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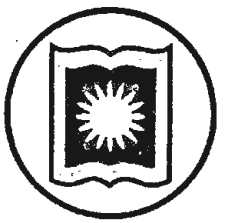
IPM of Aphid Pests on Winter Crops

Ashraf, S.M.Ali

University of Rajshahi

IPM OF APHID PESTS ON WINTER CROPS



THESIS SUBMITTED FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN THE INSTITUTE OF BIOLOGICAL SCIENCES (IBSc)
UNIVERSITY OF RAJSHAHI
RAJSHAHI-6205
BANGLADESH

By

S.M.Ali Ashraf
B.Sc.(Hons.); M.Sc.
Session : 2002-2003

January, 2010

Integrated Pest Management Laboratory
Institute of Biological Sciences
University of Rajshahi
Rajshahi-6205
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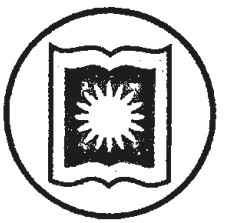

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Dedicated

To

My Parents

DECLARATION

I do hereby declare that the dissertation submitted for the Degree of Doctor of Philosophy to the Institute of Biological Sciences, University of Rajshahi, is based on my original investigation and was carried out under the supervision of Professor Md. Sohrab Ali and Professor Dr. Bidhan Chandra Das, Department of Zoology, University of Rajshahi, Bangladesh. The work as a whole or in part there of has not been submitted any where in any form for any other degree.

23.01.2010

January, 2010
Institute of Biological Sciences (IBSc)
University of Rajshahi
Rajshahi-6205
Bangladesh

(S.M. Ali Ashraf)

CERTIFICATE

This is to certify that Mr. S.M. Ali Ashraf, Assistant Professor, Department of Zoology, Govt. H.S.S. College, Magura, Bangladesh has been working under our joint supervision since July, 2003. We are pleased to forward his dissertation entitled "IPM OF APHID PESTS ON WINTER CROPS" for the degree of Doctor of Philosophy in the Institute of Biological Sciences, University of Rajshahi, Rajshahi-6205, Bangladesh.

Mr. Ashraf has fulfilled all the requirements of the regulations relating to the nature and prescribed period of research to submit the present dissertation for the award of degree of Doctor of Philosophy of the University of Rajshahi.

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proper attention to his only a son 'Ariq' due to the pressure of research work who came in the world during the course of study.

Last but not the least, the author is grateful to the UGC of Bangladesh for providing Ph.D fellowship and to the Ministry of Education, Government of the People's Republic of Bangladesh for granting three years deputation for research purpose.

The Author

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ABBREVIATIONS

%-Percent

'r'-Correlation co-efficient

<-Less than

>Greater than

A .I.-Active Ingredient

B. C. R.-Benefit Cost Ratio

BARI-Bangladesh Agricultural Research Institute

BRRI- Bangladesh Rice Research Institute

D.F.-Degrees of Freedom

DAT-Days after treatment

DBT-Days before treatment

DMRT-Duncan's Multiple Range Test

E-Early sowing

EC- Emulsifiable concentrate

EIL-Economic Injury Level

et al.,-Lt. *et alii/alia* means other people

ETL-Economic Threshold Level

'F ' Value-Variance Ratio

ha- Hectare

IPM-Integrated Pest Management

Kg.-Kilogram

L-Late sowing

M-Mid sowing

NAPP-Number of aphid per plant

NAE-Number of natural enemies per plant

R.B.D- Randomized Block Design.

S.E.-Standard Error

Std.-Standard

T_1- Spray of insecticide (First round and Second round)

T_2- Spray of insecticide (First round) and Spray of botanical (Second round)

T_3- Release of natural of enemies (First round and Second round)

T_4- Release of natural of enemies (First round) and Spray of botanical (Second round)

T_5-Dusting of Kerosinized ash (First round) and Spray of botanical (Second round)

T_6-Control, spray of water only (First round and Second round)

UGC -University Grants Commission

Var.-variety

viz.,- Lt. *videliect* means namely

Vs.-versus

Ver.-Version

W/V-Weight (Solid) by Volume (Liquid)

ABSTRACT

The present dissertation consisted of six chapters in addition to a general introduction and review of literatures. The introduction deals with the importance of aphids as pests, carriers of viruses, their numbers, host specificity and speciation, morphs and life cycles. Concepts and components of IPM, it's brief history, constraints as well as foundation and pillars of IPM are also discussed in this section. Rationale, aims and objectives of the present investigation are also included at the end of general introduction. Related works to the present investigation both from home and abroad are mentioned under the title of "**Review of Literatures**".

Chapter 1 contains the population dynamics of three aphid pests *viz.*, *Aphis craccivora* Koch, *Aphis gossypii* Glover, *Lipaphis erysimi* (Kalt.) (Homoptera: Aphididae) infesting bean, brinjal and mustard plant respectively. Population of natural enemies of said aphids were also recorded. Highest population of *A. craccivora* was recorded (71.66±1.67 per twig) in the 3rd week of December, 2003 and lowest (9.00±0.58 per twig) in the 1st week of November, 2003. Population of *A. gossypii* was highest (17.00±1.16 per plant) in the 4th week of December ,2003 and lowest (2.00±0.58 per plant) in the 4th week of January, 2004 and the population of *L. erysimi* reached to its peak (43.00±1.53 per twig) in the 4th week of December, 2003 and lowest (9.66± 0.33 per twig) in the 2nd week of November, 2003. The impacts of environmental factors *viz.*, temperature, relative humidity, dew point and rainfall on the weekly number of aphids and their natural enemies were investigated by calculating the degree of relationships between the said variables. In order to do this analysis of 'r' (Correlation co-efficient) values were calculated separately.

Chapter 2 deals with the natural enemies complex of *A. craccivora, A. gossypii* , and *L. erysimi.* For this purpose, bean ,brinjal and mustard fields were surveyed intensively during November 2003 to January 2004. Altogether 8 species of predators and one species of hymenopteran parasitoid were recorded as the natural enemies of above three aphid species . Among the predators 6 and 2 belong to order Coleoptera and Diptera respectively. *Micraspis discolor* (Fabr.) was predominant in all three crop fields while *Coccinella transversalis* (Fabr.)was predominant both in brinjal and

mustard crops. *Syrphus confracter* Wiedemann on the other hand was predominantly found only in mustard crop.

Chapter 3 embodies the functional response of aphidophagous predators, *Coccinella transversalis* (Fabr.), *Micraspis discolor* (Fabr.)and *Syrphus confracter* Wiedemann on bean aphid, *A. craccivora* ,brinjal aphid, *A. gossypii* and mustard aphid, *L. erysimi* respectively. The consumption rate of predators increased with the increase of prey density and reduction of aphids took place at higher percentage when the initial aphid density was higher compared to low density level.

Instarwise larval voracity and developmental periods of the aforesaid predators on *A. craccivora* , *A. gossypii* and *L. erysimi* were studied in the laboratory under ambient conditions. Voracity varied significantly ($P<0.001$) among different larval instars of each predator species. The mean incubation period of *C. transversalis* was found to be 2.2±0.20, 2.6±0.19 and 2.0±0.00 days when feed on *A. craccivora* , *A. gossypii* and *L. erysimi* respectively as against 2.1±0.10,2.4±0.10 and 2.0±0.00 days for *M. discolor* and 2.2±0.09, 2.4±0.19 and 1.9±0.09 days for *S. confracter.* The larva of *C. transversalis*; *M. discolor* had four instars and *S. confracter* on the other hand had three instars covering a total average period of 13.0±0.54, 16.2±0.67 and 14.0±0.63 days for *C. transversalis* on *A. craccivora*, *A. gossypii* and *L. erysimi* respectively as prey. The corresponding larval periods were recorded as 13.6±0.65, 16.2±0.58 and12.6±0.44 days for *M. discolor* and 6.2±0.19, 6.8±0.67 and 6.0±0.00 days for *S. confracter* on same food. On an average the duration of the pupal stage was recorded as 3.1±0.10, 3.2±0.12 and 3.0±0.00 days for *C. transversalis* whereas this duration was 3.7±0.12, 3.8±0.12 and 3.3±0.12 days for *M. discolor* and 2.5±0.22; 2.2±0.12 and 2.0±0.00 days for *S. confracter* on *A. craccivora*, *A. gossypii* and *L. erysimi* respectively.

Adult (male and female)voracity of *C. transversalis* and *M. discolor* on three species of aphids *viz., A. craccivora*, *A. gossypii* and *L. erysimi* were studied and significant ($P<0.05$;$P<0.01$ and $P<0.001$) differences were observed. Voracity among the male and female members of two predator species on single prey aphid also varied significantly($P<0.05$;$P<0.01$ $P<0.001$).

Chapter 4 represents the integrated management of bean aphid, *A. craccivora* infesting two bean varieties, BARI Seem-1 and BARI Seem-2. Seeds of the said varieties were sown in earthen tubs on three dates (Early, Mid and Late sowing). Altogether thirty tubs were prepared from each variety and each sowing date and divided them into six blocks (T_1-T_6) i.e. five tubs comprised as a block. Admire 200 SL (Imidacloprid) as insecticide, crude extract of tobacco leaf as botanical, third instar larvae of *C. transversalis* as natural enemies, kerosinized ash as natural product were applied two times separately or in combination with one another as treatment materials. Population of *A. craccivora* before and after 1, 3, 7 and 20 days of each treatment were recorded. Yield of bean for two varieties were harvested separately from the block of specific treatment and sowing date. Reduction in aphid's population and subsequent yield were found significant ($P<0.05$; $P<0.01$; $P<0.001$) between treated and untreated crops of each sowing date of each variety.

Chapter 5 deals with the integrated management of brinjal aphid, *A. gossypii* infesting two BARI brinjal cultivars, Nayantara and Kazla. Seeds of each cultivar were sown on three dates in separate fields. Eighteen tubs were prepared from the seedling of each cultivars and each sowing date and divided them into six blocks, i.e. three tubs comprised as a block. The blocks were treated with various combinations of treatments *viz.*, two times insecticide(Nymbicidine), one time insecticide plus one time botanical(Bankalmi leaf extract), two times natural enemies (third instar larvae of *C. transversalis*), one time natural enemies plus one time botanical and one time kerosinized ash plus one time botanical. The treatment block T_6 was kept as controlled. The population of *A. gossypii* was counted before and after 1, 3, 7 and 20 days of each treatment. Yield of brinjal for two varieties were harvested separately from the block of specific treatment and sowing date. Statistical analysis both on aphid population and yield showed significant difference ($P<0.05$; $P<0.01$; $P<0.001$) between controlled and treated blocks of each sowing date of each variety.

Chapter 6 deals with the integrated management of mustard aphid, *L. erysimi* infesting two mustard varieties, BARI Sharisha-6 and BARI Sharisha-7. Accordingly seeds of the two varieties were sown on three dates in separate fields. Classic 20 EC (Chlorpyriphos) as insecticide, crude extract of Dhutra leaf as botanical, third instar

larvae of *C. transversalis* as natural enemies, kerosinized ash as natural product were applied two times separately or in combination with one another as treatment materials. The population of *L. erysimi* was counted before and after 1, 3, 7 and 20 days of each treatment and yield of mustard for two varieties were harvested separately from the block of specific treatment and sowing date. Regarding aphid population and yield, statistics revealed that significant differences ($P<0.05$; $P<0.01$; $P<0.001$) exist between controlled and treated blocks of each sowing date of each variety.

Works those are cited in the text are given as "**References**". Few photographic plates are provided as "**Appendices**" at the end of the dissertation.

GENERAL INTRODUCTION

Aphids as pests:

Aphids (Homoptera:Aphididae) are major insect pests of world agriculture, damaging crops by removing photo assimilates and vectoring devasting plant viruses(Smith and Boyko, 2007). They are the largest group of plant phloem feeders (Raychaudhuri, 1980; Smith and Boyko, 2007; Gao, *et al.*, 2007; Shannag, 2007). The complex life cycles and polymorphism of aphids have enabled them to exploit a wide range of host plants (Dixon, 1973, Singh *et al.*, 2003). Undoubtedly they are the most important pest insects in the agriculture of the temperate climatic zone where few plant species are without a specific aphid (Dixon, 1973; Minks and Harrewijn, 1989). Aphids are pests since they cause losses by direct feeding damage and indirect damage as vectors of viruses (Burn, 1987; Quiroz *et al.,* 1991; Milne and Delves, 1993; Doring *et al.*, 2004).The damage is caused both by nymph and adult aphids (Sahu *et al.*,2006). They are efficient virus vectors because of their fecundity and rapid maturation, mobility of the winged forms and the forms of their mouth parts (Jones and Jones, 1984; Gair *et al.,* 1987). Besides some species of aphids by their copious secretion of honey dew occlude the stomatal openings of leaves hampering thereby the normal physiological processes like transpiration and photosynthesis of the plants (Devjani *et al.*,2006). Deposition of honey dew on the leaf surface also allows the growth of sooty mould which in turn proves detrimental to the plant life. As a result of their direct attack curling of the tender leaves, twisting of the tender shoots and general devitalization of the host plants occurred. Sometimes inflorescence may fall and fruits may likewise fail to develop normally which may also show various malformations like twisting of the pods, impaired development of healthy and viable seeds. In rare cases, however the very young seedling succumb to the injury. Accordingly, this group of pests has received special attention at the hands of pest control practitioners for the last few decades. This is mainly because of their intricate life style in close association with their host plants and their unequalled rate of multiplication which rapidly raise them above economic threshold levels (Dixon and Kundu, 1998).

Aphids as carriers of viruses:

Accessory salivary glands of aphids are important in virus transmission (Gildow *et al.*, 2000).Virus particles are observed in the lumen of the salivary duct. Aphids transmit viruses by one of two general processes (Kennedy *et al.*, 1962) .Non-persistent viruses are concentrated in the epidermis of the plant, and aphids acquire the viruses when they probe the surface of the infected plants. Aphids can acquire the viruses with a single probe, within seconds and also can subsequently transmit it to a healthy plant within seconds. However, non-persistent viruses are retained by the aphid for only a short period –usually only an hour or two. After that period the aphid no longer can transmit the virus unless it feeds on another infected plant (Reavy and Mayo, 2002; Gray and Gildow, 2003). Because of the rapid acquisition and transmission of the non persistent viruses ,insecticides have little or no effect. Once an aphid has acquired a persistent virus, the virus moves internally in the insect and eventually migrates to the accessory salivary gland (Ponsen, 1972). Completion of this circulation within the insect can take days after feeding on an infected plant. However, once the virus begins to appear in the salivary glands the aphid will transmit it for the remainder of its life. Insecticides can be somewhat more effective in reducing spread of persistent viruses than non persistent viruses, particularly if the insecticides rapidly incapacitates the aphid vector. Examples of persistent viruses spread by aphids include potato leaf roll virus and beet western yellow virus (Gray and Gildow, 2003).

