MANAGEMENT OF WHITEFLY, *BEMISIA TABACI* GENN. IN TOMATO BY INTERCROPPING

MD. ARIFUL ISLAM

DEPARTMENT OF ENTOMOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
SHER-E-BANGLA NAGAR
DHAKA- 1207, BANGLADESH

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BY

MD. ARIFUL ISLAM

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Approved by:

Prof. Dr. Mohammed Ali	**Prof. Dr. Md. Abdul Latif**
Supervisor	**Co-Supervisor**

Prof. Dr. Md. Razzab Ali

Chairman
Examination Committee

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka

CERTIFICATE

This is to certify that the thesis entitled, **"MANAGEMENT OF WHITEFLY, *BEMISIA TABACI* GENN. IN TOMATO BY INTERCROPPING"** submitted to the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in ENTOMOLOGY** embodies the results of a piece of bona-fide research work carried out by **MD. ARIFUL ISLAM**, **Registration No. 09-03746** under my supervision and guidance. No part of the thesis has been submitted to any where for any degree or diploma.

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

(Prof. Dr. Mohammed Ali)
Supervisor

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Place: Dhaka, Bangladesh

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SAU, Dhaka

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Abstract

A field experiment was conducted in the experimental field of Sher-e-Bangla Agriculture University to find out the effect of intercropping on the management of whitefly (*Bemisia tabaci* Genn.) in tomato (*Lycopersicon esculentum* Lin.) during November 2010 to April 2011. The crop combinations were tomato (*Lycopersicon esculentum* Lin.) + garlic (*Allium sativum*), tomato + radhuni (*Trachyspermum roxburghianum*), tomato + mouri (*Foeniculum vulgare*), tomato + methi (*Trigonella foenium-graecum*), tomato + radish (*Raphanus sativum*), tomato + coriander (*Coriandrum sativum*) and Sole tomato (control). The experiment was laid out in a Randomized Complete Block Design with three replications. Significantly, the lowest number of infested plant/plot ($5m^2$) (0.00, 0.67 and 1.67 at 40, 80 and 115 DAT respectively), lowest number of leaf curl infested plant/plot (0.67), lowest number of white fly/plant (2.67, 4.50 and 5.33 at 40, 80 and 115 DAT respectively), highest number of healthy plant/plot ($5m^2$) (12.00, 11.33 and 10.33 at 40, 80 and 115 DAT, respectively), highest number of total natural enemy/plant (3.33), highest healthy tomato yield (16.00 t/ha), lowest infested tomato yield (1.00 t/ha), highest total tomato yield (17.00 t/ha), highest relative yield (1.80 t/ha), highest tomato equivalent yield (17.69 t/ha) and highest gross return (Tk. 621600.00/ha) were recorded in tomato + garlic intercropping system. But in case of total number of other insect pest/plant the lowest (1.33) was achieved from Tomato + radhuni intercropping system. In terms of percent (%) reduction or increase over control, the highest reduction on number of infested plant/plot ($5m^2$) (100%, 83.25% and 74.96% at 40, 80 and 115 DAT respectively), number of white fly/plant (77.75%, 72.73% and 74.21% at 40, 80 and 115 DAT respectively), number of leaf curl infested plant/plot (81.74%), highest percent (%) increase of healthy plant/plot ($5m^2$) (28.62%, 41.63% and 93.81% at 40, 80 and 115 DAT respectively) and total number of natural enemy/plant (226.47%) over control were recorded in tomato + garlic intercropping system. As a result the treatment combination of tomato + garlic was the best treatment followed by tomato + methi, tomato + radhuni, tomato + mouri, tomato + radish and tomato +coriander where sole treatment (control) gave the lowest performance in turns of gross return.

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LIST OF ABBRIVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
^{o}C	=	Degree Centigrade
CV	=	Coefficient of Varience
DAS	=	Days after sowing
et al.	=	and others *(at elli)*
Kg	=	Kilogram
Kg/ha	=	Kilogram per hectare
g	=	gram(s)
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Metre
P^{H}	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
SE	=	Standard Error
TSP	=	Triple Super Phosphate
Ton/ha	=	ton per hectare
%	=	Percent

CHAPTER I

INTRODUCTION

Tomato *(Lycopersicon esculentum* Lin.), a member of the Solanaceae family, is one of the most widely grown vegetables. It outranks all others in terms of total contribution of vitamins and minerals to the diet, mainly because of the large volume consumed both in fresh and processed forms (Opena, 1987). It is one of the most important popular salad vegetables and used to make soups, conserves, pickles, ketchups, sauces, juices etc. It is also an excellent source of vitamin C and so commonly referred to as poor man's orange (Dash *et al.*, 1987).

The area under tomato in Bangladesh during the 2010 was 58.85 thousand hectares with a production of 190.21 thousand metric tons (BBS, 2010). The average yield of tomato in here is very low compared to world average or some other tomato growing countries. (Haque *et al.*, 2001).

The whitefly, *Bemisia tabaci* (Gennadius Homoptera: Aleyrodidae) feeds on a wide range of vegetables (Hirano *et al.*, 1993).Sucking of plant sap by large populations of whitefly nymphs and adults can greatly reduce the plant vigor.

Chlorotic spots appear at feeding sites on the leaf surface, followed by wilting and resulting leaf shedding. The viral disease, tomato yellow leaf curl virus (TYLCV), causing devastating damage to tomato is exclusively transmitted by it (Hinata, 1986). Astry and Sing (1973) estimated that 20-75% loss in tomato yield occured due to tomato leaf curl virus (TYLCV) disease in India.

Since tomato is a most important vegetable of the world and whitefly is a major pest of tomato, it should be controlled perfectly. By spraying chemical insecticide we can control whitefly but it has hazard on the human health and bad effect in the environment. That's why intercropping is one of the alternative ways to control whitefly.

Intercropping is the practice of growing two or more crops in close proximity. The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop. Careful planning is required, taking into account the soil, climate, crops, and varieties (Fackhnath, 1996). It is particularly important not to have crops competing with each other for physical space, nutrients, water, or sunlight. Examples of intercropping strategies are planting a deep-rooted crop with a shallow-rooted crop, or planting a tall crop with a shorter crop that requires partial shade. When crops are carefully selected, other agronomic benefits are also achieved. Lodging-prone plants, those that are prone to tip over in wind or heavy rain, may be given structural support by their companion crop (Trenbath, 1976). Delicate or light sensitive plants may be given shade or protection, or otherwise wasted space can be utilized. An example is the tropical multi-tier system where coconut occupies the upper tier, banana the middle tier, and pineapple, ginger, or leguminous fodder, medicinal or aromatic plants occupy the lowest tier. Intercropping of compatible plants also encourages biodiversity, by providing a habitat for a variety of insects and soil organisms that would not be present in a single crop environment. This biodiversity can in turn help to limit outbreaks of crop pests (Srinivasan, 1991) by increasing the diversity or abundance of natural enemies, such as spiders or parasitic wasps.

Increasing the complexity of the crop environment through intercropping also limits the places where pests can find optimal foraging or reproductive conditions. The degree of spatial and temporal overlap in the two crops can vary somewhat, but both requirements must be met for a cropping system to be an intercrop. Numerous types of intercropping, all of which vary the temporal and spatial mixture to some degree, have been identified (Andrews and Kassam, 1976).

These are some of the more significant types: Mixed intercropping, as the name implies, is the most basic form in which the component crops are totally mixed in the available space. Row cropping involves the component crops arranged in alternate rows. This may also be called alley cropping. A variation of row cropping is strip cropping, where multiple rows, or a strip, of one crop are alternated with multiple rows of another crop.

