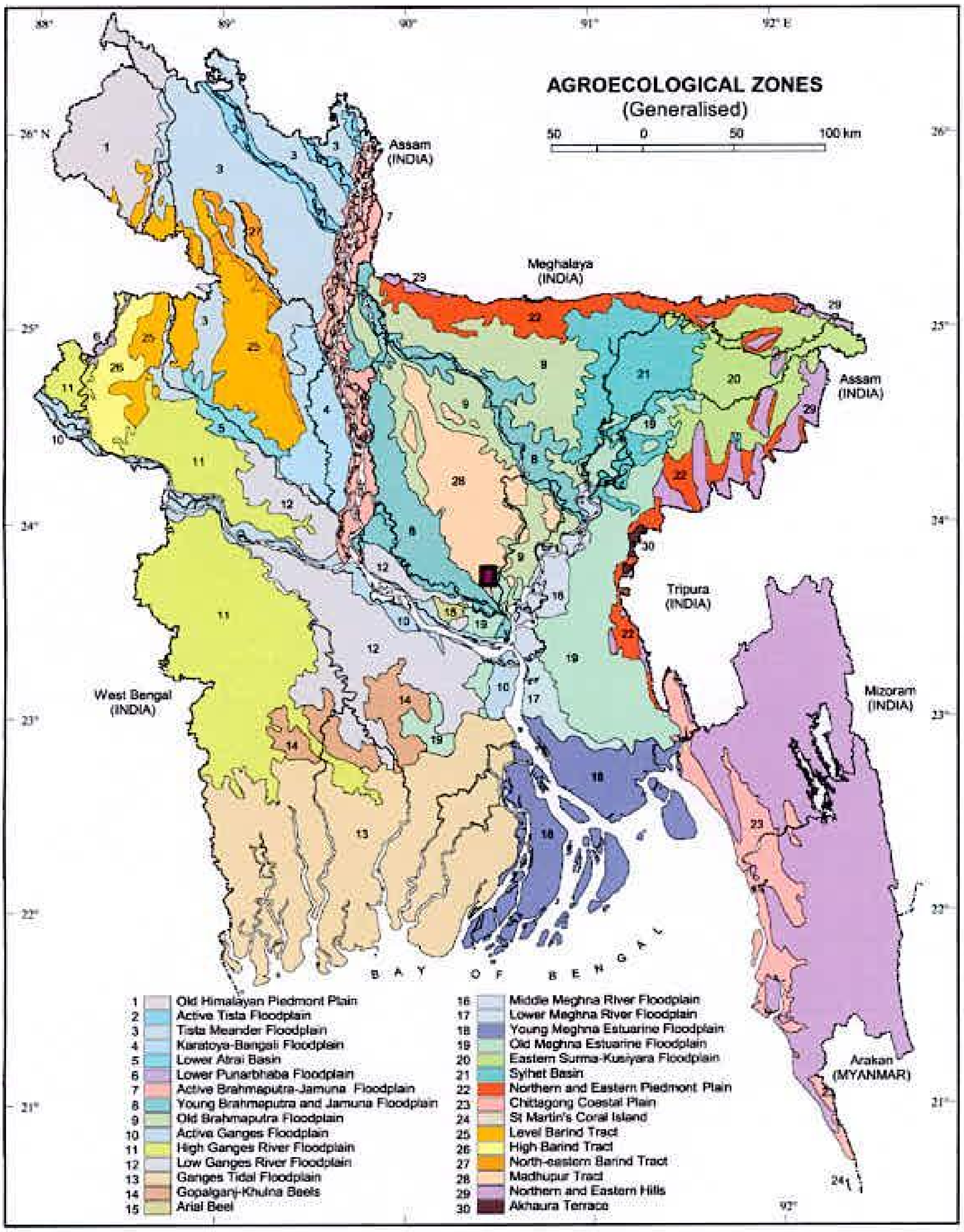
APPENDICES

Appendix I. Map showing the experimental sites under study



■ **The experimental site under study**

Appendix II. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from October 2009 to May 2010

Month	RH (%)	Max. Temp. (°C)	Min. Temp. (°C)	Rain fall (mm)
October	73.36	29.46	19.19	Terract
November	71.15	26.98	14.88	Terrace
December	68.30	25.78	14.21	Terace
January	69.53	25.00	13.46	0
February	50.31	29.50	18.49	0
March	44.95	33.80	20.28	11
April	69	33.6	23.6	163
May	71	32.4	27.2	134

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212

Appendix III: Physical characteristics and chemical composition of soil of the experimental plot.

Soil Characteristics	**Analytical results**
Agrological Zone	Madhupur Tract
P^H	5.47 – 5.63
Total N (%)	0.43
Available phosphorous	22 ppm
Exchangeable K	0.42 meq / 100 g soil

Appendix IV: Layout of the experiment

T_1	T_4	T_1
T_3	T_5	T_7
T_5	T_6	T_2
T_2	T_5	T_4
T_4	T_1	T_3
T_7	T_8	T_6
T_3	T_2	T_8
T_6	T_8	T_7