Aphid numbers:

Out of the 4702 aphid species recorded world over (Ramandiere and Remandiere, 1997), 1015 are known to be in the oriental region (Agarwala and Ghosh ,1984). Out of which Bangladesh accounts for 30 species belonging to 20 genera infesting 58 economic important crops like vegetables, fruits, fiber crops, pulses, oilseeds, sugarcane, cereals and ornamental crops in addition to forest flora (Das, 1994). These crops belongs to the family leguminosae, solanaceae, gramineae, cruciferae, compositae, rosaceae, malvaceae, cucurbitaceae and rutaceae. Some aphid species are host specific and some are polyphagous in nature. Ganguli and Agarwala (1985) recorded 12 aphid species infesting agricultural crops in Tripura, North East India out

of which 8 aphid species including *Aphis craccivora* Koch, *Aphis gossypii* Glover and *Lipaphis erysimi* (Kalt.) are also found in Bangladesh. The reason for this similarity is geographical proximity and common features of agriculture and climate. The total number of aphids in Bangladesh represents less than 0.75% of the world, and 2.94% of the oriental region (Das ,1994).

Aphid morphs and life cycles:

The life cycle of most aphids is complicated and is very much dependent on the bio-geographical conditions. Aphid dispersal occurs in autumn, spring and summer, the duration of each dispersal ranging from one to six weeks. In most dispersals, female winged aphids reproduce parthenogenetically giving rise to small fully- formed immature forms, nymph (Margaritopoulos *et al.*,2009). The nymphs undergo four moults to become viviparous adult females with (alate) or without (apterous) wings (Johnson, 1963). Several parthenogenetic generations are produced during a year and the proportion of alate to apterous forms usually increase in dry weather and as the host- plants get older (Behura, 1978). Some aphid species are anholocyclic, i.e. continuously parthenogenetic, while others are holocyclic, i.e. sexual generation alternate with parthenogenetic reproduction. Aphids which under go holocyclic life cycle are extremely polymorphic presenting five or six morphs, such as male, female, fundatrice, gynoparae, varginoparae, sexuparae. Sexual forms (Sexuparae) are generally produced in autumn, on secondary herbaceous host-plants, usually annuals, which return to primary woody host-plants, usually a perennial in winter to give rise to sexual males and females (sexuales) viviparously and parthenogenetically. After mating, the oviparous females lay eggs on the primary host, the egg overwinter, giving rise to wingless, parthenogenetic viviparous forms (faundatrices/stem mother)in the spring. Subsequent generations are followed by the developments of winged migrants (termed allnicolae) in the colony which migrate to suitable secondary host-plants to establish new colonies by viviparous and parthenogenetic reproduction. The production of alates and apterae depends on population density (e.g. crowding at larval and adult stage), temperature, humidity, sometimes quality of food, starvation and photoperiodism.

Host specificity and speciation of aphids :

Many aphid pest species of agricultural importance are considered polyphagous ,as they infest a wide range of crops, others are oligophagous and limited to a number of hosts belonging to single family (Takemura *et al.*, 2006). Host specificity in aphids and plant resistant against aphid infestation are greatly influenced by plant chemistry(Van Emden,1972; Klingauf, 1987; Montllor, 1991). Most aphids are autoecious living on one or a few species of a particular genus of plants(Eastop,1973).About 10% are heteroecious, spending autumn, winter and spring on a primary host plant ,and the summer on a secondary host plant(s), which is closely related to the primary host.

Concepts and components of IPM:

Integrated pest management (IPM) is an ecological approach to pest management. In general pest elimination is not a goal of IPM. Rather, IPM seeks to use all appropriate tools and tactics to keep pest populations below economic damaging levels while avoiding adverse effects to humans, wildlife and the environment. Although the IPM concept originated in the 1950s but the acronym was not actually coined until after 1972. The term IPM is now more or less universally understood but what actually comprises an IPM is still open to discussion. IPM is a system of pest control that uses a wide spectrum of cultural, biological and chemical methods to maximize economic benefits while minimizing environmental impacts (Thomas *et al.,* 1988). Watson *et al.,* (1975) on the other hand have defined IPM as "the practical manipulation of pest population using sound ecological principles to keep the pest population below the level causing economic injury". In 1998, the United States Department of Agriculture (USDA) defined IPM with a further acronym PAMS. It proposed that IPM be a combination of prevention, avoidance, monitoring and suppression of pests. This definition also deviates from the original proposal given by Stern *et al.,* (1959) in that it fails to implicitly integrate control strategies. Monitoring(Scouting),forecasting of pests population and their phenology, utilization of the economic threshold level (ETL) and economic injury level (EIL), manipulation of resistant varieties and cultural practices are also the important tools of IPM. In simple terms, IPM aims at combining all available methods or tools of insect pest control in a judicious manner that minimizes insecticide use and disturbance to

the ecosystem (environment). Obviously the method does not remain a single system but becomes a multidisciplinary ones. However, the hazardous effect of insecticides and economy of pest control in view of the high cost of insecticides are likely two key factors that led to the origin and evolution of the concept of IPM. The challenge of IPM is how its components can be best combined to give the farmer an acceptable and socially and environmentally desirable form of prevention of crop losses (Van Emden ,1982). An effective IPM system requires that all aspects of crop production system, biology and ecology of all pests present in the system, advantages, and disadvantages of various control strategies and cost-benefit ratio on control tactics also.

History of IPM:

The history of IPM can be traced back to the late 1800s when ecology was identified as the foundation for scientific plant protection (Kogan,1998).Throughout the late nineteenth and early twentieth centuries, in the absence of powerful pesticides, crop protection specialists relied on knowledge of pest biology and cultural practices to produce multi-tactical control strategies that in some instances were precursors of modern IPM systems (Gaines, 1957). During the first half of the twentieth century, economic entomology was the sub discipline responsible for research on and teaching about economically important insect species (pests) and the means to control them. "Pest control" was understood as the set of actions taken to avoid, attenuate, or delay the impact of pests on crops or domestic animals. Goals and procedure of pest control were clearly understood. That stance changed in the early 1940s with the advent of organosynthetic insecticides (Pimentel and Perkins, 1980) when crop protection specialists began to focus on testing chemicals, to the detriment of studying pest biology and non insecticidal methods of control. The period from the late 1940s through the mid 1960s has been called the dark ages of pest control (Newson, 1980). By the late 1950s, however warnings about the risks of the preponderance of insecticides in pest control began to be heard. Concern arose mainly from traditional centers of excellence in biological control, particularly in California (Ripper, 1956) and from works on cotton in North and South America (Dout and Smith, 1971), and deciduous tree fruit in Canada, the United States and Europe (MacPhee and MacLellan, 1971) who detected early signs of the catastrophic results from over reliance on insecticides.

The seed of the idea of integrated control appears in a paper by Hoskins *et al.*,(1939), as cited in Smith (1974): "biological and chemical control are considered as the two edges of the same sword". Conceivably integrated control was uttered by entomologists long before formally appearing in publication towards the end of the 1960s, integrated control was well entrenched both in the scientific literature and in the practice of pest control (Smith, 1974; Smith and Huffaker, 1973), although by then "Pest management" as a sibling concept was gaining popularity (Rabb and Guthric, 1970).

Foundation and pillars of IPM:

To construct an IPM package for a particular setting, several basic types of information must be available (Irwin, 1999). These types of information include biosystematics, bio-ecology, aerobiology, biometry and socio-economics.These information are referred to as the foundation of IPM by Ullyet (1951) and Levins (1980). On the other hand, there are several broad categories of tactics to suppress pests, the major ones include chemical control, biological control, molecular or genetic mechanisms, use of botanicals and bio-pesticides are also denoted as the pillars of IPM (Hartzell and Wilcoxon, 1941; Fienstein, 1952; Rahman, 1987; Rahman and Quayum, 1987; Grainge and Ahmed, 1988; Minks and Harrewinj, 1989; Khan and Mannan, 1991; Srivastava, 1993; Vishwapremi, 1995; Irwin, 1999; Ghosh, 2000; Mamun, *et al.,* 2008).

Constraints to IPM adoption:

A large number of constraints to IPM use have been identified in various studies (Grieshop *et al .,* 1988; Wearing ,1988) of which technical, financial, educational (Apple and Smith,1976), organizational or institutional (Kuhr,1981) and social constraint (Zalom *et al.*,1987) are most important although their relative rank also varied.

Rationale, aims and objectives of the present study:

Due to agroclimatological factors aphids are very much seasonal in Bangladesh. They appear at the advent of winter and many important vegetables, oilseeds, ornamental and cereal crops are badly affected by aphid pests. Of these, *Aphis craccivora* Koch, *Aphis gossypii* Glover and *Lipaphis erysimi* (Kalt.) are frequently

considered as the major ones infesting bean, brinjal and mustard crop respectively (Das,1994; Karim *et al*,2001;Kundu *et al*,2002). Their attack sometimes cause a considerable loss of the said crops (Prasad and Phadke, 1984). Thus the need of their control is very important from the point of national socio-economic development of our country. Unfortunately like other developing countries, attempts have been made to control them by pesticides only and review of literatures shows a large number of references on this aspect (Islam *et al.*, 1990; Rouf and Kabir, 1997; Islam and Sardar, 1997;Bari and Sardar 1998; Rahman *et al.*, 2003).But over dependence on synthetic pesticides in the endeavor to control the agricultural pests including aphids and other diseases of the crops is not only expensive but also leads to negative environmental consequences in addition to increased health hazards to the growers and consumers. But integrated pest management (IPM) on the other hand is an economical, sustainable and environmentally safe control strategy although conceptual frame work of IPM varies with time as revealed from the definitions mentioned earlier. In fact, no one took any initiative for the integration of IPM components *viz.*, cultural, biological, botanical and chemical control method against these aphids in this land. So there is a big gap of information to formulate an IPM package against aphid pests especially *A. craccivora*, *A. gossypii* and *L. erysimi* in natural field condition. Keeping these necessities in mind, a research project entitled "IPM of aphid pests on winter crops" was under taken to study the following in order to strengthen our present state of knowledge.

1) Population dynamics of bean aphid, *Aphis craccivora* Koch, brinjal aphid, *Aphis gossypii* Glover and mustard aphid *Lipaphis erysimi* (Kalt.)in terms of biotic and some abiotic factors.

2) Survey of natural enemies complex of bean aphid, *A. craccivora*, brinjal aphid, *A. gossypii* and mustard aphid *L. erysimi* .

3) Functional response and voracity of *Coccinella transversalis*(Fabr.); *Micraspis discolor* (Fabr.) (Coleoptera:Coccinellidae) and *Syrphus confracter* Wiedemann (Diptera: Syrphidae) including their developments.

4) Integrated management of bean aphid, *Aphis craccivora* Koch.

5) Integrated management of brinjal aphid, *Aphis gossypii* Glover.

6) Integrated management of mustard aphid, *Lipaphis erysimi* (Kalt.).

REVIEW OF LITERATURES

In this dissertation, main findings of different workers in home and abroad relevant to the present work are stated briefly under the 'discussion' section of the respective chapters. In this connection, some important references relating to the most three common aphid pests *viz.*, *Aphis craccivora* Koch, *Aphis gossypii* Glover, *Lipaphis erysimi* (Kalt.) and their natural enemies may be categorized under different sub headings as follows:

1. *Aphis craccivora* Koch

A. World perspective:

i. Survey/collection /records: Attia *et al.*,1986; Chhabra and Kooner,1989; Singh and Singh, 1995.

ii. Biology: Hamid *et al.*,1977; Raju and Panda,1983; Ansari,1984; Ogenga and Khaemba,1985; Atiri and Thottappilly,1985; Attri *et al.*,1987; Mohammad and Abdulla,1988; Srikanth and Lakundi,1988; Patel and Srivastava,1989; Das,1991; Traicevski and Ward,2002; Bhattacharyya *et al.*,2002.

iii. Ecology: Radke *et al.*,1972; Ansari,1984; Messina *et al.*, 1985; Ofuya,1986; Lal *et al.*,1989; Ofuya,1990;1993; Dimetry and El-Hawary,1995; Kundu *et al.*,2000; Shah *et al.*,2001; Edwards 2001; Dutta and Das, 2002; Rajendran, 2002; Ahamed *et al.*,2004; Kamali *et al.*,2005.

iv. Population dynamics: Krisnamurti,1928,1950; Saharia,1980; Sithanantham *et al.*,1984; Attri *et al.*,1986;Hijam and Singh,1989; Srikanth and Lakundi,1990; Ibrahim and Yeow,1990; Traicevski and Ward,1994; Atakan and Ozgur, 1996; Kumar *et al.*,1997.

v. Morphometrics: Basu *et al.*,1969; Radke *et al.*,1972.

vi. Host/Varietal preference: Basu *et al.*,1969; Reddy *et al.*,1983; Verma *et al.*,1983; Messina *et al.*,1985; Singh *et al.*,1990, 1991; Robert and Le-gallic,1991; Ansari *et al.*,1992; Traicevski and Ward,2002.

vii. Control and Management: Thakur *et al.*,1984; Atiri *et al.*,1987; Chauhan *et al.*,1988;Gaffer *et al.*,1990; Lokhande and Mohan, 1990; Khurana and Kaushic,1991; Foster and Kelly,1991; Patro and Sontakke,1994;Abate and Ampofo,1996; Islam and Sardar,1997; Hossain *et al.*,2000; Ahamed *et al.*,2004; Hsu *et al.*,2005.

viii. IPM: Messina *et al.*,1985; Jackai and Singh,1991; Ahamed *et al.*,2004.

ix.Virus: Atiri *et al.*,1984; Atiri and Thottappilly,1985; Atiri *et al.*,1987.

x. EIL: Johnston and Bishoo,1987.

B.Bangladesh perspective

i. Survey/collection /records: Alam *et al.*,1964; Alam,1965a,b; 1967; 1970; Haque and Islam,1978a,b; Islam and Nasiruddin,1979; Islam and Sardar,1997; Das,1994; 2002; Ahmed *et al.*,2003.

ii. Biology: Alam, 1967.

ii. Ecology: Hossain *et al.*,2000; Das,2002.

iv. Control and Management: Islam and Nasiruddin,1979; Ahmed *et al.*,2003.