Considering the above facts view in mind, the experiment has been undertaken with the following objectives:

- To study the infestation status of tomato at different growth stages in sole and intercropped conditions,
- To study the effects of intercropping on the yield and economic return and
- To study the best intercropping system combination in respect of the highest return from tomato cultivation.

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.

Yin-Xian 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 (TLCV) 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. 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 TYLCV. Whitefly adults hold the highest population during January 2010 in the field. The population of whitefly larvae 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 soyabean were the preferred hosts of whiteflies.

Bird and Kruger (2009) studied the behaviour of *Bemisia tabaci* females to establish whether this taxon showed reduced feeding and fecundity when exposed to different crops (mixed crops; tomato, bean and cucumber) or different tomato cultivars (mixed cultivars) 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 *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 (Wi11ey, 1985).

2.2 Relationship between intercropping with insect: Experimental

evidences

2.2.1 Insect pests

Murugan (2009) conducted a field experiment at Paiyur, Tamil Nadu, India, to study the effects of intercropping on pest and disease incidence and on the yield of tomato cv. PKM1. *Cyamopsis tetragonoloba* cv. Pusa Cluster, green gram cv. Paiyur 1, and Indian mustard cv. Seetha were sown as intercrops after every second row of tomato (2:1). Neem seed kernel extract (5%) and monocrotophos (0.07%) were sprayed at 30 days after transplanting and at the time of maximum flowering and fruit set. The occurrence of tomato spotted wilt virus (TSWV) was recorded at 60 and 90 days after transplanting (DAT) while the incidence of leaf curl virus (LCV) was determined at 30, 60, and 90 DAT. Intercropping reduced pest and disease occurrence and increased the yield of tomato. Tomato intercropped with Indian mustard had the lowest incidence of *Bemisia tabaci* and *Thrips tabaci* at 30, 45, and 60 DAT; *Helicoverpa armigera* at 60, 75, 90, 105, and 120 DAT; TSWV (2.54 and 8.34% under irrigated and rainfed conditions, respectively) at 60 and 90 DAT; and LCV (5.42 and 7.97%) at 30, 60, and 90 DAT. Intercropping with Indian mustard also gave the highest yield (15 and 7.810 t/ha of undamaged fruits) and net returns (Rs. 7080 and 12400/ha). The highest incidence of TSWV and LCV was observed from August to December 1999. Damage due to TSWV and LCV was 45-60% higher in sole tomato (30% damage) than in tomato intercropped with Indian mustar.

Saha *et al*. (2008) observed that 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 2006-07. 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.

Saha *et al*. (2006) conducted an investigation in Uttar Pradesh, India to determine the effect of intercropping and spacing of lentils (cv. HU-4-11) and tomatoes (cv. Pusa Ruby) on the incidence of infestation during the winter season of 2005-06. Treatments comprised: three spacings (30, 45 and 60 cm), sole lentil, sole tomato and two ratios of lentils:tomatoes (1:1 and 2:1). Tomato fruit borer (*Helicoverpa armigera*) heavily infested sole tomato plots compared to all intercrop treatments. The borer population was also found on sole lentil plots but was less than that on sole tomato plots. The fruit borer population was, more or less, similar in all intercropped plots even in the sole lentil plot. Both black aphid (*Aphis craccivora*) and jassid (*Amrasca bigutulla*) showed the highest populations in the sole tomato plot. Their populations were higher on sole lentil but were less than tomato. Their populations were significantly below the damaging level in all intercropped treatments at different ratios and spacings. The black aphid population in intercropped plots varied from 10.1 to 10.9 and the population of jassid varied from 2.8 to 3.4. However, in sole tomato plots, the black aphid and jassid populations were 32.6 and 10.9, while in sole lentil, the populations were 22.6 and 9.7, respectively. The sole crop of lentil was less infested by the fruit borer throughout the cropping season.

Kandoria *et al*. (2005) carried out a trials in Indian Punjab, India, during November to March 2003-04, found that planting one row of late season cauliflower (Snowball 16) with one row of main season tomato (Punjab Kesri) significantly reduced the incidence of diamondback moth *Plutella xylostella* when the cauliflower was planted 30 days after the tomato.

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 intermittenly. 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 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 during the period from November 2010 to March 2011. The materials and methods used for conducting the experiment are presented under the following headings:

3.1 Experimental site

The experiment was conducted at the Agronomy Farm, 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.

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 period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix I.

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 II.

3.4 Treatments

Combination of tomato, garlic, radhuni, mouri, methi, radish and coriander constitute the intercropping systems.

The intercropping treatments were

(1) T_1 = Intercropping tomato with garlic (Tomato + garlic)

(2) T_2 = Intercropping tomato with Radhuni (Tomato + radhuni)

(3) T_3 = Intercropping tomato with Mouri (Tomato + mouri)

(4) T_4 = Intercropping tomato with Methi (Tomato + methi)

(5) T_5 = Intercropping tomato with Radish (Tomato + radish)

(6) T_6 = Intercropping tomato with Coriander (Tomato + coriander)

(7) T_7 = Sole tomato (Control)

The pictorial views of the treatments are as follows:

Plate 1. Intercropping tomato with garlic

Plate 2. Intercropping tomato with

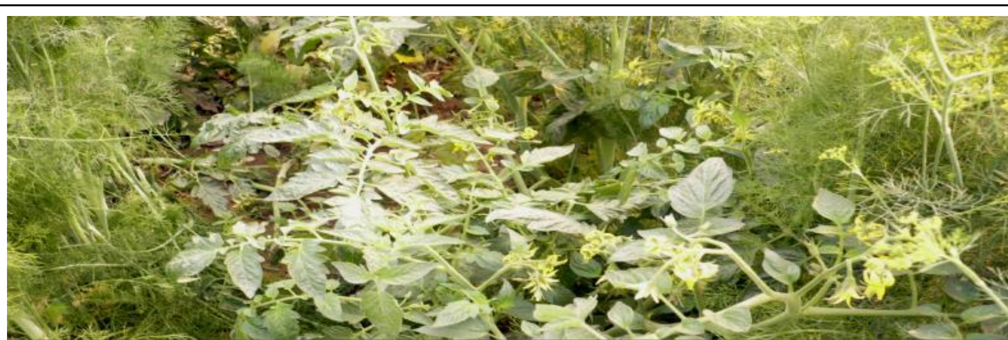

Plate 3. Intercropping tomato with

Plate 4. Intercropping tomato with methi

Plate 5. Intercropping tomato with

Plate 6. Intercropping tomato with

Plate 7. Sole tomato (Control)

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 2.5m × 2m. The distance between plots and blocks was 1m and 1m respectively. Plant to plant and row to row distance for tomato was 50 cm. But for garlic, radhuni, mouri, methi, radish and coriander row to row distance was 30cm and plant to plant distance was 15 cm. In case of intercropping, bulbs of garlic and seed of radhuni, mouri, methi, radish and coriander were sown in an alternate row arrangement.

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 Plant materials

3.7.1 Major crop: Tomato (*Lycopersicum esculentum Lin.*) considered as major crop under the present study.

3.7.2 Intercropped crops: Garlic, Radhuni, Mouri, Methi, Radish and Coriander were considered as intercropped crops.

3.8 Seed source and transplanting

The tomato seeds were tomato seeds were collected from Karwanbazar, coriander from Kustia Seed Vander, Mirpur, Garlic, Methi from Agargaon bazaar and Radhuni, Mouri seed were collected from Farm Section of Sher-E-Bangla Agriculture University, Dhaka. Tomato seeds were sown in seed bed on 1st November 2010. Tomato seedlings were transplanted in sole and in intercrop on 24 November 2010. After establishment of tomato, the intercrops were sown/transplanted in between the tomato lines.

3.9 Cultural practices

Damaged seedlings of tomato were replaced immediately by new ones in the experimental field. Weeding and mulching were done at 30, 50, 70 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.

3.10 Data collection

1. Number of infested plant/plot
2. Number of healthy plant/plot
3. Number of whitefly/plant
4. Number of other pests/plant
5. Number of natural enemy/plant
6. Weight of infested and healthy tomato (kg)
7. Weight of intercropped seed (kg)

3.11 Procedure of recording data

1. **Number of infested plant/plot**

   Total number of infested plant was counted at 40, 80 and 115 DAT from each replication.

2. **Number of healthy plant/plot**

Total number of healthy plant was counted at 40, 80 and 115 DAT from each replication.

3. Number of whitefly/plant

Number of white fly was counted from randomly selected five plants at 40 days interval started at 40 DAT to 115 DAT and then averaged to whitefly/plant. Number of insect was measured by Pitfall trap method and Sweeping net method in the morning.

4. Number of other pest/plant

Number of other pest was counted from randomly selected five plants at 40 days interval started at 40 DAT to 115 DAT and then averaged to number of other pest/plant. Number of insect was measured by Pitfall trap method and Sweeping net method.

5. Number of natural enemy

Number of natural enemy was counted from randomly selected five plants at 40 DAT to 115 DAT and then averaged to number of natual enemy/plant. Number of natural enemy was measured by Pitfall trap and Sweeping net method.

6. **Yield of tomato**

Yield/plant was measured 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. Healthy and infested fruit was separated and separated yield was measured.

7. **Yield of intercropped crops**

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

8. **Percent reduction over control**

The following formula was used to calculate Percent reduction over control

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

9. **Percent increase over control**

The following formula was used to calculate Percent increase over control

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

Value of sole crop (tomato)

3.12 Measurement of the incidences of whitefly, other insect pests and natural enemies

There were two methods were used to count the number of whitefly, other insect pest and natural enemy during the present study

3.12.1 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 dept. of Entomology, SAU and other standard taxonomic keys. Data were recorded against each treatment.

The insects that were collected with this method were whitefly, stink bug and flea beetles. Here it was also mentioned that whitefly was more in number but stink but and flea beetles were minor in number. With this method, epilachna beetle, ladybird beetle and wasp was also identified as natural enemies in the crop field.

3.12.2 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 return 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.

The insects that were collected with this method were whitefly, aphids, vegetable leaf miner and flea beetles. Here it can be mentioned that white fly was more in number but aphids, vegetable leaf miner and flea beetles were minor in number. With this method, epilachna beetle, lady bird beetle and wasp was also identified as natural enemy in the crop field.

3.13 Harvesting and yield of the crops

Tomato: Tomato was harvested when fruit of a plant was matured completed. At each harvest, data was taken by weight and recorded separately per plot. The cumulative tomato yield per plot was calculated.

Garlic: Garlic was harvested 115 days after transplanting. The harvested bulb of garlic was 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 115 days of sowing. The harvested Radhuni, Mouri, Methi and coriander was threshed manually and seeds were separated, clean and dried in bright sunshine. The dried seed yield thus obtained was converted into per hectare yield.

Radish: Radish was harvested when its maturation was completed. At each harvest, data was taken by weight and recorded separately per plot. The cumulative radish yield per plot was calculated.

3.14 Relative yield of tomato

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

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

3.15 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 (Anjaneyulu *et a1*., 1982) as follows:

i) Tomato equivalent yield for garlic = $Y_t + \dfrac{Y_g \times P_g}{P_t}$

ii) Garlic equivalent yield for tomato = $Y_g + \dfrac{Y_t \times P_t}{P_g}$

iii) Tomato equivalent yield for radhuni = $Y_t + \dfrac{Y_r \times P_r}{P_t}$

iv) Radhuni equivalent yield for tomato = $Y_r + \dfrac{Y_t \times P_t}{P_r}$

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

vi) Mouri equivalent yield for tomato = $Y_{mo} + \dfrac{Y_t \times P_t}{P_{mo}}$

vii) Tomato equivalent yield for methi = $Y_t + \dfrac{Y_{me} \times P_{me}}{P_t}$

viii) Methi equivalent yield for tomato = $Y_{me} + \dfrac{Y_t \times P_t}{P_{me}}$

ix) Tomato equivalent yield for radish = $Y_t + \dfrac{Y_{ra} \times P_{ra}}{P_t}$

x) Radish equivalent yield for tomato = $Y_{ra} + \dfrac{Y_t \times P_t}{P_{ra}}$

xi) Tomato equivalent yield for coriander = $Y_t + \dfrac{Y_{co} \times P_{co}}{P_t}$

xii) Coriander equivalent yield for tomato = $Y_{co} + \dfrac{Y_t \times P_t}{P_{co}}$

Where, Y_t = Yield of tomato in intercrop (t/ha); Y_g = Yield of garlic in control, 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_{ra} = Yield of radish in intercrop (t/ha); Y_{co} = Yield of coriander in intercrop (t/ha); P_t = Price of tomato 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_{ra} = Price of radish in intercrop (Tk./ha); P_{co} = Price of coriander in intercrop (Tk./ha) and P_o = Price of onion in intercrop (Tk./ha).

3.16 Statistical analysis

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

CHAPTER IV

RESULTS AND DISCUSSION

The results on the effect of intercropping systems with tomato + garlic, tomato + radhuni, tomato + mouri, tomato + methi, tomato + radish and tomato + coriander compared to its monoculture on insect pests and their natural enemy complex are presented and discussed under the following sub headings.

4.1 Incidence of whitefly in intercropping

4.1.1 Number of plants affected by whiteflies

Tomato plants and with intercropped crops were greatly influenced by the presence of whitefly that harm cropping system. Results under the present study showed that significant variation was observed in terms of affected plants by whitefly at different growth stages of tomato (Table 1). Results showed that the lowest number of affected plants/plot (0.00, 0.67 and 1.67 at 40, 80 and 115 DAT, respectively) was recorded in tomato + garlic (T_1) intercropping system which was very closely (0.66, 2.00 and 2.67 at 40, 80 and 115 DAT respectively) to tomato + radhuni (T_2) intercropped combination. On the other hand, the highest number of affected plants/plot (2.67, 4.00 and 6.67 at 40, 80 and 115 DAT respectively) caused by whitefly was recorded in sole tomato (T_7). It was also observed that the second highest number of affected plant (1.67, 3.00 and 4.33 at 40, 80 and 115 DAT respectively) by whitefly was found in tomato + radishes (T_5) crop combination system but significantly lower than sole cropping (T_7).

The lower presence of whitefly in number in tomato and garlic intercropped field (T_1) might be due to cause of garlic crop, because garlic has pungent smell and that might be cause of reduced whitefly. The other intercrops under the present study had also different smell and reduced number of whitefly also found with these treatments, but garlic was more effective compared to others for protection of whitefly.

Table 1.Effect of intercropping tomato with other crops on the number of infestedplants plot^{-1} by whitefly during the cropping period

Treatments	**Number of infested plant plot^{-1}**		
	40 DAT	**80 DAT**	**115 DAT**
T_1	0.00 e	0.67 f	1.67 f
T_2	0.66 d	2.00 e	2.67 e
T_3	1.33 c	2.33 d	3.33 cd
T_4	1.33 c	2.11 de	3.11 d
T_5	1.67 b	3.00 b	4.33 b
T_6	1.33 c	2.67 c	3.57 c
T_7	2.67 a	4.00 a	6.67 a
$LSD_{0.05}$	0.236	0.2443	0.2684
CV (%)	7.842	8.936	8.142
SE	0.056	0.084	0.108

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).