2. *Aphis gossypii* Glover

A. World perspective:

i. Survey/collection /records: Singh and Singh,1989.

ii. Population dynamics: Arauio and Sales,1985; Banerjee *et al.*,1986; Rai *et al.*,1989; Raj,1989b; Jamwal and Kandoria,1990; Verma and Parihar,1991(1995); Slosser *et al.*,1998; Karim *et al.*,2001., Lee *et al.*,2002; Steinkraus *et al.*,2002; Nag *et al.*, 2003; Rondon *et al.*,2005; Das *et al.*, 2006.

iii. Biology: Liu ,1987; Singh *et al.*,1988; Liu and Hwang,1991;Veeravel and Baskaran,1994; Wool and Hales,1996; Henneberry *et al.*, 2000; Wang *et al.*, 2001; Karim *et al.*, 2002; Satpathi and Mondal, 2006; Nonita *et al.*, 2006; Panja and Mondol, 2006.

iv. Control and management: Ullah and Paul,1985; Nagia *et al.*,1989; Singh and Singh,1989; Saito,1990; 1991; Chen *et al.*,1991; Jarende and Dethe,1994; Gopali

and Patil, 1994; Khan *et al.*,2003; Panja and Mandal,2006; Veeravel and Jeganathan, 2006.

v. IPM: Das, 2001.

vi. Host/Varietal preference: Reddy and Biradar,1990.

B. Bangladesh perspective:

i. Survey/collection /records: Das,1994.

ii. Population dynamics: Karim *et al.*,1994.

iii. Biology: Karim *et al.*, 1998; Samad *et al.*,2002.

3. *Lipaphis erysimi* (Kalt.)

A. World perspective:

i. Survey/collection/records : Raychaudhuri, 1980; Ganguli and Agarwala, 1985; Bakhetia and Sekhon, 1989; Khursheed *et al.*,2006; Gu *et al.*,2007.

ii. Biology : Sachan and Bansal 1975; Brar and Sandhu, 1978; Singh, 1992; Agarwala and Das, 1998; Pandey and Sachan, 2004; Kumar *et al.*, 2007.

iii. Ecology : Prasad and Phadke, 1983; Ram and Gupta, 1987; Singh *et al.*, 1993; Ghosh *et al.*, 2004.

iv. Population dynamics : Atwal *et al.*, 1971; Ghosh, 1980; Saharia, 1984; Prasad and Phadke, 1988; Singh *et al.*, 1989; Sinha *et al.*,1990; Ahuja 1990; Agarwala and Bhattacharya, 1994; Sekhon, 2001; Desh Raj *et al.*, 2002; Mishra and Kanwat, 2003; Prasad, 2003; Shukla and Kumar, 2004; Singh and Singh, 2004; Biradar and Dhanorkar, 2004; Chattopadhyay *et al.*, 2005; Rana, 2005; Ansari *et al.*, 2007; Singh *et al.*, 2007.

v. Chemical control : Chowdhury and Roy,1975; Prasad, 1979; Bakhetia,1984; Tripathi and Sachan, 1990; Zaman, 1990; Prasad, 1994; Liu and Chen, 2001b; Aslam and Ahmed, 2001; Afzal *et al.*, 2002; Sarwar *et al.*,2003; Singh, 2006.

vi. Biological control : Agrawala and Bhattacharya, 1999; Seema and Singh, 1999; Davi *et al.*,2001,Singh *et al.*, 2003; Omkar and Bind, 2004; Singh *et al.*, 2005; Rana, 2006; Singh, 2006.

vii. Cultural control : Bhattacharjee, 1961; Rawat *et al.* ,1968; Phadke, 1980; Ghosh and Ghosh, 1981;Phadke and Prasad, 1987; Chakraborty *et al.* ,1991; Bhadauria *et al.,* 1992; Upadhyay,1995; Singh *et al.*,2002; Singh, 2006.

viii. Botanical control : Singh and Sindhu, 1958; Singh *et al.* ,1988; Singh and Sachan, 1997; Srivastava and Kumar, 1999; Arya and Singh, 2001; Srivastava and Guleria, 2003; Dey *et al.,* 2005; Mishra *et al.*, 2006.

ix. Yield loss: Bakhetia, 1983; Singh *et al.,* 1983; Singh *et al.,*1984; Brar *et al.*, 1987; Singh and Sachan, 1994,1995; Patel *et al.*, 2004.

x. Intercropping : Banik *et al.,* 2000; Mishra *et al.,* 2001; Tahir *et al.,* 2003.

xi. EIL and ETL : Bath and Sing, 1989; Subhash *et al.*,1994; Mishra, 1995; Sigh and Sachan, 1997; Singh and Malik, 1998.

xii. Functional response: Sinha *et al.*, 1982; Shukla *et al.*,1990; Kumar *et al.*, 1999; Siddiqui *et al.,* 1999; Kumar *et al.*, 2002; Srivastava and Srivastava, 2003; Rana, 2006.

Xiii. Plant varieties : Prasad and Phadke, 1983; Singh and Singh, 1987; Bhadauria *et al.,* 1995; Agarwal *et al.,* 1996; Jatoi *et al.*,2002; Aslam *et al.,* 2004; Rana, 2005.

XIV. Host/Varietal preference: Munmun *et al.*, 2007.

XV: Management : Aslam and Rajaq ,2004.

B. Bangladesh perspective:

i. Survey/collection/records : Alam *et al.*, 1964, Alam,1967, 1969; Ahmed *et al.*, 1989; Gapud, 1992; Das, 1994; 2002; Rahaman and Mannan, 1994; Aslam and Bashar, 2001.

ii. Biology : Mondal *et al.*, 1992; Sarker *et al.*, 1993; Kundu *et al.,* 1997; Kundu *et al.*, 2002.

iii. Ecology : Mondal and Kar, 1983; Rahman *et al.*, 1983a; Ashraf and Das, 1998; Hannan *et al.*, 1998; Biswas *et al.* ,2000.

iv. Population dynamics : Kabir *et al.* 1984; Rahman *et al.*1985; Rahman *et al.* 1989; Islam *et al.,* 1991; Biswas and Das, 2000; Biswas *et al.* 2000.

v. Chemical control : Alam *et al.*, 1964; Ahmed and Mannan, 1977; Ahmed *et al.*, 1977; Haque *et al.,* 1979; Islam *et al.*, 1990; Begum *et al.*, 1991; Rouf and Kabir, 1997; Mannan *et al.*, 2002.

vi. Biological control : Islam and Nasiruddin ,1976,1979; Malek *et al.*, 1984; Rahman, 1984; Rahman *et al.,* 1985.

vii. Cultural control : Rahman *et al.*, 1988; Biswas, 1989; Kabir *et al.*, 1989; Rahman *et al.* ,1989; Karim *et al.,* 1990; Islam *et al.*, 1991; Mondal *et al.*, 1999a,b,c,d; Biswas *et al.*, 2000; Biswas *et al.* ,2002; Ahmed *et al.,* 2005.

viii. Botanical control : Kabir and Mia, 1987.

ix. Plant varieties : Begum *et al.*, 1990; Mondal *et al.* ,1992; Husain and Shahjahan, 1997.

x. EIL : Begum ,1995.

4. Natural enemies

A. World perspective :

Ibrahim,1955; Hagen, 1962. Alam and Hafiz, 1963; Rawat and Modi,1969; Parker and Sing,1973; Hukusima and Takeda,1975; Roy,1976; Radke *etal.*,1977;SamloandMahendranath,1977;MishraandSatpathy,1984,Honek,1985;A miad *et al.*,1987; Ngammuang,1987; Agarwala *et al.*,1988; Debraj and Singh, 1989; Chen *et al.*,1989; Lokhande and Mohan 1990; Frazier and McGreor,1992; Singh and Deol,1993; Patro and Sontakke,1994; Sing and Sing,1994a; Hodek and Honek,1996; Jagadish *et al.*,1996; Agarwala and Bhattacharya,1999; Evans, 2000; Michuad, J. P., 2000; Omkar and Parvez,2000; Isikber and Copland, 2001; Mollah *et al.*,2001; Reddy *et al.*,2001; Stamp,2001; Koch,2003; Omkar and Srivastava,2003; Srivastava and Srivastava,2003; Evans *et al.*,,2004; Soares *et al.*, 2004; Nelson *et al.*,2004; Tsaganou *et al.*,2004; Evans and Gunther, 2005; Katsarou *et al.*,2005; Mari *et al.*, 2005; Omkar,2005; Omkar and James,2005; Isikber,2005; Frechette *et al.*, 2006; Gupta *et al.*,2006; Khursheed *et al.*, 2006; Nelson and Rosenheim,2006; Rana,2006; EI-Gawad and EI-Zoghbey,2009.

B. Bangladesh perspective:

Islam and Nasiruddin,1976, 1978, Haque and Islam,1978a,b; Islam and Nasiruddin 1979;Quayum *et al.*,1979; Ali *et al.*,1981; Rahman *et al.*,1983a, b;1984,1987, Rahman and Quayum,1987; Rahman *et al.*, 1988a,b; 1990a,b; 1991; Ali,1991; Das,1991;Das *et al.*,1992, Khan and Mannan,1991; Rahman *et al.*,1993; Das,1994; Ashraf *et al.*,1994; Prodhan *et al.*,1995; Islam and Sardar,1997; Ashraf and Das,1998; Haque and Islam, 2008.

CHAPTER 1

Population dynamics of bean aphid, *Aphis craccivora* Koch, brinjal aphid, *Aphis gossypii* Glover and mustard aphid, *Lipaphis erysimi* (Kalt.)

1.1. Introduction

Insect populations are groups of individuals set in a frame that is limited in time and space (Pedigo, 2004). Population dynamics is the study of abundance and distribution of organisms and factors that regulate populations in space and time (Williams *et al.*, 2002). Fluctuations in population size are caused by changes in birth, death, immigration, and emigration rates (Begon *et al.*, 1996). These vital rates, in turn, vary with biotic factors such as predation and competition and with abiotic factors such as extreme weather conditions (Williams *et al.*, 2002). Population dynamics involves five basic component of interest to which all changes in populations can be related: Birth, death, sex ratio, age structure and dispersal (Yazdani and Agarwal, 1997).

Many factors influence the population dynamics of aphids such as the strong seasonality of their host plants (Sequeira and Dixon, 1997) and climate (Singh and Sharma, 2002), and their vulnerability to a wide range of natural enemies (Hughes, 1988). Characteristic aphid biology, such as parthenogenesis (Kindlmann and Dixon, 1989), telescoping of generations (Dixon, 1985) and polymorphism, not only provides the means by which an aphid population responds to complex and rapidly changing environmental opportunities and constraints (Day *et al.*, 2004). Aphids have an immense capacity for population increase (Karley *et al.*, 2004).

The knowledge on population dynamics is a basic tool for establishing an IPM package against a pest insect associated with cultivated plants. (Imai, 1984; Chon *et al.*, 2000). Investigations on patterns of population fluctuations through time and the processes responsible for such variations are crucial to predict periods of high abundance and to assess the role of the natural control agents in the observed dynamics. The low complexity shown by agro-ecosystems compared to natural systems make them very adequate tools for the assessment of theoretical concepts on population ecology. This potential contribution, in turn, provides feedback for applied entomology (Canto-Silva and Romanowski, 2003).

Many workers studied the population dynamics of *A. craccivora, A. gossypii* and *L. erysimi* throughout the world which are already mentioned in Review of

Literatures . In Bangladesh, works on population dynamics of *A. craccivora* is all most nil till today, very few on *A. gossypii* and *L. erysimi* (Karim *et al.*,1994, 2001; Islam *et al.*, 1991; Sarker *et al.*, 1993; Biswas *et al.*, 2000 and Biswas and Das 2000). But none of them worked on the present varieties of the said crops. The objective of the present study is therefore to have an idea on the population of *A. craccivora* infesting bean, *A. gossypii* infesting brinjal and *L. erysimi* infesting mustard and to identify the causes of their numerical changes and to explain how these causes act and interact to produce the observed pattern of numbers.

1.2. Materials and Methods

An experiment was conducted in the research field of I.B.Sc., Rajshahi University during the period from September 2003 to January 2004 to study the population dynamics of bean aphid, *A. craccivora,* brinjal aphid, *A. gossypii* and mustard aphid, *L. erysimi* and their natural enemies. Seeds of the aforesaid crops (Var. BARI Seem - 1, BARI brinjal Nayantara and BARI Sharisha -6) were collected from BARI, Joydebpur ,Gazipur. The seeds and seedlings of bean and brinjal were sown on September, 2003 in separate fields. The size of each field was 20 m^2. Spacing between plants and rows for bean and brinjal were maintained as 1.5×2.0 and 0.6× 1.0 meters respectively. The seeds of mustard were sown in the field of same size during October of the same year. Here, the spacing were 30 cm and 15 cm for rows and plants respectively. During field preparation 15 ton cow dung ,250 Kg Urea,150 Kg TSP, 125 Kg MP per hectare for brinjal as per Rashid(1993) and 250-300Kg Urea,170-180Kg TSP,85-100Kg MP(Mondal and Wahhab, 2001) for mustard were applied as biological and chemical fertilizers. Two times irrigation only in mustard field were done, first one was immediately before the flowering and second one was immediately before the pod formation. Temporary scaffold for bean plants was made for their raising on it. Regular observations were made on aforesaid crops in order to notice the presence or absence of aphids and natural enemies. Counting started immediately after their appearance (first week of November,2003) and continued till the end of January, 2004. Different morphs of aphids (nymphs, apterae and alatae) and natural enemies (larvae, pupae and adult) were counted weekly from randomly selected 10 plants of each crop from four corners and middle (two from each site) .

For bean and mustard three types of leaf (young, mature and old) plus apical twigs of 5 cm in length from each plant and only above three types of leaf for brinjal were selected for counting of aphids. In case of thick colonies aphids were dislodged from the above mentioned plant parts by means of a camel hair brush (0 size) on a white sheet and counted. After counting the aphids were cautiously kept in their previous position on the plant. The plants observed once were not taken for subsequent observation. Weather data *viz.*, temperature, relative humidity, dew point and rainfall of the experimental period were obtained from the nearby Meteorology station, Shympur, Rajshahi, Bangladesh.

Data analysis:

Impact of physical factors of the environment, *viz.*, temperature, relative humidity, dew point and rainfall on the population of aphids and their natural enemies were investigated using simple correlation co-efficient ('r') analysis. Regression lines were drawn only in case of significant relationships ($P<0.01$ and $P<0.001$).

1.3. Results

Weekly population (from 1st week of November, 2003 to 4th week of January 2004) of bean aphid ,*A craccivora* , brinjal aphid, *A. gossypii* and mustard aphid, *L. erysimi* along with their natural enemies in terms of environmental parameters *viz.*, temperature, relative humidity, dew point and rainfall are plotted in Figs. 1, 2 and 3 respectively. Population of *A. craccivora* was highest (71.66±1.67 per twig)in the 3rd week of December,2003 and lowest (9.00±0.58 per twig) in the 1st week of November,2003 (Fig.1).Population of *A. gossypii* was highest (17.00±1.16 per plant) in the 4th week of December ,2003 and lowest (2.00±0.58 per plant) in the 4th week of January, 2004 (Fig.2) and the population of *L. erysimi* reached to its peak (43.00±1.53 per twig) in the 4th week of December 2003 and lowest (9.66± 0.33 per twig) in the 2nd week of November, 2003 (Fig.3).