T_1 = Tomato + garlic

T_2 = Tomato + radhuni

T_3 = Tomato + mouri

T_4 = Tomato + methi

T_5 = Tomato + radish

T_6 = Tomato + coriander

T_7 = Sole tomato (Control)

4.1.2 Percent reduction of affected plants by number over control

Significant reduction of infestation affected by whitefly over sole crop was observed with different crop combinations under the intercropping system of the present study (Table 2). Effective reduction of infested plant by whitefly was achieved but gradually decreased trend was found during whole cropping period. Results showed that the highest reduction (100%, 83.25% and 74.96% at 40, 80 and 115 DAT respectively) of affected plant was maintained by tomato + garlic (T_1) intercropping system. The second highest performance was observed by tomato + radhuni (T_2) crop combination (75.28%, 50.00% and 59.97% at 40, 80 and 115 DAT respectively) but significantly different from tomato + garlic (T_1) intercropping system. On the other hand, the lowest reduction of plant infestation by whitefly over control (37.45%, 25.00% and 35.08% at 40, 80 and 115 DAT respectively) was gained by tomato + radishes (T_5) crop combination. The crop combination of tomato + mouri (T_3), tomato + methi (T_4) and tomato + coriander (T_6) also showed lower reduction of affected plant by whitefly but significantly different from tomato + garlic (T_1) intercropping system.

4.1.3 Number of uninfested plants

Tomato plants and with intercropped crops were greatly influenced by presence of whitefly that harm cropping system. Result under the present study showed that significantly variation was observed in terms of healthy plants at different growth stages of tomato (Table 3). Results showed that the highest number of healthy plants/plot (12.00, 11.33 and 10.33 at 40, 80 and 115 DAT respectively) was recorded in tomato + garlic (T_1) intercropping system. Tomato + radhuni (T_2) intercropped combination also showed comparatively higher number of healthy plants/plot (11.34, 10.00 and 9.33 at 40, 80 and 115 DAT, respectively) but significantly different from tomato + garlic (T_1) intercropping system. On the other hand, the lowest number of healthy plants/plot (9.33, 8.00 and 5.33 at 40, 80 and 115 DAT respectively) was recorded in sole tomato (T_7). It was also observed that the results from other treatments gave intermediate results compared to highest and lowest healthy plants/plot. The results obtained from the present study, might be due to cause of garlic; treated as intercrop that gave the best result because of its pungent smell and that cause reduced number of whitefly and more healthy plants in the crop field.

Table 2. Effect of intercropping tomato with other crops on percent reduction of infested plant plot^{-1}by number over control during cropping period

Treatments	Percent reduction of infested plantplot^{-1} by number overcontrol		
	40 DAT	**80 DAT**	**115DAT**
T_1	100.00 a	83.25 a	74.96 a
T_2	75.28 b	50.00 b	59.97 b
T_3	50.19 c	41.75 d	50.07 c
T_4	50.19 c	47.25 c	53.37 c
T_5	37.45 d	25.00 f	35.08 e
T_6	50.19 c	33.25 e	46.48 d
T_7	--	--	--
$LSD_{0.05}$	4.863	3.892	4.784
CV (%)	6.188	8.326	7.855
SE	0.0752	0.0686	0.0844

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).

T_1 = Tomato + garlic

T_2 = Tomato + radhuni

T_3 = Tomato + mouri

T_4 = Tomato + methi

T_5 = Tomato + radish

T_6 = Tomato + coriander

T_7 = Sole tomato (Control)

Table 3. Effect of intercropping tomato with other crops on the number of uninfested plantsplot^{-1} with the incidence of whitefly during cropping period

	Number of uninfested plants plot^{-1}

Treatments	40 DAT	80 DAT	115 DAT
T_1	12.00 a	11.33 a	10.33 a
T_2	11.34 b	10.00 b	9.33 b
T_3	10.67 c	9.67 cd	8.67 cd
T_4	10.67 c	9.89 c	8.89 c
T_5	10.33 d	9.00 e	7.67 e
T_6	10.67 c	9.33 d	8.43 d
T_7	9.33 e	8.00 f	5.33 f
$LSD_{0.05}$	0.144	0.272	0.264
CV (%)	5.854	7.186	8.462
SE	0.084	0.122	0.088

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).

T_1 = Tomato + garlic

T_2 = Tomato + radhuni

T_3 = Tomato + mouri

T_4 = Tomato + methi

T_5 = Tomato + radish

T_6 = Tomato + coriander

T_7 = Sole tomato (Control)

4.1.4 Percent increase of uninfested plants by number over control

Significant increase of healthy plants over sole crop was observed with different crop combinations under the intercropping system of the present study (Table 4). Effective increase of healthy plant was achieved and gradually increased trend was found during whole cropping period. Results showed that the highest increase (28.62%, 41.63% and 93.81% at 40, 80 and 115 DAT, respectively) of healthy plant was maintained by tomato + garlic (T_1) intercropping system. The second highest performance was observed by tomato + radhuni (T_2) crop combination (21.54%, 25.00% and 75.05% at 40, 80 and 115 DAT respectively) which was significantly different from tomato + garlic (T_1) intercropping system. But the lowest increase of healthy plant over control (10.72%, 12.50% and 43.90% at 40, 80 and 115 DAT respectively) was obtained by tomato + radishes (T_5) crop combination. The crop combination of tomato + mouri (T_3), tomato + methi (T_4) and tomato + coriander (T_6) also showed encouraging result but regarding percent (%) increase of healthy plant/plot but significantly different from tomato + garlic (T_1) intercropping system.

4.1.5 Presence of whiteflies as affected by intercropping system

Presence of whitefly in the crop field affected the intercropping system significantly under the present study (Table 5). Result showed that significant variation was observed in terms of presence of whitefly at different growth stages of tomato. It was observed that the lowest number of whitefly/plant (2.67, 4.50 and 5.33 at 40, 80 and 115 DAT respectively) recorded from 5 tomato plants in tomato + garlic (T_1) intercropping. On the other hand, the highest number of whitefly/plant (12.00, 16.50 and 20.67 at 40, 80 and 115 DAT respectively) was recorded in sole tomato (T_7). Comparatively higher number of whitefly in tomato was also found in tomato + radish (T_5) and tomato + coriander (T_6) crop combination but significantly lower than sole cropping (T_7).The results from other intercropped combinations (tomato + radhuni; T_2, tomato + mouri; T_3 and tomato + methi, T_4) showed intermediate results compared to the highest and lowest presence of whitefly. Among all the intercropped treatments, Tomato + garlic showed the best result because it might be due to its repellent characters for whitefly under the present study.

Table 4. Effect of intercropping tomato with other crops on percent increase of by uninfested plant plot^{-1} by number over control during cropping period

Treatments	**percent increase of uninfested plantplot^{-1} by number over control**		
	40 DAT	**80 DAT**	**115DAT**
T_1	28.62 a	41.63 a	93.81 a
T_2	21.54 b	25.00 b	75.05 b
T_3	14.36 c	20.88 d	62.66 d
T_4	14.36 c	23.63 c	66.79 c
T_5	10.72 d	12.50 f	43.90 f
T_6	14.36 c	16.63 e	58.16 e
T_7	--	--	--
$LSD_{0.05}$	3.792	2.788	4.384
CV (%)	6.854	6.884	7.366
SE	0.247	0.185	0.206

Figures in the same columnaccompanied by the same letter(s) are not significantly different at 5% level as per Least Significant Difference test (LSD).

T_1 = Tomato + garlic

T_2 = Tomato + radhuni

T_3 = Tomato + mouri

T_4 = Tomato + methi

T_5 = Tomato + radish

T_6 = Tomato + coriander

T_7 = Sole tomato (Control)

Table 5. Effect of intercropping tomato with other crops on the incidence of whitefly during thecropping period

Treatments	Presence of whiteflyplant^{-1} by number		
	40 DAT	80 DAT	115DAT
T_1	2.67 f	4.50 g	5.33 g
T_2	5.50 e	6.33 f	8.50 f
T_3	6.83 d	8.50 d	12.00 d
T_4	6.50 d	7.67 de	10.33 e
T_5	8.33 b	10.83 b	14.50 b
T_6	7.33 c	9.67 c	13.67 c
T_7	12.00 a	16.50 a	20.67 a
$LSD_{0.05}$	0.843	1.146	0.764
CV (%)	7.784	7.266	6.843
SE	0.048	0.126	0.142

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).