During the whole study period atmospheric temperature decrease more or less regularly except 3rd week of December, 2003; 2nd and 3rd week of January 2004 (Figs.1-3). But in the case of relative humidity a number of peaks (about 3) were recorded

Table 1. Correlation co-efficient (r- values) and regression equation of population of natural enemies and aphids, *Aphis craccivora* Koch, *Aphis gossypii* Glover and *Lipaphis erysimi* (Kalt.) infesting bean, brinjal and mustard plants respectively along with prevailing temperature(^{0}C),relative humidity(%),dew point(^{0}C),and rainfall(in mm).

Aphid	Variables	Correlation co-efficient (r- values)	Regression equation
Aphis craccivora Koch	Temperature and NAPP	0.39	
	Relaive humidity and NAPP	-0.18	
	Dew point and NAPP	-0.37	
	Rainfall and NAPP	-0.37	
	Temperature and NAE	0.34	
	Relaive humidity and NAE	-0.42	
	Dew point and NAE	-0.54	
	Rainfall and NAE	0.38	
Aphis gossypii Glover	Temperature and NAPP	0.26	
	Relaive humidity and NAPP	-0.10	
	Dew point and NAPP	-0.40	
	Rainfall and NAPP	-0.51	
	Temperature and NAE	0.17	
	Relaive humidity and NAE	-0.22	
	Dew point and NAE	-0.81**	Y=21.208-4.144x; R^2=.6629
	Rainfall and NAE	0.31	
Lipaphis erysimi (Kalt.)	Temperature and NAPP	0.12	
	Relaive humidity and NAPP	-0.29	
	Dew point and NAPP	-0.75*	Y=21.238-0.2597x; R^2=0.5561
	Rainfall and NPP	-0.22	
	Temperature and NAE	0.40	
	Relaive humidity and NAE	-0.42	
	Dew point and NAE	-0.31	
	Rainfall and NAE	-0.44	

*P<0.01; **P<0.001; NAE=Natural enemies; NAPP=Number of aphid per plant

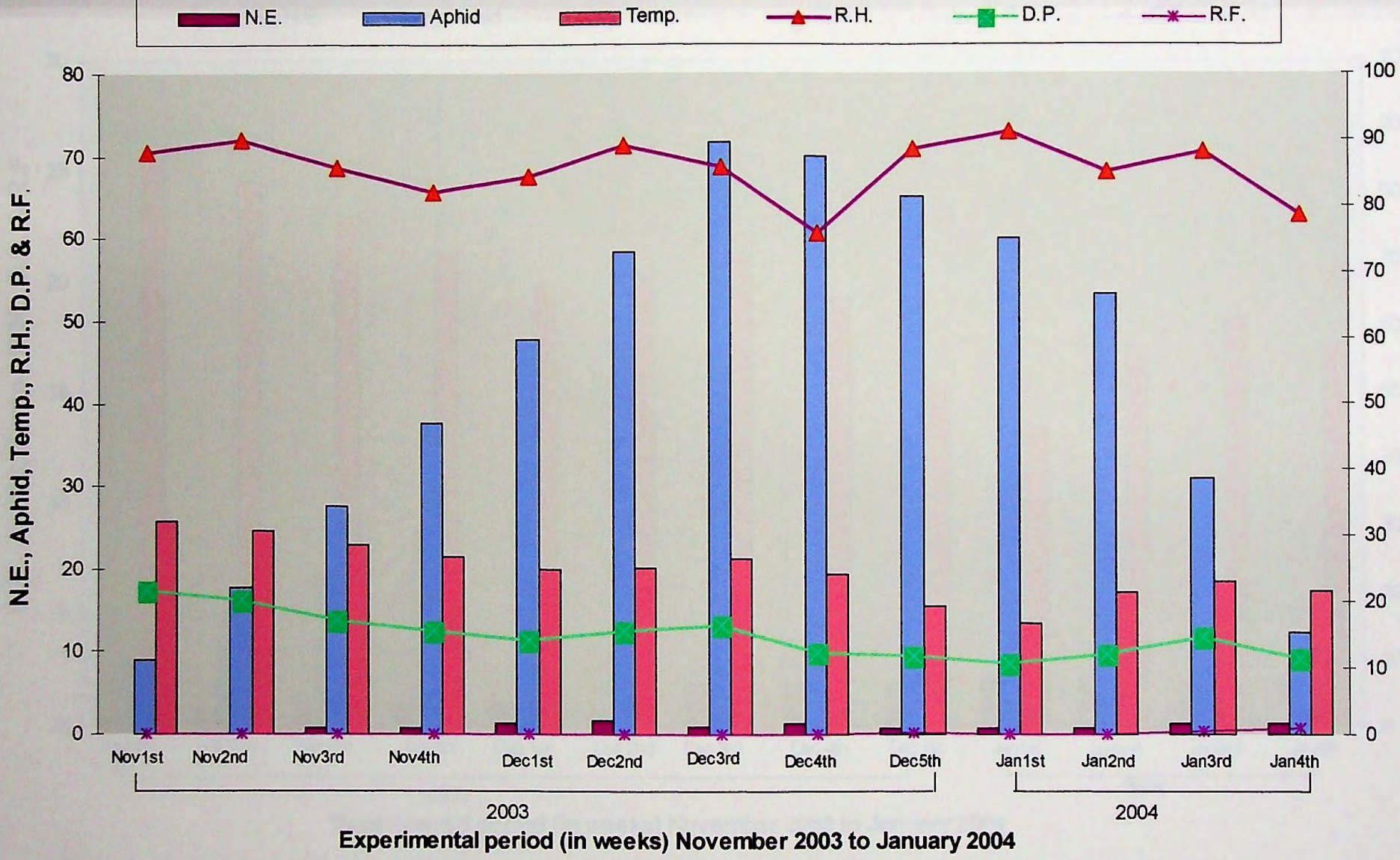


Figure 1: Weekly Population of bean aphid, *Aphis craccivora* Koch and their natural enemies (N.E.) along with prevailing temperature (Tem.^{0}C), relative humidity (R.H.%), dew point (D.P. ^{0}C) and rainfall (R.F. mm) for thirteen weeks.

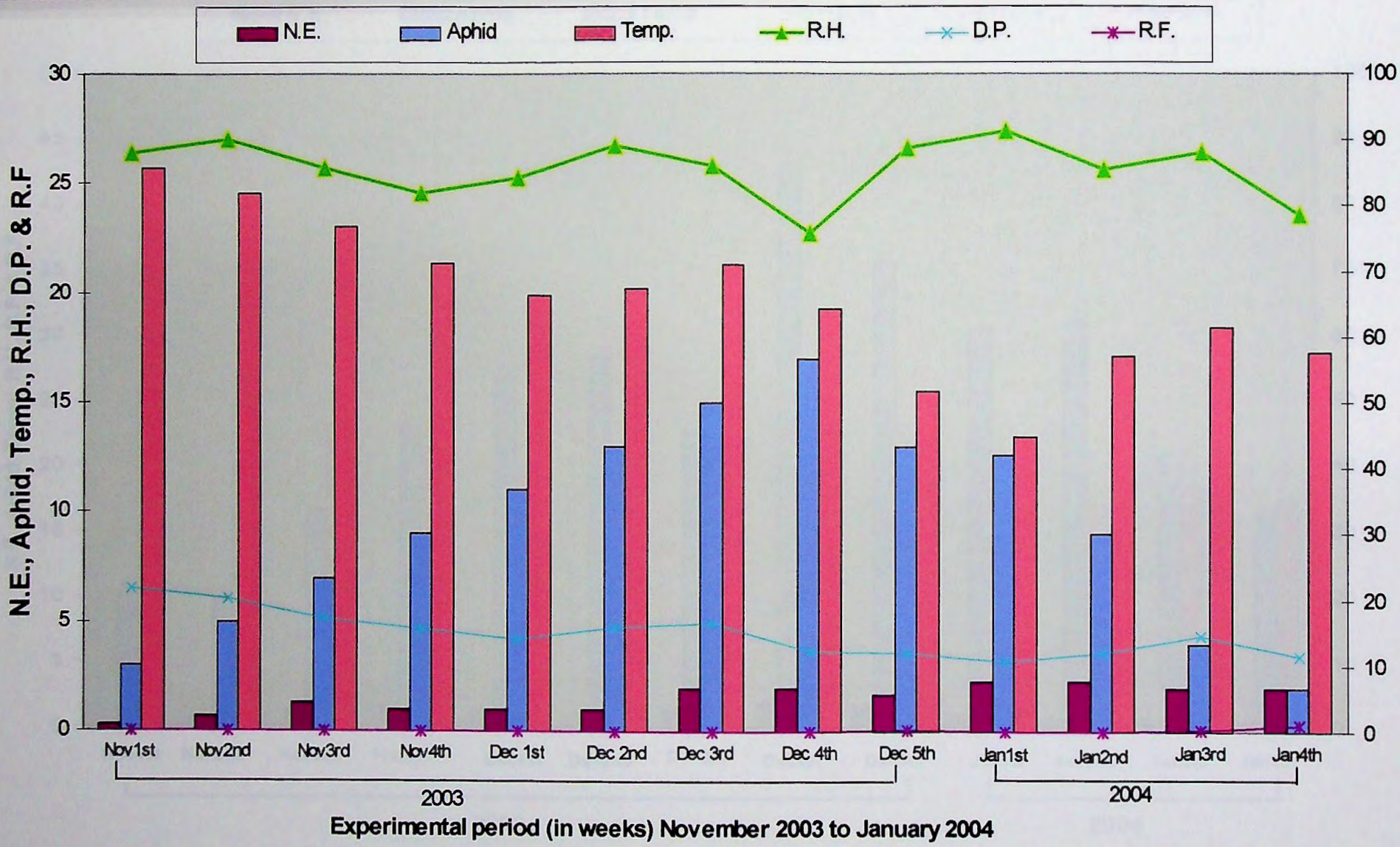


Figure 2: Weekly Population of brinjal aphid, *Aphis gossypii* Glover and their natural enemies (N.E.) along with prevailing temperature (Tem.^{0}C), relative humidity (R.H.%), dew point (D.P.^{0}C) and rainfall (R.F. mm) for thirteen weeks.

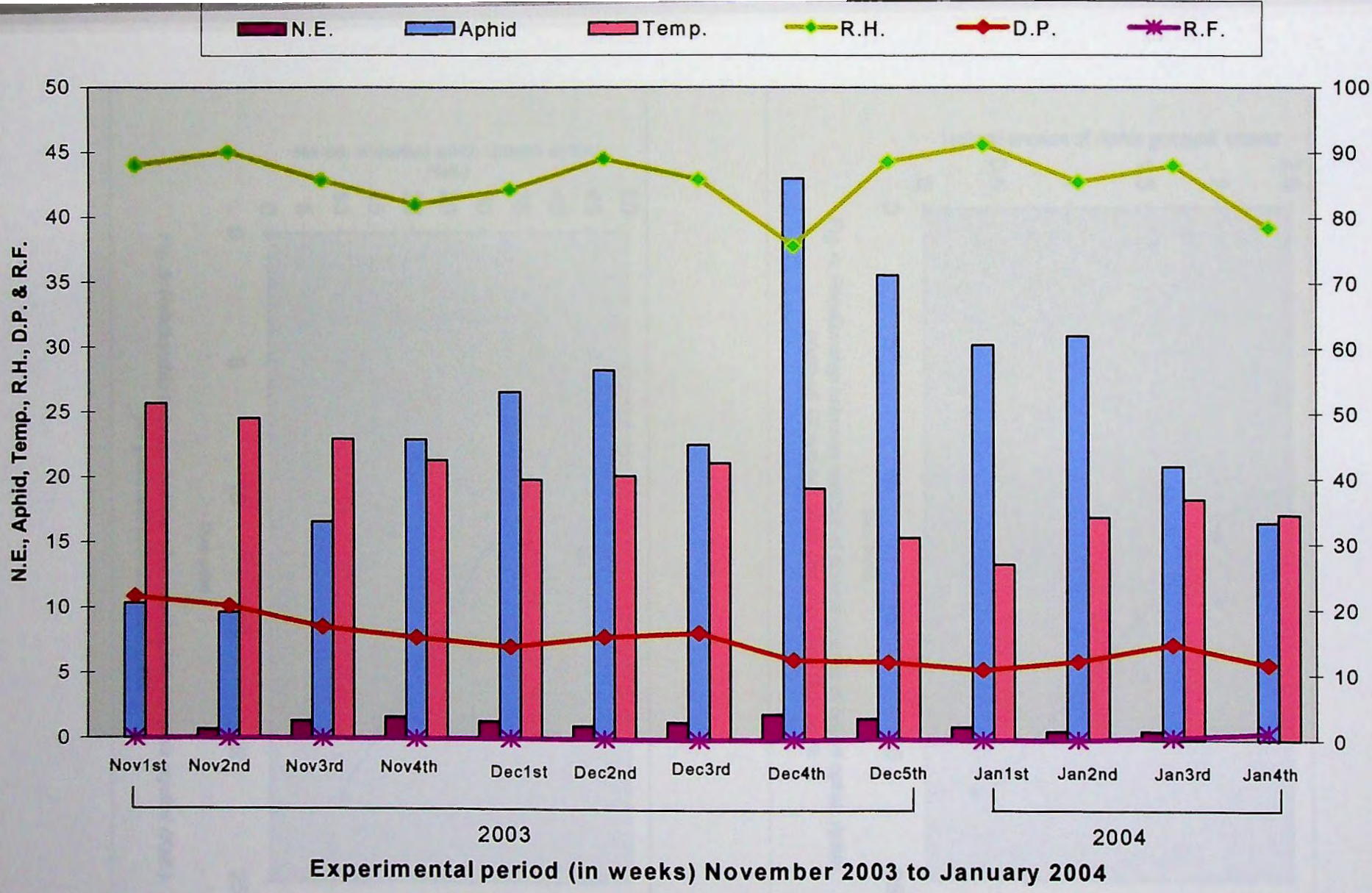


Figure 3: Weekly Population of mustard aphid, *Lipaphis erysimi* (Kalt.) and their natural enemies (N.E.) along with prevailing temperature (Tem.^{0}C), relative humidity (R.H.%), dew point (D.P. ^{0}C) and rainfall (R.F. mm) for thirteen weeks.