T_1 = Tomato + garlic

T_2 = Tomato + radhuni

T_3 = Tomato + mouri

T_4 = Tomato + methi

T_5 = Tomato + radish

T_6 = Tomato + coriander

T_7 = Sole tomato (Control)

4.1.6Percent reduction of whitefly over control

Intercropping system significantly reduced whitefly over sole crop. Effective percent reduction of whitefly was found during whole cropping period (Table 6). Results showed that the highest reduction (77.75%, 72.73% and 74.21% at 40, 80 and 115 DAT respectively) was maintained by tomato + garlic (T_1) intercropping system. Tomato + radhuni (T_2) also gave promising performance (54.17%, 61.64% and 58.88% at 40, 80 and 115 DAT respectively). But the lowest reduction of whitefly over control (30.58%, 34.36% and 29.85% at 40, 80 and 115 DAT respectively) was gained by tomato + radish (T_5) crop combination. The crop combination of tomato + corander (T_6) also showed lower reduction percentage of whitefly but slightly higher than that of tomato + radish (T_5) combination.

Table 6. Effect of intercropping tomato with other crops on percent reduction of whiteflyover control during cropping period

Treatments	**Percent of reduction of whitefly over control**		
	40 DAT	**80 DAT**	**115 DAT**
T_1	77.75 a	72.73 a	74.21 a
T_2	54.17 b	61.64 b	58.88 b
T_3	43.08 c	48.48 d	41.94 d
T_4	45.83 c	53.52 c	50.02 c

T_5	30.58 d	34.36 f	29.85 f
T_6	38.92 e	41.39 e	33.86 e
T_7	--	--	--
$LSD_{0.05}$	4.367	4.649	3.689
CV (%)	8.644	7.924	8.266
SE	0.236	0.146	0.188

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).

T_1 = Tomato + garlic

T_2 = Tomato + radhuni

T_3 = Tomato + mouri

T_4 = Tomato + methi

T_5 = Tomato + radish

T_6 = Tomato + coriander

T_7 = Sole tomato (Control)

4.2 Incidence of other insect in intercropping

4.2.1 Presence of other insect

Presence of other insects in the crop field affected the intercropping system significantly under the present study (Table 7). Various kinds of other insect pest were found in the crop field. Stink bug, aphids, vegetable leaf miner and flea beetles were found as other insect pest.

Result showed that significant variation was observed in terms of presence of other insects at different growth stages of tomato. It was observed that the lowest number of other insects/plant (1.33) was recorded from tomato+ radhuni (T_2) intercropping. On the other hand, the highest number of other insects/plant (7.33) was recorded in sole tomato (T_7). Comparatively higher number of other insects/plant (5.33) was found in tomato + radish (T_5) where comparatively lower number of other insects/plant (2.67) was found in tomato + garlic (T_1). The results from other intercropped combinations (tomato + mouri; T_3 and tomato + methi, T_4) showed intermediate results compared to the highest and lowest presence of other insects. Lower presence of other insect pest in tomato + radhuni crop field might be due to cause of special flavor which helps to prevent such type of insects.

4.2.2 Percent reduction of other insects over control

Intercropping system significantly reduced other insects over sole crop. Effective percent (%) reduction of other insects was found during whole cropping period (Table 7). Results showed that the highest reduction (81.86%) was maintained by tomato + radhuni (T_2) intercropping system. Tomato + garlic (T_1) also gave promising performance (63.57%). But the lowest reduction of other insects over control (27.27%) was obtained by tomato + radish (T_5) crop combination. The crop combination of tomato + coriander (T_6) also showed lower reduction percentage (38.61%) of other insects but slightly higher than that of tomato + radish (T_5) combination.

Table 7. Effect of intercropping tomato with other crops on the incidence of other pest except whitefly during cropping period

Treatments	Incidenceof other insect pestsplant^{-1}	
	Incidence of other insect pests by number	**Percent reduction of other insect pests over control by number**
T_1	2.67 f	63.57 b
T_2	1.33 g	81.86 a
T_3	3.67 d	49.93 d
T_4	3.00 e	59.07 c
T_5	5.33 b	27.29 f
T_6	4.50 c	38.61 e
T_7	7.33 a	--
$LSD_{0.05}$	0.289	3.947
CV (%)	5.842	5.886
SE	0.228	0.264

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).

T_1 = Tomato + garlic
T_2 = Tomato + radhuni
T_3 = Tomato + mouri
T_4 = Tomato + methi
T_5 = Tomato + radish
T_6 = Tomato + coriander
T_7 = Sole tomato (Control)

4.3 Presence of natural enemy

4.3.1 Presence of natural enemy by number

Presence of natural enemy in the crop field influenced the intercropping system significantly under the present study (Table 8). Mainly, lady bird beetle and wasp were found in the crop field as natural enemy. Result showed that significant variation was observed in terms of presence of natural enemy at different growth stages of tomato. It was observed that the highest number of natural enemy/plant (3.33) was recorded in tomato + garlic (T_1) intercropping which was closely followed by tomato + radhuni (T_2) intercropped combination (3.06). On the other hand, the lowest number of natural enemy/plant (1.02) was recorded in sole tomato (T_7) which was closely followed by tomato + radish (T_5). The results from other intercropped combinations (tomato + mouri; T_3, tomato + methi; T_4 and tomato + coriander; T_6) showed intermediate results compared to the highest and lowest presence of natural enemy.

4.3.2 Percent increase of natural enemy over control

Intercropping system significantly increased natural enemy over sole crop. Effective percent (%) increase of natural enemy was found during whole cropping period (Table 8). Results showed that the highest increase (226.47%) was maintained by tomato + garlic (T_1) intercropping system. Tomato + radhuni (T_2) also gave promising performance (200.00%). But the lowest percent increase of natural enemy over control (82.35%) was obtained by tomato + radish (T_5) crop combination. The crop combination of tomato + mouri; T_3, tomato + methi; T_4 and tomato + coriander; T_6 gave intermediate results compared to highest and lowest percent increase of natural enemy.

Table 8. Effect of intercropping tomato with other crops on the incidence of other pest except whitefly during cropping period

Treatments	Presence of natural enemies by number	
	Presence of natural enemy by number	Percent increase of natural enemy over control by number
T_1	3.33 a	226.47 a
T_2	3.06 ab	200.00 b
T_3	2.50 c	145.10 d
T_4	2.67 c	161.76 c
T_5	1.86d	82.35 f
T_6	2.50 c	145.10 e
T_7	1.02 e	--
$LSD_{0.05}$	0.3264	6.849
CV (%)	6.594	7.332
SE	0.098	0.248

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).

T_1 = Tomato + garlic

T_2 = Tomato + radhuni

T_3 = Tomato + mouri

T_4 = Tomato + methi

T_5 = Tomato + radish

T_6 = Tomato + coriander

T_7 = Sole tomato (Control)

4. 4 Leaf curl infestation

4.4.1 Leaf curl infestation/ plot by number

Leaf curl infestation/plot by number was significantly influenced by different intercropping system (Table 9). Result showed that the lowest number of infested plant/plot (0.67) was recorded from tomato + garlic (T_1) intercropping. Tomato + radhuni (T_2) also showed better performance (1.33) compared to other intercrop combinations. On the other hand, the highest number of infested plant/plot (3.67) was recorded in sole tomato (T_7). But in the intercropping treatments (without sole crop), tomato + radish (T_5) showed the highest (3.00) infestation. The results from other intercropped combinations (tomato + mouri; T_3 and tomato + methi;T_4) showed intermediate results compared to the highest and lowest leaf curl infestation. The best performance, obtained from tomato + garlic (T_1) might be due to cause of its repellent character.