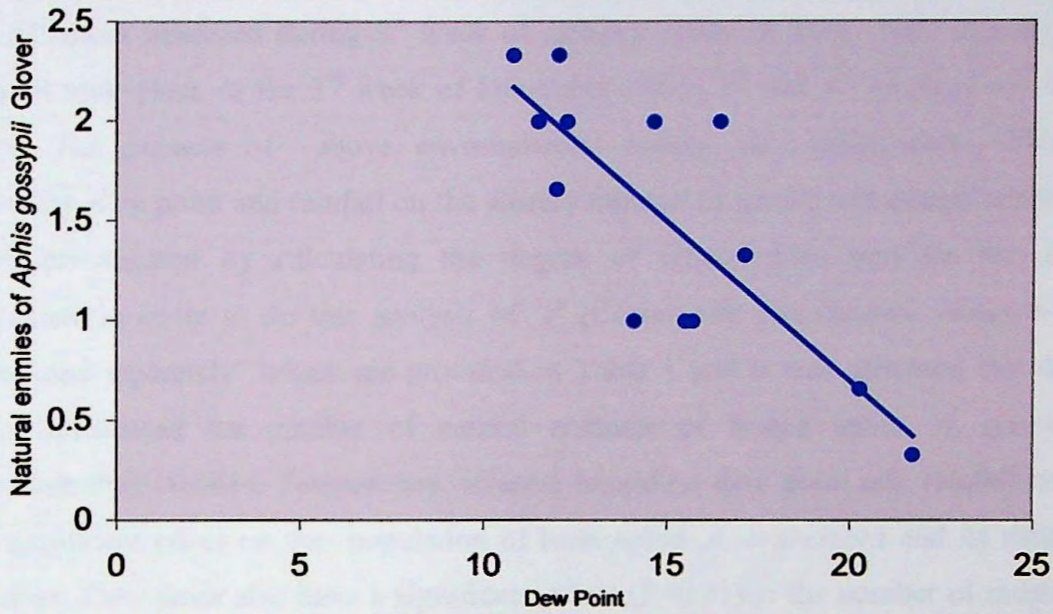


Fig. 4: Relationship between number of natural enemis of brinjal aphid, *Aphis gossypii* Glover per plant and prevailing dew point.

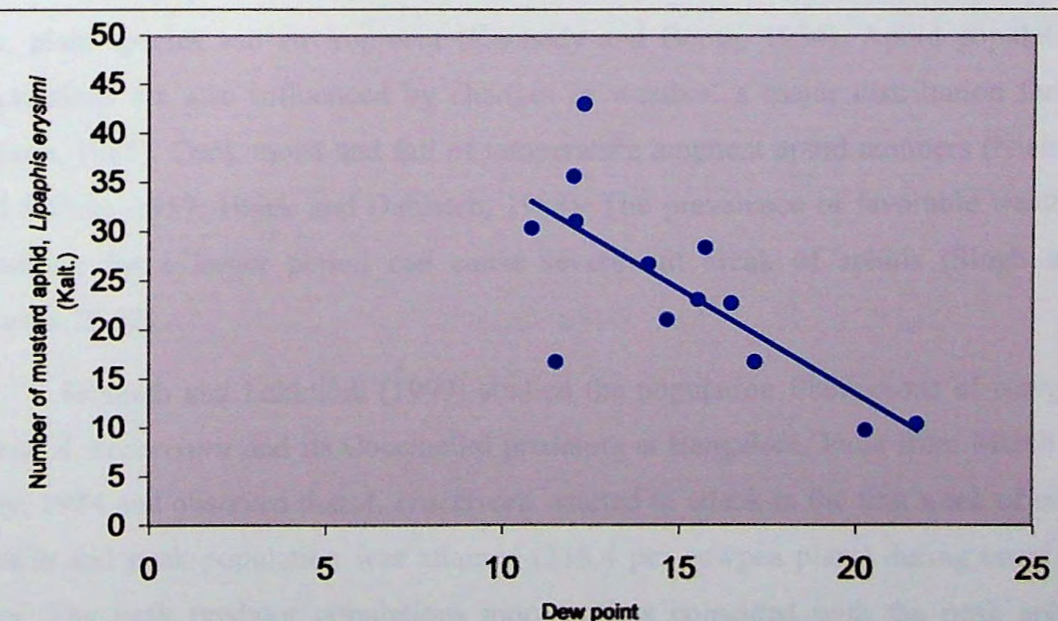


Fig. 5: Relationship between number of mustard aphid, *Lipaphis erysimi* (Kalt.) per plant and prevailing dew point.

during the experimental period. Of them highest peak of relative humidity (91.21%)was observed during 1st week of January ,2004. A very little amount of rainfall took place in the 3rd week of December 2003; 3rd and 4th week of January 2004. The impacts of above environmental factors *viz.*, temperature, relative humidity, dew point and rainfall on the weekly number of aphids and natural enemies were investigated by calculating the degree of relationships between the said variables. In order to do this analysis of 'r' (Correlation co-efficient) values were calculated separately which are provided in Table 1 and it was observed that dew point influenced the number of natural enemies of brinjal aphid, *A. gossypii* significantly($P<0.001$). Temperature, relative humidity, dew point and rainfall have no significant effect on the population of bean aphid ,*A. craccivora* and its natural enemies. Dew point also have a significant effect ($P<0.01$)on the number of mustard aphid, *L. erysimi*. The regression lines are drawn only in the case of significant relationships (Figs. 4 and 5).

1.4. Discussion

Aphid population on plant is determined by nutrition, natural enemies, plant age, plant species and environment (Kennedy and Booth, 1954). Aphid population fluctuations are also influenced by changes in weather, a major distribution factor (Dixon, 1985). Cool, moist and fall of temperature augment aphid numbers (Nielson and Barnes, 1957; Hajek and Dahlsten, 1988). The prevalence of favorable weather condition for a larger period can cause severe out break of aphids (Singh and Sharma, 2002).

Srikanth and Lakkundi (1990) studied the population fluctuations of cowpea aphid, *A. craccivora* and its Coccinellid predators at Bangalore, India from March to May, 1984 and observed that *A. craccivora* started to attack in the first week of crop growth and peak population was attained (318.4 per cowpea plant) during onset of May. The peak predator populations more or less coincided with the peak aphid population and thus demonstrated a prey dependant predator growth. From the experiment on cowpea, Saharia (1980) also indicated the potential of this aphid to multiply and spread in a short time span with the availability of sufficient space and

nutrients in the plant materials. Worked on the seasonal variations of *A. craccivora* on cowpea at Kangbai (500 m above MSL) and Mao (2000 m above MSL) in Manipur ,North Eastern region of India revealed that infestation started right from the seedling stage in April, attained peak in May and then slightly declined during June in both the areas. Once again the aphid number showed an increasing trend in July and subsequently decreased in August (Hizam and Singh, 1989).Decrease in the number of aphids in June might be due to the adverse effect of rainfall which was 40 cm and 17 cm , at Mao and Kangbai respectively. The study also revealed that the minimum temperature within the range of 17-20^{0}C, maximum temperature 29-32^{0}C, R.H. between 77-83% and rainfall less than 4 cm were optimum for build up of *A. craccivora* at Kangbai station. But at Mao the aphid population reached maximum during May with minimum temperature of 10-13^{0}C and maximum of 24-27^{0}C, R.H. between 77-82% and rainfall 5 cm. Because of the difference in agro-climatic conditions, altitudes of the area, and cultivar of the host plant, results of the present study disagreed with the findings of Hizam and Singh (1989). Lal *et al.*,(1989) come to a conclusion from their study, population of *A. craccivora* on chickpea are influenced by cultivar and planting density. The highest and lowest number of aphids was found on the cultivars 2184B (7.62/twig) and 75-35 (3.25/twig) respectively. Fewer aphids were found on plants sown on 30 cm ×10 cm apart than on plants sown on 60 cm ×20 cm apart which is quite reverse with the results of Lee *et al.*, (2002) who detected population of *A. gossypii* on Chilli was significantly higher ($P<0.05$)in the dense planting than in the sparse Chilli planting density.

A. gossypii was found throughout the year on brinjal plant at Bhubaneswer and their heaviest infestation occurred during September to November (Roy and Behura, 1979).Karim *et al.,* (1994) worked on the population of *A. gossypii* on egg plant, *Solanum melongena* L. interms of weather parameter from October 1992 to March 1993 at Rajshahi, Bangladesh and observed maximum number of aphids during January,1993 when average temperature, R.H., dew point , sun light and rainfall were obtained as 16.55^{0}C, 74.55%, 12.40^{0}C, 6.43 (hour) and 0.00 mm respectively. They also mentioned aphid began to appear during October, 1992 and disappeared during March, 1993. The 'r' values for temperature and rain fall showed significant ($p<0.05$) effect on the population growth of the aphid. But in the present study peak population

of *A. gossypii* (17.00±1.16/plant) was obtained in the 4th week of December, 2003 when average temperature, R.H., dew point , and rainfall were noticed as 19.32^{0}C, 75.72%, 12.29^{0}C and 0.00 mm respectively. Slosser *et al.* (1992) observed that the population of *A. gossypii* increased rapidly during August only in June planted cotton, which suggests that time of year interacts with plant age to influence population development. The number of *A. gossypii* on brinjal plant decreased gradually in older leaves and increased in younger leaves towards harvest(Banerjee and Raychauduri ,1987).From a twelve years (1972-1983) study of Raj (1989b), highest population build up (745 aphids/100 leaves) of *A. gossypii* infesting potato Var.Kufri Bahar was observed in Deccan Plateau during 3rd Std. week in January in early rabi crop (planted on first week of November) when average temperature was ranging from 10.7^{0}C- 29.9^{0}C and R.H. between 31-81%. The population development was low in kharif (planted on first week of July) and late rabi crop(planted on middle of December).The kharif crop was subjected to high temperature and intermittent rains. Jamwal and Kandoria (1990) observed the appearance and build up of *A. gossypii* on june planted brinjal Var. Chamkila from July 1986 to December 1986 at Punjab and found that the population varied from 2 to 84 aphids/30 plants from the end of July to end of August. The population reached it's peak by the third week of September and started decreasing drastically from fourth week of September onwards. Maximum activity of the aphid was recorded in September when the average temperature and relative humidity varied from 27.2-29.7^{0}C and 68-73% respectively. Five years (1983-87) mean data on the population of *A. gossypii* in relation to weather factors showed that it appeared on potato at emergence stage during 45th Std. week (November) and attained two peaks, first with low population (13 aphids /100 leaves) in 48th Std. week (December) and second with high incidence (86.8 aphids /100 leaves) during 5th Std. week (January). It's population started declining considerably from 6th Std. week (February) and almost disappearing from 11th Std. week (March).Significant negative correlation with maximum (-0.484) and minimum temperatures (-0.574) and non significant negative correlation with relative humidity (-0.311) and aphid population were also observed (Verma and Parihar,1995). Populations of *A.gossypii* on strawberries grown in green house were monitored twice weekly from January to May during 2002 and 2003 at University of Florida. The average temperature in the

green house during this experiment was 22 and 16^{0}C day and night respectively. In both the years, number of aphids on bud were greater than on the leaves (Rondon *et al.*, 2005). In 2002, two peaks were observed on bud on 15th February (24.65±9.87 aphids/plant) and 15th March (56.40±11.35 aphids/plant).But in 2003, one peak was observed on bud on 15th February (33.16±2.89 aphids/plant) .

Observation on the incidence of *L. erysimi* on mustard in two rabi seasons (1986-87 and 1987-88) at Haryana, India indicated that incidence initiated from mid November to early December and peak incidence occurred during second fortnight of February to first fortnight of March when 85 to 200 aphids/10 cm main shoot were recorded (Yadav and Kalra,1990). In India and Bangladesh where more or less similar ecological zones are present, *L. erysimi* appears there in the field during the first week of November and goes its peak during January and is disappeared by February (Das, 2002; Singh and Sharma, 2002 and Bakhetia and Sidhu, 1983). Early sown varieties are less susceptible for aphid infestation in comparison to late sowing varieties (Singh *et al.*, 1984; Singh and Bakhetia, 1987; Bakhetia and Sekhon, 1989; Patel, 2004; Singh and Dhaliwal, 2004).Bakhetia and Sidhu (1983) recorded the high population of *L. erysimi* up to second week of February (122.30 aphids/plant on 11 February, 1978) after which it decreased suddenly(27.17 aphids/plant on 18 February, 1978). They mentioned that this sharp decline was due to 33 mm rainfall received from 12-17 February, 1978. Bakhetia and Sidhu (1983) also reported that the aphid colonies were dislodged and killed by the continuous rainfall for 4-5 days. In their studies (Bakhetia and Sidhu, 1983), the aphid did not build-up higher proportions in the subsequent weeks contrary to the earlier report by Atwal *et al.*, (1971).According to Saharia (1984) population of *L. erysimi* attained it's peak during mid-January to mid-February in Jorhat, Assam, India, and population variation had relationships with that of the reproductive rate of the aphid and the abundance of its predator, *Coccinella repanda*. Pandey *et al.*, (1986) recorded higher population of *L. erysimi* during 3rd week of December and the first week of January in India and mentioned that the most favourable temperature and R.H. for population build up of the said aphid was 15°C to 20°C and 60% to 70% respectively.