4.4.2 Percent reduction of other insects over control

Intercropping system significantly reduced leaf curl infestation/plot (Table 9). Effective percent reduction of leaf curl infestation/plot was found during whole cropping period. Results showed that the highest reduction (81.74%) was maintained by tomato + garlic (T_1) intercropping systemtomato + radhuni (T_2) also gave promising performance (63.76%). But the lowest reduction of leaf curl infestation/plot over control (18.26%) was obtained by tomato + radish (T_5) crop combination.

Table 9. Effect of intercropping tomato with other crops on the leaf curl infestation during cropping period

	Leaf curl infested plant plot^{-1}

Treatments	**Leaf curl infested plant plot^{-1} by number**	**Percent reduction of leaf curl infested plant plot^{-1} over the control by number**
T_1	0.67 f	81.74 a
T_2	1.33 e	63.76 b
T_3	2.67 c	27.25 d
T_4	2.67 c	27.25 d
T_5	3.00 b	18.26 e
T_6	2.33 d	36.51 c
T_7	3.67 a	--
$LSD_{0.05}$	0.024	5.349
CV (%)	6.594	7.332
SE	0.078	0.028

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).

T_1 = Tomato + garlic

T_2 = Tomato + radhuni

T_3 = Tomato + mouri

T_4 = Tomato + methi

T_5 = Tomato + radish

T_6 = Tomato + coriander

T_7 = Sole tomato (Control)

4.5 Yield performance of tomato

4.5.1 Weight of healthy fruit

Considerable effect was observed on healthy fruit yield of tomato as affected by intercropping treatments (Table 10). It was observed that highest healthy tomato yield (8.00/plot kg i.e. 16 t/ha) was performed by tomato + garlic (T_1) intercropping system where the lowest healthy fruit yield (2.33 kg/plot i.e. 4.66 t/ha) of tomato was found in control treatment (T_7). The results from tomato + radhuni; T_2, tomato + mouri; T_3, tomato + methi, T_4 and tomato + coriander; T_6 gave intermediate results compared to highest and lowest healthy fruit yield of tomato.

4.5.2 Weight of infested fruit

Significant effect was observed on infested fruit yield of tomato as affected by intercropping treatments (Table 10). It was observed that lowest infested tomato yield (0.50 kg/plot i.e. 16 t/ha) was performed by tomato + garlic (T_1) intercropping system where the highest infested fruit yield (2.40 kg/plot i.e. 4.80 t/ha) of tomato was found in control treatment (T_7). The results from tomato + radhuni; T_2, also gave lower infested fruit yield and tomato + mouri; T_3, tomato + methi, T_4 and tomato + coriander; T_6 gave intermediate results compared to highest and lowest infested fruit yield of tomato.

4.5.3 Weight of total fruit

Considerable effect was observed on total tomato yield as affected by intercropping treatments (Table 10). It was observed that highest total yield of tomato (8.50 kg/plot i.e. 17 t/ha) was performed by tomato + garlic (T_1) intercropping system. On the other hand the lowest total fruit yield (4.73 kg/plot i.e. 9.46 t/ha) of tomato was found in control treatment (T_7). The results from tomato + radhuni; T_2, tomato + mouri; T_3, tomato + methi, T_4 and tomato + coriander; T_6 gave intermediate results compared to highest and lowest total fruit yield of tomato.

4.5.4 Yield performance of intercropped crops

Yield performance of intercropped crops was also significantly influenced by different intercropping systems (Table 10). Results showed that the highest yield of different intercropped crops by weight was achieved from radish (15 t/ha) and garlic (2.24 t/ha) by tomato + radish (T_5) and tomato + garlic (T_1) respectively where the lowest yield/ha by weight was from radhuni (0.60 t/ha) and mouri (0.70 t/ha) by tomato + radhuni (T_2) and tomato + mouri (T_3) respectively. But in terms of economic return the best performance was recorded from garlic (Tk. 145600.00/ha) by tomato + garlic (T_1) intercropping system where the lowest economic return (Tk. 84000.00/ha) was from coriander by tomato + coriander (T_6) intercropping system (Table 9).

Table 10 .Yield performance of tomato and intercropped crops

Treatments	Yield of tomato						Intercropped yield		
	Weight of healthy fruit (kg plot^{-1})	**Weight of healthy fruit (ton ha^{-1})**	**Weight of infested fruit (kg plot^{-1})**	**Weight of infested fruit (ton ha^{-1})**	**Total fruit yield (kg plot^{-1})**	**Total fruit yield (ton ha^{-1})**	**Name of component crops**	**Yield (kgplot^{-1})**	**Yield (ton ha^{-1})**
T_1	8.00 a	16.00 a	0.50 e	1.00 e	8.50 a	17.00 a	Garlic	1.12	2.24
T_2	5.83 b	11.66 b	0.70 d	1.40 d	6.53 b	13.06 b	Radhuni	0.30	0.60
T_3	4.67 c	9.34 c	0.90bc	1.80 c	5.57 c	11.14 c	Mouri	0.35	0.70
T_4	4.83 c	9.66 c	0.90 bc	1.80 c	5.73 c	11.46 c	Methi	0.45	0.90
T_5	4.33 c	8.66 d	1.20 b	2.40 b	5.53 c	11.06 c	Radish	7.50	15.00
T_6	4.50 c	9.00 c	1.10 b	2.20 b	5.60 c	11.20 c	Coriander	0.28	0.56
T_7	2.33 d	4.66 e	2.40 a	4.80 a	4.73 d	9.46 d	--	--	--
$LSD_{0.05}$	0.3528	0.216	0.1846	0.1264	0.826	1.468	--	--	--
CV (%)	7.862	8.946	6.586	8.366	7.289	7.548	--	--	--
SE	0.462	0.385	0.128	0.296	0.385	0.226	--	--	--

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).

T_1 = Tomato + garlic

T_2 = Tomato + radhuni

T_3 = Tomato + mouri

T_4 = Tomato + methi

T_5 = Tomato + radish

T_6 = Tomato + coriander

T_7 = Sole tomato (Control)

4.6 Yield and economics

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

4.6.1 Relative yield of tomato

Relative yield indicates the competitive ability of component crops in an intercropping system (Wahua and Miller, 1978). The results were significantly influenced by different intercropping system under the present study (Table 11). The highest relative yield of tomato (1.80 t/ha) was recorded from tomato + garlic (T_1) which was significantly different from all other intercropped treatments. On the other hand, the lowest relative yield of tomato (1.17 t/ha) among the intercropped treatments was found from tomato + radish (T_5) which was statistically identical with tomato + mouri (T_3) and tomato + coriander (T_6).

Among the component crops tomato was found to be more competitive (1.80 t/ha) than the other crops. Higher competitive ability of tomato may be attributed to its bushy and leafy structures which dominated over the under storied crops. Similar result was also reported byHaque and Hamid (2001) in maize + sweet potato intercropping system where tall maize were more competitive than the shorter sweet potato.

4.6.2 Tomato equivalent yield with intercropped crops

Tomato equivalent yield with intercropped crops was significantly influenced by different intercropping system (Table 11). Results showed that the highest tomato equivalent yield with intercropped crops (17.69 t/ha) was recorded from tomato + garlic (T_1) intercropping system, which was significantly different from all other treatments. On the other hand, the lowest tomato equivalent yield with intercropped crops (54.68

t/ha) was recorded from tomato + coriander (T_6) intercropping system which was statistically identical with tomato + mouri (T_3) and tomato + methi (T_3) intercropping system.