It was observed from the study of Biswas and Das (2000), infestation of *L. erysimi* was first noticed in the first week of January in 1997, while in 1998, it was in

the third week of January in Gazipur, Bangladesh. The peak population was recorded by them during 8th February in both 1997 (98.26 aphids/plant) and 1998 (76.22 aphids /plant). The ambient sunshine (5.76 to 8.6 hr), relative humidity (62.00%-74.28%) and maximum temperature (23.66^{0}C to 25.37^{0}C) during January to February was congenial for aphid multiplication, while the activity of aphids ceased at 52.43% relative humidity and below (Biswas and Das, 2000).Rana *et al.*, (2001) studied the population of *L. erysimi* in Garhwal Himalayas, India and observed that it's population rapidly increased and reached first peak during last week of December at 24^{0}C temperature and 72% relative humidity. Mishra and Kanwat (2003) worked on the population build-up of *L. erysimi* infesting Indian mustard (*Brassica juncea* Var. Varuna) during 2000-2001 and 2001-2002 in Jobner, Rajasthan, India. They found that *L. erysimi* was most abundant during the last week of January. The peak population in 2001 and 2002 was observed under mean maximum temperatures of 23.1°C and 21.4°C, mean minimum temperatures of 1.4°C and 3.7°C, and mean relative humidities of 53% and 59%, respectively (Mishra and Kanwat, 2003). They mentioned that the aphid population declined sharply in the first week of February when the temperature was high. A negative correlation was observed between aphid population and maximum and minimum temperatures, whereas a significant positive correlation was observed between aphid population and relative humidity (Mishra and Kanwat, 2003). Talpur and Khuhro (2004) studied the relative occurrence and abundance of mustard aphid (*L. erysimi*) in Sind, Pakistan, during 2000-01 and revealed that the aphid appeared on rape leaves during the 3rd week of January and on the inflorescences during the 2nd week of February and continued up to harvesting on both the cultivars (Rainbow and Oscar).They mentioned that peak populations per leaf and per inflorescences on the Rainbow (42.7 and 7.5, respectively) and Oscar (28.7 and 6.6, respectively) cultivars. They recorded the highest mean population ranges per leaf and per inflorescences on Oscar (9.2-28.7 and 3.9-6.6, respectively) and Rainbow (25.1-42.7 and 2.3-7.6) were from 15 February to 5 March. The temperature range of 16.5 ^{0}C to 20.6 ^{0}C seems to have favoured the pest multiplication. Chattopadhyay *et al.*, (2005) observed the appearance of *L. erysimi* on the inflorescences of the mustard plants in few places of India (Bharatpur, Pantnagar, Berhampur, Mohanpur, New Delhi, S.K. Nagar, Kangra and Sriganganagar). They observed that *L. erysimi* population was positively

correlated to a maximum temperature between 20–29 ^{0}C in the preceding week and also to a morning R. H. Long hours of leaf wetness and minimum temperature >5^{0}C also favoured aphid infestation (Chattopadhyay *et al.*, 2005).Ansari *et al.*, (2007) carried out an experiment on the population dynamics of *L. erysimi* in Serwar, Bharatpur, India and observed that *L. erysimi* appeared in the fields on 11th January and disappeared after 2nd March. The peak aphid population was found at a maximum, minimum and average temperature of 23.37 ^{0}C, 6.87 ^{0}C and 15.76^{0}C respectively and the mean relative humidity of 54.75%. Thereafter their population declined, simultaneously increased predator (*Coccinella* spp.) population. They found that maximum and average temperature had positively non-significant effect while minimum temperature caused negatively non-significant effect on the population of aphid. Relative humidity had a negative effect. In the present study, the impact of environmental factors on the population of *A. craccivora*, *A. gossypii, L. erysimi* and their natural enemies was insignificant almost in all cases ,which should not have been so. Only the dew point have negatively significant effect on the population of *L. erysimi* and natural enemies of brinjal aphid, *A. gossypii* and coincided with results of Singh and Singh (1994b) who did not find any significant relation between most of the abiotic factors except evening R.H. and population of *L.erysimi* infesting mustard and rapeseed Var. 'RH 30' and 'BSH-I' respectively in India.

CHAPTER 2

Natural enemies of bean aphid, *Aphis craccivora* Koch, brinjal aphid, *Aphis gossypii* Glover and mustard aphid, *Lipaphis erysimi* (Kalt.)

2.1. Introduction

There is an increasing interest in the role of natural enemies (predators, parasitoids and pathogens) in limiting aphid populations (Singh and Sharma, 2002). This interest has been stimulated by costly outbreaks of aphid pests and serious concern over the use of toxic chemicals to control these insects. The wide spread use of insecticides has damaged the environment selected for resistant strains of aphids and increased production costs. Further more the careless application of pesticides directly endangers the health of man and his domestic animals. Approximately 18,902.50 metric tons of formulated pesticides were used in Bangladesh in the year 2000, costing about Tk.3002.56 million in agriculture purpose (Anonymous, 2001).Our farmers are becoming poorer and crops vulnerable to pest attack and diseases. Because of these drawbacks the need of researches on natural enemies as bio regulators aphids is voiced by many individuals in home and abroad (Rahman *et al.*,1991; Omkar and Parvez, 2000; Reddy *et al.*,2001; Srivastava and Srivastava, 2003; Omkar and James, 2005; Gupta *et al.*,2006; Frechette *et al.*,2006; Haque and Islam,2008; EI-Gawad and EI- Zoghbey, 2009). Greater use of biological agents in IPM programme may ensure satisfactory yields and reduce the harmful effects of recent agricultural practices on the environment. Moreover increased utilization of natural control agents for aphid pests would reduce costs associated with the use of insecticides (Chhabra and Kaur, 1994).

A good number of workers studied different aspects of the biology of various species of coccinellid beetles as predators of aphids throughout the world of which the few important ones are: effect of temperature and humidity on the larval development of *Coccinella transversalis* (Fabr.) (Ashraf *et al.,* 1994); life history and feeding habit of *Harmonia octomaculata* (Fabr.) (Rahman *et al.*, 1983b); predatory efficiency of the larvae of *Coccinella transversalis* (Fabr.) (Debraj and Sing, 1989); life history and feeding habit of *Micraspis discolor* (Fabr.) (Rahman, 1991); cues for oviposition by lady bird beetles (Evans and Dixon, 1986); biology of *Micraspis discolor* (Fabr.) (Prodhan *et al.*, 1995); functional response of *Coccinella septempunctata* L.

(Srivastava and Srivastava, 2003); Pray preference of *Cheilomenes sexmaculata* (Fabr.) (Omkar and Bind, 1998); biology and feeding potential potential of *Cheilomenes sexmaculata* (Reddy *et al.*, 2001); vertical distribution of aphidophagous coccinellids (Shantibala *et al.*, 1991); seasonal abundance of aphids infesting potato crop (Raj, 1989a); performance of *Coccinella septempunctata* L. to varying prey densities (Bilashimi *et al.*, 2006) etc. Despite these publications, works on the species composition of natural enemies (predators, parasitoids and pathogens) of aphids are some what scanty in this country except one or two stray papers published by Alam *et al.*, 1964; Kabir, 1975; Das, 1994. Most of our ignorant farmers are not well acquainted with the natural enemies of pest, they are accustomed to use pesticides indiscriminately without monitoring the pest populations above economic threshold level (ETL)as well as consulting experts of this line. The present study was therefore undertaken to have an idea regarding species diversification of natural enemies of aphids infesting bean, brinjal and mustard crop respectively. The out comes of the present study would be helpful to formulate am IPM program against specific aphid species utilizing natural enemies.

2.2. Materials and Methods

Collection, preservation and identification of specimens:

An experiment was conducted to explore the species composition and relative abundance of natural enemies of *Aphis craccivora* Koch; *Aphis gossypii* Glover and *Lipaphis erysimi* (Kalt.) infesting bean, brinjal and mustard crop respectively. Fields of the aforesaid crops (Var. BARI Seem -1, BARI brinjal Nayantara and BARI Sharisha-6), each of twenty square meter area were intensively surveyed weekly during the period from November 2003 to January 2004 around the Rajshahi University Campus where chemical treatments against aphids have never been carried out. In this survey randomly selected thirty plants of brinjal and mustard from four corners and middle (six from each site) were critically examined for presence or absence of natural enemies. In case of bean plant one and half square meter canopy size were considered for sampling unit. Crop wise members of each species of aphids and their natural enemies were collected manually by hand, forceps, aspirators, sweeping net and also by beating. The principle of beating is to hit a

branch of a crop enough with a stick in such a way that the insects fall on the white sheet placed below where they can be captured. Both adults and larval forms were collected. In order to proper identification of the immature stages of natural enemies, they were brought into the laboratory and reared to have their adult stages. The collected adult insects were poured into killing bottles of $1^{1/4}$ inches in diameter and 5 inches high for their killing with chloroform. The killed insects especially beetles were properly labeled and pinned through right wing cover close to its front end and near the middle line which separates the wing covers. But in case of flies pinning were done through thorax between base of front wings but slightly to the right of middle. The aphids and larval forms of natural enemies were killed by dropping them in water at the boiling point for five minutes, then preserved in 70% alcohol. A little glycerin (5%) were used with the alcohol in order to prevent shrinkage and keeps the specimen lifelike. Regular insect pins made of fine stiff steel wire and which are about one and half inches long were used for this purpose. Aphid colonies were care fully obtained by camel hair brush (0 size) in plastic container (6 cm height ×6.5 cm diameter). The mouth of the container was covered with thin cloths secured with rubber band to permit aeration. The aphids of the container were reared in the laboratory to obtain parasitoids from them. The pinning insects were finally kept in airtight boxes made of wood and glass. The naphthalene balls were used in the box to repel the undesirable organisms and ultimately to prevent their attack. The preserved specimens were identified following the standard procedure.

2.3. Results

During the survey, 3 species of aphids *viz.*, *A. craccivora*, *A. gossypii* and *L. erysimi* were found to be the most destructive pest of bean, brinjal and mustard crop respectively. Besides, certain mites, pod borer, leaf miner, leaf beetle, leaf eating catterpillers, chrysomelids were observed as pests that were not possible to identify. Eight species of predators were also observed during the survey. Among the predators 6 and 2 species belonged to order Coleoptera and Diptera respectively. Crop wise identified aphid species and their natural enemies along with their relative abundance are listed in Table 2. From the table it is observed that *Cheilomenes sexmaculata* (Fabr.)and *Coccinella septempunctata* L. and *Micraspis discolor* (Fabr.) are commonly

Table 2. Natural enemies of aphids and their relative abundance

Host plant	Aphid	Natural enemies
Bean (*Lablab perpureus* L.)	*Aphis craccivora* Koch	**Predators:** **(Coleoptera:Coccinellidae)** ++1.*Cheilomenes sexmaculata* (Fabr.) (Plate-XXXV) + 2.*Coccinella septempunctata* L. (Plate-XXXVI) +++ 3. *Micraspis discolor* (Fabr.) (Plate-XXX) + 4. *Scymnus coccivora* Ayyar (Plate-XVII)
Brinjal (*Solanum melongena* L.)	*Aphis gossypii* Glover	**Predators:** **(Coleoptera:Coccinellidae)** ++1. *Cheilomenes sexmaculata* (Fabr.) + 2. *Coccinella septempunctata* L. +++ 3. *Coccinella transversalis* (Fabr.) (Plate-XXIII) +++ 4. *Micraspis discolor* (Fabr.) **(Diptera:Syrphidae)** + 5. *Ischiodon scutellaris*(Fabr.) (Plate-XXXVIII) **Parasitoid:** 1. *Trioxys indicus*(Suba Rao&Sharma) (Plate-XXXI)
Mustard (*Brassica campestris* L.)	*Lipaphis erysimi* (Kalt.)	**Predators:** **(Coleoptera:Coccinellidae)** ++1. *Cheilomenes sexmaculata* (Fabr.) + 2. *Coccinella septempunctata* L. +++ 3. *Coccinella transversalis* (Fabr.) +++ 4. *Micraspis discolor* (Fabr.) +5. *Micraspis yasumasui* Sasaji (Plate-XXXVII) **(Diptera:Syrphidae)** +6. *Ischiodon scutellaris*(Fabr.) +++7. *Syrphus confracter* Wiedemann (Plate-XXXIX)

+, ++, +++ indicates low, moderate and high intensity of predator species

found in all three crop fields. *Scymnus coccivora* Ayyar and *Syrphus confracter* Wiedemann have restricted their distribution exclusively in bean and mustard crop respectively. Species diversity of the predator was highest in mustard crop followed by brinjal. This was mostly because of the high prevalence of the prey aphids of the experimental fields. Relatively low species diversity was found in *A. craccivora* infested bean crop. The insect predator belonging to the order Coleoptera was observed to be the major groups of aphidophagous insect fauna. One species of Hymenopteran parasitoid, *Trioxys indicus* (Suba Rao and Sharma) was recorded from brinjal aphid. No parasitoids were emerged from the bean and mustard aphid.

From the field observation it has also been found that the number of natural enemies increases with the increase of aphid population. But with the advent of summer i.e. when the aforesaid crops were harvested, they migrated into nearest wheat and rice fields where they were few in number. In the adverse climatic condition i.e. when they cope with heavy rainfall, storms etc. they remain in diapausing condition in the shady places at the base of grass and other available substratum.

2.4. Discussion

Raj (1989a) studied the abundance of natural enemies of aphids infesting potato crops in India and found seven species of coccinellid predators, two species of syrphid fly, one species of chrysopid. Besides, three species of hyperparasites on these predators were also recorded by him during the same period. Among the coccinellid predators *Coccinella septempunctata* L .and *Menochilus sexmaculatus* (Fabr.) were the predominant species. The former was most active in potato fields during 5^{th} to 9^{th} standard weeks. Population of these predators increases with the increase of prey aphids. Results of the present survey thus agreed with the findings of Raj (1989a). In Madhya Prodesh, India, five coccinellid predators *viz.,Menochilus sexmaculatus* (Fabr.), *Scymnus nubilus* (Mulsant) ,*Brumoides suturalis* (Fabr.), *Coccinella septempunctata* L. and *Coccinella repanda* Thunberg, an endoparasite *Diaeretus rupae* and one syrphid fly was recorded as natural enemies of the mustard aphid, *L. erysimi* (Singh and Verma, 1990). Poorani (2002) given a annotated checklist of

Coccinellids of Indian subregion where the observed species of present study were also included. From a three year study of Coccinellid communities in maize crops grown as repeated monoculture and under crop rotation in Hungry and it was found 11 species with dominance of *Propylea quatuordecimpuncatata* L. and *Coccinella septempunctata* L. followed by *Hippodamia tredecimpunctata* L.and *Adonia variegate* (Goetze) (Radwan and Lovei, 1983).The abundance of the latter species varied annually. From a survey on brinjal aphids and their insect predators in different Zones of West Bengal, India and observed three species of aphids *viz.,Aphis gossypii* Glover, *Aphis craccivora* Koch, *Myzus Persicae* (Sulzer) and their 42 species of insect predators. Among them 26, 12 and 4 species belonged to order Coleoptera, Diptera and Neuroptera respectively (Satpathi and Mondal, 2006).The preponderance of *Cheilomenes sexmaculata* (Fabr.) and *Micraspis discolor* (Fabr.)was recorded in the red and laterite and new alluvial zone. Six species of coccinellid beetles encountered during the present study were also mentioned in the list of Rahman (1983a). Das (1994) detected twenty nine species of aphids infesting different agricultural crops in Bangladesh. In those crop fields 19 predators and 5 parasitoids were encountered of which explored predators and parasitoid species of the present study were also included. Quayum *et al.*, (1979) studied the incidence of *Coccinella transversalis* (Fabr.)(=*Coccinella repanda* Thunberg) and reported that, the lack of aphid in cotton field during summer months is positively correlated with the absence of coccinellid. The present investigation confirms that immensity and scarcity of *C. transversalis* were mainly dependant on the availability of preys, thus agree with the views of Quayum *et al.*, (1979).