Yield advantage or yield reduction of intercropping system depends on complementary or competitive behavior of component crops (Spitters, 1983).

4.6.3 Intercropped crops equivalent yield with tomato

Intercropped crops equivalent yield with tomato was significantly influenced by different intercropping system (Table 11). Results showed that the highest intercropped crops equivalent yield with tomato (66.93 t/ha) was recorded from tomato + radhuni (T_2) treatment which was significantly different from all other treatments. On the other hand, the lowest tomato equivalent yield with intercropped crops (31.72 t/ha) was recorded from tomato + mouri (T_3) intercropping system which was statistically identical with tomato + methi (T_4) intercropping system.

4.6.4 Gross return

From the economic point of view, it was observed that intercropping of different combinations gave higher economic return than monoculture (Table 11). In the studied intercropping systems, tomato + garlic (T_1) were more compatible than other intercropping system. It was observed that the highest gross return (Tk. 621600.00/ha) was achieved by tomato + garlic (T_1) intercropping system. The second, third and fourth highest gross return were more or less same and that were Tk. 437880.00/ha, Tk. 437680.00/ha and Tk. 423920.00/ha obtained by tomato + methi (T_4), tomato + radhuni (T_2) and tomato + methi(T_3) intercropping system respectively. On the other hand, the lowest gross return (Tk. 264880.00/ha) was achieved from control treatment (T_7). But in intercropping treatment, the lowest (Tk. 397600.00/ha) was achieved in tomato + coriander (T_6) 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 11. Effect of intercropping tomato with other crops on intercropped yield performance
by weight regarding whitefly infestation

Treatments	**Relative yield of tomato (ton ha^{-1})**	**Tomato equivalent yield with intercropped crops (ton ha^{-1})**	**Intercroed equivalent yield with tomato (ton ha^{-1})**	**Gross return**		
				From tomato (Tk. ha^{-1})	**From inter-cropped crops (Tk. ha^{-1})**	**Total (Taka)**
T_1	1.80 a	17.69 a	57.82 b	476000	145600	621600
T_2	1.38 b	13.18 c	66.93 a	365680	72000	437680
T_3	1.18 c	11.39 d	31.72 e	311920	112000	423920
T_4	1.21 c	11.79 d	32.33 e	320880	117000	437880
T_5	1.17 c	16.15 b	47.62 c	309680	105000	414680
T_6	1.18 c	11.35 d	42.37 d	313600	84000	397600
T_7	1.00 d	--	--	264880	--	264880
$LSD_{0.05}$	0.056	1.158	2.446	--	--	--
CV (%)	5.368	6.344	8.652	--	--	--
SE	0.084	0.136	0.098	--	--	--

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).

T_1 = Tomato + garlic
T_2 = Tomato + radhuni
T_3 = Tomato + mouri
T_4 = Tomato + methi
T_5 = Tomato + radish
T_6 = Tomato + coriander
T_7 = Sole tomato (Control)

Market price of tomato, garlic, radhuni, mouri, methi, radish and coriander Tk. 28.00/kg, Tk. 65.00/kg, Tk. 120.00/kg, Tk. 160.00/kg, Tk. 130.00/kg, Tk. 7.00/kg, Tk. and Tk. 150.00/kg respectively.

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY

A field experiment was conducted at Sher-e-Bangla Agriculture University Farm to find out the effect of intercropping on the management of whitefly (*Bemisiatabaci*Genn.) in tomato during November 2010 to April 2011. The crop combinations were:tomato + garlic, tomato + radhuni, tomato + mouri, tomato + methi, tomato + radish, tomato + coriander and Sole tomato (control). The experiment was laid out in the Randomized Complete Block Design with three replications.

Data was collected on the number of infested plants/plot (5m^2), number ofuninfested plants/plot (5m^2), number of whiteflies/plant, number of other insect pests/plant, number of natural enemies/plant, yields of tomato and intercropped crops, relative yield, equivalent yield and gross return(Tk).

Significantlythe lowest number of infested plant/plot (5m^2) (0.00, 0.67 and 1.67 at 40, 80 and 115 DAT respectively), number of leaf curl infested plant/plot (0.67) and number of whiteflies/plant (2.67, 4.50 and 5.33 at 40, 80 and 115 DAT respectively) were recorded in tomato + garlic intercropping system. On the other hand, the highest number of infested plant/plot (5m^2) (2.67, 4.00 and 6.67 at 40, 80 and 115 DAT respectively), number of leaf curl infested plant/plot (3.67) and number of white fly/plant (12.00, 16.50 and 20.67 at 40, 80 and 115 DAT respectively) were recorded in control treatment. But in intercropping treatments the highest number of infested plant/plot (5m^2) (1.67, 3.00 and 4.33 at 40, 80 and 115 DAT respectively), number of leaf curl infested plant/plot (3.00) and number of whiteflies/plant (8.33, 10.83 and 14.50 at 40, 80 and 115 DAT respectively) were recorded in tomato + radish intercropping system. In case of total number of other insect pests/plant the lowest (1.33) was achieved from tomato + radhuni intercropping system where the highest presence (7.33) was observed in sole treatment. But in the intercropped treatments, tomato + radish showed the highest presence of other insect pest (5.33).

Again, the highest number of healthy plant/plot ($5m^2$) (12.00, 11.33 and 10.33 at 40, 80 and 115 DAT respectively) and total number of natural enemies/plant (3.33) were achieved by tomato + garlic intercropping system where the lowest number of healthy plant/plot ($5m^2$) (9.33, 8.00 and 5.33 at 40, 80 and 115 DAT respectively) and total number of natural enemy/plant (1.02) were achieved by control treatment. But in intercropping treatments the lowest number of healthy plant/plot ($5m^2$) (10.33, 9.00 and 7.67 at 40, 80 and 115 DAT respectively) and total number of natural enemy/plant (1.86) was recorded in tomato + radish intercropping system.

In terms of percent reduction over control, the highest reduction on number of infested plant/plot ($5m^2$) (100%, 83.25% and 74.96% at 40, 80 and 115 DAT respectively), number of whiteflies/plant (77.75%, 72.73% and 74.21% at 40, 80 and 115 DAT respectively) and number of leaf curl infested plant/plot (81.74%) over control was recorded in tomato + garlic intercropping system. On the other hand, the lowest reduction on number of infested plant/plot ($5m^2$) (37.45%, 25%, and 35.08% at 40, 80 and 115 DAT respectively), number of whiteflies/plant (30.58%, 34.36% and 29.85% at 40, 80 and 115 DAT respectively) and number of leaf curl infested plant/plot (18.26%) was recorded in tomato + radish intercropping system.

Again, in terms of percent increase over control, the highest increase on healthy plant/plot ($5m^2$) (28.62%, 41.63% and 93.81% at 40, 80 and 115 DAT respectively) and total number of natural enemy/plant (226.47%) over control were achieved by tomato + garlic intercropping system where the lowest percent increase on number of healthy plant/plot ($5m^2$) (10.72%, 12.50% and 43.90% at 40, 80 and 115 DAT respectively) and total number of natural enemies/plant (82.35%) over control were achieved from tomato + radish intercropping system.

In terms of yield performance, the highest healthy tomato yield (16.00 t/ha), lowest infested tomato yield (1.00 t/ha) and highest total tomato yield (17.00 t/ha) was obtained in tomato + garlic intercropping system where the lowest healthy tomato yield (4.66 t/ha), highest infested tomato yield (4.80 t/ha) and lowest total tomato yield (9.46 t/ha) was obtained in control treatment. But in intercropped treatment the lowest healthy tomato yield (8.66 t/ha), highest infested tomato yield (2.40 t/ha) and lowest total tomato yield (11.06 t/ha) was achieved by tomato + radish intercropping system.