CHAPTER 3

Functional response and voracity of *Coccinella transversalis* (Fabr.), *Micraspis discolor* (Fabr.) (Coleoptera:Coccinellidae) and *Syrphus confracter* Wiedemann (Diptera: Syrphidae)

3.1. Introduction

Pest control particularly for aphids has been revolutionized by the application of predators and parasitoids for a long time. Several species of coccinellid beetles, syrphid flies and their immature stages have been proved to be the most successful bio-control agents against aphids for over a century (Hodek and Honek, 1996; Obrycki and Kring, 1998; Dixon, 2000; Omkar and Pervez, 2005; Bilashini *et al.*, 2006; Shannag and Obeidat, 2006 and Sarmento *et al.*, 2007). Among the alternative methods of chemical control, biological control is an important alternative (Bari and Sardar, 1998; Ito *et al.*, 2005) and seems to have great potential in terms of profitability, safety for humans, animals, environment and for the sustainability of agricultural activities (Mollah *et al.*, 2001; Barratt and Moeed, 2005). Biological control is one of the important components of IPM (Mollah *et al.*, 2001; Delfosse, 2005; Solangi and Lahor, 2005).

Voracity of coccinellid predators means the ability of predation on its prey or rate of consumption of prey (Meyling *et al.*, 2003). Voracity studies are the usual preliminary investigations of the potential of a predator for biological control (Meyling *et al.*, 2003). Measuring the voracity of predators is an important step in assessing the potential of a biological control agent (Lucas *et al.*, 1997). Many researchers worked on the predation and voracity as well as feeding performance of different coccinellid predators on different aphid species, some of them can be mentioned here: Devi *et al.*, (2001); Liu and Chen (2001a); Kumar *et al.*,(2002); Singh *et al.*, (2002); Omkar and James (2004); Omkar and Bind (2004); Omkar and Pervez (2005); Solangi and Lahor (2005) and Khursheed *et al.*, (2006). In Bangladesh few works in relation to the voracity of coccinellid predators have also been reported (Alam *et al.*, 1964; Rahman, 1984 and Das, 1994; 2002).

The functional response of a natural enemy offers a good conceptual frame work for understanding the action of agents in inundative releases (Waage and Greathead, 1988; Mandour *et al.*, 2006). Determining the effects of predations on prey populations is most commonly done through the analysis of functional and numerical

responses (Huffaker and Messenger, 1976). The functional response defines the rate of prey consumption, by a given number or density of predators, as a function of prey density (Holling, 1959) and therefore, can predict the maximum number of prey that can be consumed by a given predator per day. Thus the number of prey attacked can be used to help predict predator development, survival and reproduction (Oaten and Murdoch, 1975).

However for the successful utilization of coccinellids and syrphids as bio-regulatros of aphids, it is of paramount importance to know their feeding habits as well as the rate of food consumption and developmental biology. Accordingly an investigation was carried out in the present study to have a comparative idea regarding functional response, voracity and developmental periods of two common coccinellid predators, *viz., Coccinella transversalis* (Fabr.), *Micraspis discolor* (Fabr.) and one syrphid fly, *Syrphus confracter* Wiedemann under field and laboratory conditions respectively on bean aphid *Aphis craccivora* Koch, brinjal aphid *Aphis gossypii* Glover and mustard aphid *Lipaphis erysimi* (Kalt.).

3.2. Materials and Methods

Two experiments were conducted in the present study, first one was on the functional responses of the two coccinellid predators, *C. transversalis* , *M. discolor* and one syrphid fly, *S. confracter* under field and second one was on the comparative feeding potential of the said predators in laboratory condition. Field preparation and cultivation of bean, brinjal and mustard crop for this purpose were done following the same method already described in Chapter 1.

Stock culture of predators:

Adult *C. transversalis, M. discolor* and *S. confracter* were collected from the field and they were kept in plastic containers (6 cm height × 6.5 cm diameter) separately. The mouth of each container was covered with transparent mesh nylon net with rubber band to permit aeration. In this way thirty plastic containers were prepared from each species. Collected adult predators were kept in the containers at the rate of one adult per container. They were fed mustard aphid, *L. erysimi* for four days. After four days, at least 10 adults (male and female) from each species were

kept in the container and allowed sufficient number of *L. erysimi* as food for their random mating to get their eggs. After 24 hours each mated female was separated and kept singly in a container (6 cm height × 6.5 cm diameter). Foods in the containers were changed daily to avoid fungal and bacterial infection. The containers were kept on open shelves in the laboratory (at 14 to 22^{0}C temperature and 62 to 90 % R.H.). Mated females were checked daily in order to have their eggs. The female from each container was removed immediately after their laying of eggs. The eggs were then allowed to hatch. The bottom of each container contained cotton pad soaked in water to provide necessary moisture for egg hatching. After hatching, individual larva was reared separately in the plastic container of desired size.

Experimental design for functional response:

The study was based on different population densities of prey aphids and fixed number of predator larvae. Aphid infestation to host plants (bean, brinjal and mustard crop)and natural occurrence of predators were monitored through weekly sampling before predator release. For functional response study the methodology of Das and Chakrabarti (1985) was followed with some modifications. For this, a special type of detachable platforms were made by the flat wood of 20 cm^2 size. A hole of approximately 1.5 cm in diameter was made at the center of wood. Through the center of the hole, the said flat wood was cut and thus the hole and wood piece was divided into two equal halves. Two long nails were fixed horizontally in one piece of wood in such a manner, so that about 2.0 cm of the said nails were exposed outside. Just opposite to nails two small grooves were made on other piece of wood, so that the two pieces of wood can be attached or detached smoothly. For each platform four legs were made according to the required heights. Plastic containers (18 cm height ×12 cm diameter) were used during the experimental period to have a micro- chamber /cage above the platform around the leaves and twigs of experimental bean, brinjal and mustard plants. Newly emerged third instar larvae of *C. transversalis, M. discolor* and first instar larvae of *S. confracter* were released separately at the rate of two larvae per chamber. Before the release of predator larvae the hole of the wood piece around the twigs and buds of leaves was closed tightly with cotton balls. The open top of the container was enclosed temporarily by a piece of fine cloth with a tension rubber to

permit aeration and also to protect the attack of unwanted insects. Control cages where no predator larva was used. Each treatment was replicated thrice with one host plant considered as a replicate. Caging was made on 10 cm apical twigs for bean and mustard and three kinds of leaf (young, mature and old) for brinjal. Both adults and nymphs of aphid population were present in each cage. The observations were made on the number of aphids decreased or increased in each treatment at 1, 3 and 7 days after predator release.

Experimental design for comparative feeding potential:

At regular intervals within 24 hours, each larva in the container was provided with the fixed number of aphids, *A. craccivora*; *A. gossypii* and *L. erysimi*. First and second instars nymphs of aphids were provided as food to the first instar predator larvae, whereas, subsequent instars were provided third, fourth and well developed nymphs. The number of the aphids remained in the container was counted on the following day (after 24 hours). The number of aphids consumed by individual larval instar within 24 hours was determined from the difference of the aphid supplied and aphids left. In all the experiments, excess number of aphids was kept in the containers, which were more than the required number that an individual predator can consume. This was done to determine the exact feeding ability of the predator. The larval instars and duration were determined on the basis of casting of exuviae. The larvae were checked twice daily until pupation to record the time of moulting and number of moults. Instarwise duration of four larval stadia was recorded as:

(a) Duration of first instars : Time from hatching till first moult.

(b) Duration of second instars : Time from the end of first moult to second moult.

(c) Duration of third instars : Time from the end of second moult to third moult.

(d) Duration of fourth instars : Time from the end of third moult to pupation.

Similar procedure was followed for the adult. The adults obtained through rearing the larvae and pupae, which were utilized in subsequent experiments. The sex of adult coccinellid predators were determined by the mode of their mating behaviour.

Data analysis:

In order to examine the difference in voracity in terms of larval instars, predator species and sex (adults), the data for each was analyzed by a Statistical Software SPSS (Ver. 11.5) for analysis of variance (ANOVA). Comparison of means was done by Duncan's Multiple Range Test (DMRT) at 0.05 level of significance.

3.3. Results

Functional response:

Replicate cage 1, 2 and 3 of each plant for each treatment were determined on the basis of natural infestation of high, medium and low aphid density respectively. The larval consumption of *C. transversalis*, *M. discolor* and *S. confracter* on bean aphid *A. craccivora* were as 1.78 to 3.57, 2.14 to 3.21 and .92 to 2.00 aphids per larva per day respectively(Table-3). Per day consumption of each larva of *C. transversalis*, *M. discolor* and *S. confracter* were found to be 0 .73 to 1.43, 1.21 to 2.14 and 1.07 to 1.43 aphids as *A. gossypii* (Table-4) as against 2.93 to 5.00, 2.86 o 5.71 and 0.21 to 2.86 aphids as *L. erysimi* (Table-5). The feeding action of the larvae of *C. transversalis*, *M. discolor* and *S. confracter* in a week resulted in 45.45 to 62.50%, 37.50 to 47.37% and 27.08 to 48.28 % reduction of infesting bean aphids. The corresponding reduction of infestation by *C. transversalis*, *M. discolor* and *S. confracter* were recorded as 50.00 to 66.67%, 56.67 to 75.00%, 33.33 to 40.00 % respectively for brinjal and 42.71 to 53.85% , 33.33 to 53.33% and 8.57 to 40.00 % for mustard. In untreated bean, brinjal and mustard plants, aphids increased by 41.66 to 44.44%; 12.50 to 17.65% and 7.14 to 8.33 % respectively in seven days. In all cases the consumption rate increased with the increase of prey density. The reduction of aphids took place at higher percentage when the initial aphid density was higher compared to low density level and there was an increasing trend of aphid population in controlled plant.

Voracity:

Instarwise average larval voracity of *C. transversalis*, *M. discolor* and *S. confracter* on three species of aphids *viz.*, *A. craccivora*, *A. gossypii* and *L. erysimi* with their standard error are shown in Table-6 and it is observed that the consumption

Table 3. Number of aphids, *Aphis craccivora* Koch consumed at different densities by the larvae of *Coccinella transversalis* (Fabr.),*Micraspis discolor* (Fabr.) and *Syrphus confracter* Wiedemann in caged bean plant.

Treatment	Replicate (Cage)	Initial aphid density (DBT)	No. of aphids (Mean+S.E.)			No.of Aphids eaten/predator/ day	Aphids reduction / *increase (%)
			1DAT	3DAT	7DAT		
2 larvae of *Coccinella transversalis* (Fabr.)	1	80	70	50	30	3.57	62.50
	2	70	62	50	30	2.85	57.14
	3	55	50	40	30	1.78	45.45
2 larvae of *Micraspis discolor* (Fabr.)	1	58	50	45	30	3.21	47.37
	2	55	50	45	30	2.50	41.18
	3	48	45	40	35	2.14	37.50
2 larvae of *Syrphus confracter* Wiedemann	1	95	90	75	50	2.00	48.28
	2	85	80	75	50	1.78	45.45
	3	80	75	70	50	.92	27.08
Control	1	90	95	100	130	-	*44.44
	2	80	90	100	115	-	*43.75
	3	60	75	80	85	-	*41.66

- DBT-Day before treatment
- DAT-Days after treatment

Table 4 . Number of aphids, *Aphis gossypii* Glover consumed at different densities by the larvae of *Coccinella transversalis* (Fabr.), *Micraspis discolor* (Fabr.) and *Syrphus confracter* Wiedemann in caged brinjal plant.

Treatment	Replicate (Cage)	Initial aphid density(DBT)	No. of aphids(Mean+S.E.)			No.of Aphids eaten/predator/ day	Aphids reduction / *increase (%)
			1DAT	3DAT	7DAT		
2 larvae of *Coccinella transversalis* (Fabr.)	1	30	28	20	10	1.43	66.67
	2	28	25	20	10	1.29	64.29
	3	20	18	15	10	.73	50.00
2 larvae of *Micraspis discolor* (Fabr.)	1	40	35	25	15	2.14	75.00
	2	35	30	25	15	1.43	57.14
	3	30	28	25	13	1.21	56.67
2 larvae of *Syrphus confracter* Wiedemann	1	50	48	40	30	1.43	40.00
	2	48	45	40	30	1.29	37.50
	3	45	40	38	30	1.07	33.33
Control	1	68	70	72	80	-	*17.65
	2	60	65	65	70	-	*16.67
	3	40	42	40	45	-	*12.50

- DBT-Day before treatment
- DAT-Days after treatment

Table 5. Number of aphids, *Lipaphis erysimi* (Kalt.) consumed at different densities by the larvae of *Coccinella transversalis* (Fabr.), *Micraspis discolor* (Fabr.) and *Syrphus confracter* Wiedemann in caged mustard plant.

Treatment	Replicate (Cage)	Initial aphid density(DBT)	No. of aphids (Mean+S.E.)			No.of Aphids eaten/predator/ day	Aphids reduction / *increase (%)
			1DAT	3DAT	7DAT		
2 larvae of *Coccinella transversalis* (Fabr.)			120	100	60	5.00	53.85
	1	130	115	100	62	4.14	48.33
	2	120	90	80	55	2.93	42.71
	3	96					
2 larvae of *Micraspis discolor* (Fabr.)	1	150	140	120	70	5.71	53.33
	2	140	130	115	80	4.28	42.86
	3	120	115	100	80	2.86	33.33
2 larvae of *Syrphus confracter* Wiedemann	1	100	90	85	60	2.86	40.00
	2	80	75	70	60	1.43	25.00
	3	35	34	34	32	.21	8.57
Control	1	120	122	125	130	-	*8.33
	2	125	130	130	135	-	*8.00
	3	70	70	72	75	-	*7.14

- DBT-Day before treatment
- DAT-Days after treatment

Table 6. Instarwise larval voracity of *Coccinella transversalis* (Fabr.) , *Micraspis discolor* (Fabr.) and *Syrphus confracter* Wiedemann.