Again, the highest relative yield (1.80 t/ha) and tomato equivalent yield (17.69 t/ha) was gained in tomato + garlic intercropping system. But in case of intercropping treatments, the lowest relative yield of tomato (1.17 t/ha) and tomato equivalent yield (11.35 t/ha) was achieved by tomato + radish and tomato + coriander respectively. The highest intercropped equivalent yield with tomato (66.93 t/ha) was obtained from tomato + radhuni intercropping system where the lowest was observed from tomato + mouri intercropping system.

The highest gross return (Tk. 621600.00/ha) was recorded from the tomato + garlic intercropping system followed by tomato + radhuni (Tk. 437680.00/ha), tomato + methi (Tk. 437880.00/ha) and tomato + mouri (Tk. 423920.00/ha). The lowest gross return (Tk. 264880.00/ha) was observed in sole cropping followed by tomato + coriander (Tk. 397600.00/ha)intercropping system.

CONCLUSION

From the study, it may be concluded that the incidence of whitefly on tomato were less in intercropping. The incidence of natural enemies and beneficial insects was also higher in intercropping systems. The total yield, relative yield, equivalent yield and gross return were generally higher in intercropping than that of the sole cropping. The overall study revealedtha the intercropping was an eco-friendly pest management practice for tomato by which one can significantly reduce pest infestation without use of any chemicals. Considering the results of the present study, it mayalso be concluded that tomato + garlic was the best intercropping system followed bytomato + methi,tomato + radhuni, tomato + mouri, tomato + radish and tomato +coriander.Sole (control) gave lowest performance in respect of reducing insect pests, increasing natural enemies, relative yield, tomato equivalent yield and above all gross return.

RECOMMENDATION

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

CHAPTER VI
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APPENDICES

Appendix I. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from November 2010 to March 2011

Month	RH (%)	Max. Temp. (ºC)	Min. Temp. (ºC)	Rain fall (mm)
November	50.26	24.80	16.40	0
December	48.36	24.52	14.18	0
January	55.53	25.00	13.46	0
February	50.31	29.50	18.49	0
March	44.95	33.80	20.28	25
April	61.40	33.74	23.81	185

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

Appendix II.Characteristics of experimental soil was analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B.Physical and chemical properties of the initial soil

Characteristics	Value
Partical size analysis	
% Sand	27
%Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix III. Effect of intercropping tomato with other crops on number of infested plant plot^{-1} by whitefly during cropping period

Source of variation	Degrees of freedom	Mean square of number of infested plant plot^{-1}		
		40 DAT	80 DAT	115 DAT
Replication	2	0.0012	0.002	0.008
Factor A	6	1.116**	3.012*	2.342*
Error	12	0.146	2.114	1.136

* = Significant at 5% level of probability; ** =Significant at1% level of probability

Appendix IV. Effect of intercropping tomato with other crops on percent reduction of infested plant plot^{-1}by number over control during cropping period

Source of variation	Degrees of freedom	Mean square of percent reduction of infested plant plot^{-1} by number over control		
		40 DAT	80 DAT	115 DAT
Replication	2	0.001	0.002	0.004
Factor A	5	3.145*	4.386*	3.119*
Error	10	0.425	0.542	1.186

* = Significant at 5% level of probability

Appendix V. Effect of intercropping tomato with other crops on number of uninfested plant plot^{-1} with the incidence of whitefly during cropping period

Source of variation	Degrees of freedom	Mean square of number of uninfested plant plot^{-1}		
		40DAT	80 DAT	115 DAT

Replication	2	0.002	0.014	0.012
Factor A	6	3.325*	4.552*	5.118*
Error	12	0.226	1.589	2.248

* = Significant at 5% level of probability;

Appendix VI. Effect of intercropping tomato with other crops on percent increase of uninfested plant plot^{-1}by number over control during cropping period

Source of variation	Degrees of freedom	Mean square of percent increase of uninfested plant plot^{-1} by number over control		
		40 DAT	**80 DAT**	**115DAT**
Replication	2	0.032	0.114	0.042
Factor A	5	2.368*	6.159*	5.344*
Error	10	0.256	1.345	1.758

* = Significant at 5% level of probability;

Appendix VII. Effect of intercropping tomato with other crops on the incidence of white fly during cropping period

Source of variation	Degrees of freedom	Mean square of presence of whitefly plant^{-1} by number		
		40 DAT	**80 DAT**	**115 DAT**
Replication	2	0.024	0.033	0.036
Factor A	6	2.349*	4.258*	10.114*
Error	12	0.115	1.248	1.562

* = Significant at 5% level of probability;

Appendix VIII. Effect of intercropping tomato with other crops on percent reduction of whiteflies over control during cropping period

Source of variation	Degrees of freedom	Mean square of percent reduction of whitefly over control		
		40 DAT	**80 DAT**	**115DAT**
Replication	2	0.04	0.01	0.11
Factor A	5	1.45*	1.95*	2.42*
Error	10	0.32	0.11	0.55

* = Significant at 5% level of probability;

Appendix IX. Effect of intercropping tomato with other crops on the incidence of other pest except whitefly during cropping period

Source of variation	Degrees of freedom	Mean square of	Degrees of freedom	Mean square of
		Presence of other insect pest by number		**Percent reduction of other insect pest over control by number**
Replication	2	0.024	2	0.033
Factor A	6	4.349*	5	4.258*
Error	12	1.115	10	1.248

* = Significant at 5% level of probability;

Appendix X. Effect of intercropping tomato with other crops on the incidence of other pest except whitefly during cropping period

Source of variation	Degrees of freedom	Mean square of presence of	Degrees of freedom	Mean square of presence of
		Presence of natural enemy by number		**Percent increase of natural enemy over control by number**
Replication	2	0.02	2	0.01
Factor A	6	3.11*	5	2.45*
Error	12	0.56	10	0.325

* = Significant at 5% level of probability;

Appendix XI. Effect of intercropping tomato with other crops on leaf curl infestation during cropping period

Source of variation	Degrees of freedom	Mean square of	Degrees of freedom	Mean square of
		Number of leaf curl infested plant plot^{-1}		**Percent reduction of leaf curl infested plant plot^{-1} over control by number**
Replication	2	0.01	2	0.01
Factor A	6	1.95*	5	8.42*
Error	12	0.12	10	0.55

* = Significant at 5% level of probability;

Appendix XII. Yield performance of tomato and intercropped crops

Source of variation	Degrees of freedom	Mean square of yield of tomato					
		Weight of healthy fruit (kg $plot^{-1}$)	Weight of healthy fruit (ton ha^{-1})	Weight of infested fruit (kg $plot^{-1}$)	Weight of infested fruit (ton ha^{-1})	Total fruit yield (kg $plot^{-1}$)	Total fruit yield (ton ha^{-1})
Replication	2	0.01	0.02	0.004	0.024	0.002	0.001
Factor A	6	2.26*	4.19*	2.242*	3.658*	2.994*	3.148*
Error	12	0.14	1.23	0.254	1.223	0.134	0.456

* = Significant at 5% level of probability;

Appendix XIII. Effect of intercropping tomato with other crops on intercropped yield performance by weight regarding whitefly infestation

Source of variation	Degrees of freedom	Mean square of relative yield of tomato (ton ha^{-1})	Degrees of freedom	Mean square of	
				Tomato equivalent yield with intercropped crops (ton ha^{-1})	Intercropped equivalent yield with tomato (ton ha^{-1})
Replication	2	0.002	2	0.004	0.002
Factor A	6	2.236*	5	1.165*	0.486*
Error	12	0.138	10	0.204	0.024

* = Significant at 5% level of probability;