Predator species	Stage	Number of consumed aphids (Mean±S.E.)			P-value Row/Column	F-value Row/Column
		Aphis craccivora Koch	*Aphis gossypii* Glover	*Lipaphis erysimi* (Kalt.)		
C. transversalis (Fabr.)	1st instar larva	45.0±2.73**Ad**	27.0±1.22**Bd**	41.8±3.56**Ac**	.001/.000	12.73/127.02
	2nd instar larva	54.0±1.87**Ac**	34.0±0.99**Bc**	51.0±2.91b**Ac**	.000 /.000	26.85/516.61
	3rd instar larva	62.0±1.22**Ab**	55.0±1.58**Bb**	60.0±1.58**ABb**	.011/.000	6.73/62.08
	4th instar larva	100.0±2.52**Aa**	89.0±0.99**Ba**	97.0±2.55**ABa**	.027 /----	4.95 /-----
	Total	261.0±8.34	205.0±4.78	249.8±10.60		
M. discolor (Fabr.)	1st instar larva	20.0±1.70**Ad**	17.2±1.02**Ad**	18.0±0.89**Ad**	.304 /.000	1.32 /119.39
	2nd instar larva	36.6±1.88 **Ac**	30.0±0.00**Bc**	34.0±2.91**ABc**	.104 /.000	2.75/378.60
	3rd instar larva	57.0±2.55 **Ab**	42.0±1.22**Cb**	49.0±0.99**Bb**	.000/.000	18.78 /240.59
	4th instar larva	97.0±4.89 **Aa**	84.0±1.87**Ba**	92.0±2.55**Ba**	.053 /.----	3.79 /------
	Total	210.6±11.02	173.2±4.11	193.0±7.34		
S. confracter Wiedemann	1st instar larva	13.2±0.97**Ac**	9.2±2.28**Bc**	12.8±2.17**Ac**	.027/.000	4.99 /16.96
	2nd instar larva	14.6±1.29**Ac**	11.4±0.98**Bc**	15.0±0.00**Ac**	.036 /.000	4.46/18.31
	3rd instar larva	24.0±1.87**Bb**	5.0±3.17**Bb**	36.0±1.87**Ab**	.007/.000	7.84/110.82
	Total	51.8±4.13	25.6±6.43	63.8±4.04		

- All figures are mean of five replications
- Means(row/column) having the same letters are not significantly different at($P<0.05$); ($P<0.01$); ($P<0.001$) by DMRT
- Capital and small letters indicate the rows and column respectively

Table 7. Duration in days (Mean±S.E.) of immature stages of *Coccinella transversalis* (Fabr.), *Micraspis discolor* (Fabr.) and *Syrphus confracter* Wiedemann reared on different aphid species.

Predator species	Aphid species	Egg	Larval instars					Pupal
			I	II	III	IV	Total	
C. transversalis (Fabr.)	*Aphis craccivora*	2.2±0.20**b**	3.4±0.24**b**	2.4±0.10**ab**	2.0±0.00**b**	5.2±0.20**b**	13.0±0.54	3.1±0.10**a**
	Aphis gossypii	2.6±0.19**a**	4.6±0.24**a**	2.7±0.12**a**	2.3±0.12**a**	6.6±0.19**a**	16.2±0.67	3.2±0.12**a**
	Lipaphis erysimi	2.0±0.00**b**	3.4±0.24**b**	2.1±0.10**b**	2.4±0.10**a**	6.1±0.19**a**	14.0±0.63	3.0±0.00**a**
		P=.006;F=8.00	P=.007;F=7.714	P=.024;F=5.200	P=.001;F=13.727	P=.001;F=13.727	-	P=.335;F=1.200
M. discolor (Fabr.)	*Aphis craccivora*	2.1±0.10**b**	3.4±0.24**b**	2.4±0.10**b**	2.2±0.12**b**	5.6±0.19**a**	13.6±0.65	3.7±0.12**a**
	Aphis gossypii	2.4±0.10**a**	4.8±0.20**a**	2.8±0.12**a**	2.6±0.10**a**	6.0±0.16**b**	16.2±0.58	3.8±0.12**a**
	Lipaphis erysimi	2.0±0.00**b**	3.6±0.24**b**	2.0±0.00**c**	2.1±0.10**b**	4.9±0.10**b**	12.6±0.44	3.3±0.12**b**
		P=.012;F=6.50	P=.002;F=10.750	P=.000;F=19.000	P=.016;F=6.000	P=.001;F=13.286	-	P=.032:F=4.667
S. confracter Wiedemann	*Aphis craccivora*	2.2±0.09**a**	2.0 ±0.00**a**	2.0±0.00 **a**	2.2 ±0.19**a**	-	6.2±0.19	2.5±0.22**a**
	Aphis gossypii	2.4±0.19**a**	2.4±0.24**a**	2.2±0.19**a**	2.2 ±0.24**a**	-	6.8 ±0.67	2.2 ±0.12**ab**
	Lipaphis erysimi	1.9± 0.09**a**	2.0±0.00**a**	2.0±0.00**a**	2.0 ± 0.00**a**	-	6.0 ±0.00	2.0 ±0.00**b**
		P=.150;F2.235	P=.110;F=2.667	P=.397;F=1.000	P=.619;F=.500	-	-	P=.092;F=2.923

- All figures are mean of five replications
- Means having the same letter(s) in a column are not significantly different at (P<0.05); (P<0.01); (P<0.001) by DMRT.

Table 8. Voracity of adult *Coccinella transversalis* (Fabr.) and *Micraspis discolor* (Fabr.) for ten days.

Predator species	Sex	No.Consumed aphids			P-Values (Row)	F- Values (Row)
		Aphis craccivora Koch	*Aphis gossypii* Glover	*Lipaphis erysimi* (Kalt.)		
C. transversalis (Fabr.)	Male	173.33±52.19**Aa**	90.00± 5.78**Bb**	168.33±4.41**Aa**	.000	64.095
	Female	180.00±11.56**Aa**	100.00± .78**Bb**	176.66.±3.33**Aa**	.001	34.562
M. discolor (Fabr.)	Male	126.66±10.94**Ba**	101.66± 1.66**Bb**	115.00.±2.89**Cab**	.094	3.596
	Female	143.33±3.33**Ba**	121.66± 6.01**Ab**	135.00±2.89**Bab**	.032	6.450
		P-Values (Column)= .008 F-Values (Column)= 8.035	P-Values (Column)= .014 F-Values (Column)= 6.667	P-Values (Column)=.000 F-Values (Column)=70.333		

- All figures are mean of three replications
- Means (Column or Row) followed by same letters are not significantly different at (P<0.05; P<0.01; P<0.001)by DMRT.
- Small and capital letters indicate rows and column respectively.

of aphids increased with the maturity of larval instars for each predator species . The consumption of different larval instars of *C. transversalis*, *M. discolor* and *S. confracter* on three aphid species were significantly ($P<0.001$) different. Consumption of individual larval instars of each predator species also varied significantly ($P<0.05$; $P<0.01$ and $P<0.001$) on three prey aphids.

Female members of each predator species always consumed more aphids than male members. Adult (male and female) voracity (first 10 days of consumption) of *C. transversalis* and *M. discolor* on three species of aphids *viz., A. craccivora*, *A. gossypii* and *L. erysimi* differed significantly ($P<0.05$; $P<0.01$ and $P<0.001$) (Table-8).Voracity among the male and female members of two said predator on single prey aphid also varied significantly ($P<0.05$; $P<0.01$ and $P<0.001$).

Eggs of *C. transversalis* and *M. discolor* were more or less oval in shaped with slightly pointed ends. Color of the eggs varies from light yellowish to orange which gradually changed to dark few hours before hatching. The mean length and breadth of the egg of *C. transversalis* were 1.16 mm and 0.54 mm respectively but this measurements were 1.07 mm and 0.39 mm for *M. discolor.* Since the chorion is transparent and the first instars larvae can be clearly seen through the chorion. After hatching, the chorion appears as transparent white empty shell. On hatching the outer pole of the chorion ruptured irregularly and so that the prothorax of the first instars larva first appear followed by the head and then the rest of the body. On completion of hatching process the larva start to crawl in search of their normal food. Larvae of both species are soft bodied, elongated and some what flattened. In the first instars stage, the general color was grayish brown. The body was slightly tapering at the posterior region. The head, thorax, and abdominal segments were not distinct. The incubation period, larval durations and pupal periods of *C. transversalis*, *M. discolor* and *S. confracter* on experimental aphids with their standard error are shown in Table-7 and it is found that the incubation and larval periods of *C. transversalis* varied significantly ($P<0.05$),($P<0.01$) but no significant differences were observed in pupal periods of the same species. In case of *M. discolor* significant differences ($P<0.05$; $P<0.01$ and $P<0.001$) were observed in incubation period, larval periods of different

instars and pupal periods in terms of different aphid species. These are not significant in *S. confracter* except the pupal periods ($P<0.05$).

3.4. Discussion

Functional response:

Aphidophagous coccinellids are attracted to high population of aphid because of the aggregative responses of predator's arising from the tendency to congregate in regions of high prey density (Hagen and Vanden Bosch, 1968; Ofuya and Akingbohungbe, 1988; Babu and Ananthakrishnan, 1993.) Each third instar larva of *C. transversalis* consumed 29.2±1.4 aphids of *A. craccivora* per day (Patro and Sontakke, 1994) which is not similar with the results of present study. Singh and Deol (1993) observed that adults of *C. septempunctata,* a very related species of *C. transversalis* consumed a mean of 30.5 aphids/day over a ten day period. The corresponding figures for larvae were 23.8 aphids/day but Singh and Deol (1993) did not mention the name of prey aphid and specific stage of predator's larval instar. According to Singh and Singh (1994a) adult male of *C. septempunctata* consumed 119.80 and females 140.68 aphids/day. Laboratory observation on the effects of various periods of predation on the functional response of *C. septempunctata* at different densities of prey (*L. erysimi*) indicated that the rate of prey consumption was found to increase significantly with the increase in the period of the predator incidence and prey density (Shukla *et al.*,1990). Similar results were also reported by Fan and Zhao (1988) in the laboratory experiment that predation increased with the prey density. The results of the present study are consistent with works of Shukla *et al.*, (1990) and Fan and Zhao (1988).Functional response of *C. septempunctata* on different densities of mustard aphid, *L. erysimi* showed that the maximum prey consumption was held by fourth larval instars at the highest prey density (800) and the minimum by adult male at the lowest prey density (25). The prey consumption by predatory stages of the beetle was directly and the percentage of prey consumption was inversely proportional to the prey density. Prey handling time decreased with the increase of prey density and predatory efficiency of the predator instars was directly propotional to prey density (Srivastava and Srivastava, 2003). Functional response study of *C. septempunctata* larvae at six different prey densities *viz.*, 5, 15, 25, 35, 45,

and 60 aphids of *L. erysimi* in laboratory suggested that 45 prey/ larva was the optimum food density for the maximum performance during twenty hours of experiment beyond which no significant variation was observed (Bilashini *et al.*, 2006). From the laboratory based functional responses study of two female coccinellid predators to the cotton aphid, *Aphis gossypii*, at various temperatures, *Cycloneda sanguinea* proved to be more effective in suppressing cotton aphid populations than *Scymnus levaillanti* (Isikber, 2005). The number of aphids killed by *S. levaillanti* varying between 1.0 and 1.5 aphids/3 h at 20^{O}C; 2.5 and 4.0 aphids/3 h at 25^{O}C and 2.5 and 4.5 aphids/3 h at 30^{O}C whilst it was between 1.0 and 1.5 aphids/3 h at 20^{O}C; 2.5 and 4.0 aphids/3 h at 25^{O}C and 2.5 and 4.5 aphids/3 h at 30^{O}C for *C. sanguinea.* The functional response parameters and patterns of three coccinellid predators, *Chilomenes sexmaculata*, *Propylea dissecta*, and *Coccinella transversalis* were evaluated by Omkar and Parvez (2005) to find out how these predators respond at two different prey species across various prey densities levels. They recorded that *C. sexmaculata* responded maximally, followed by *C. transversalis* and *P. dissecta*, in terms of consumption of the aphids, *Aphis craccivora* and *Myzus persicae*, with suitable values of co-efficient of attack rates and handling times on these prey species. Differences in handling times to be significant within and between the predatory species on both prey species indicating that predators respond differentially to prey species.

Voracity:

Hodek (1967) studied the feeding ability of different coccinellids and reported that food consumption is correlated with temperature and the increase in developmental rate accompanying a rise in temperature naturally results in a higher daily feeding rate. Radke *et al.*, (1977) observed the feeding ability of larvae and adults of *C. septempunctata* and noted that the feeding ability increased with host densities. Verma and Chaudhury (1977) observed the feeding habit of *C. septempunctata* in relation to temperature and humidity and indicated that in low temperature the feeding rate become lower in comparison to higher temperature.

According to Patro and Sontakke (1994), the consumption rate by the 1st ,2nd, 3rd, 4th instars larvae and adults of *C. transversalis* was 11.4±1.6, 20.7 ±2.0, 29.2±1.4,

41.2 ±1.8 and 65.3 ±8.3 aphids of *A. craccivora* per day respectively. Egg, larval, prepupal and pupal stages lasted for 2.0±0.22, 8.23±0.66, 0.61±0.13 and 2.48 ±0.21 days on same food at a mean temperature of 28.3±1.1^{0}C and R. H. 57.9±10 % respectively.

The fourth instar larva of *C. transversalis* consumed fifty aphids of *L. erysimi* and the total larval period were recorded as 21 to 22 days on same food and this duration was higher than the present findings (Roy ,1976).

Ngammuang (1987) found that the feeding capacity of four larval and adult stages of *M. discolor* were 21.80±3.29, 41.90±7.78, 66.25±20.13, 125.15±25.20 and 1295.7±605.69 aphids of *A. craccivora*. On an average, the egg, larval, pre-pupal and pupal stages took 2, 3.43, 1.2 and 3 days respectively to complete their development. In 1991, Rahman reported that the feeding rate of *M. discolor* larvae at the 1st day after hatching ranged between 4 to 7 on cotton aphid, *A. gossypii* (average 5.2±0.58). From the 2nd day, the consumption gradually increased and reached an average of 26.8±2.59 aphids on the 8th day after which feeding rates sharply dropped. Each larva of this beetle consumed an average of 131.6±13.25 aphids in total larval period. The adult consumed 21.0 ±2.21 aphids during 1st day and the rates gradually increased up to 9th day which was 86.4±4.84 aphids. Rahman (1987) studied the larval and adult voracity of *C. trasversalis* (=*C. repanda* Thunb) on *A. gossypii* and noted that average feeding rate of the newly hatched grub(first day after hatching) was 7-2 aphids. From the second day the rate increased up to an average of 70.8 aphids on the 9th day. There after, the feeding rate of the grub declined suddenly and on the 10th day on an average it was 33.7 aphids. Incase of adults feeding rate was 24.4 aphids first day after emergence and gradually increased from the second day onwards and averaged 96.2 aphids on the 9th day and then come down to 88.7 aphids on the 10th day. Singh and Singh (1994a) investigated the predatory potential of *C. septempuncata* L. and found that 1st, 2nd, 3rd and 4th instar larvae of *C. septempunctata* consumed averages of 22.78, 66.00, 172.50 and 333.11 aphids of *L. erysimi* in the laboratory at 28°C. Rahman (1984) recorded the larval durations of *C. transversalis* as 89.38±3.25, 64.76±1.52, 73.18±2.24 and 245.02±3.19 hours for 1st, 2nd, 3rd and 4th instars respectively at 20°C and the feeding rate of both larvae and adults increased with the

increase of their age. But Rahman (1984) did not mention the name of the prey aphid used during his experiment. According to Khursheed *et al.*, (2006) the first, second, third and fourth instar larvae of *C. septempuncata* L. consumed 10.0±1.73, 29.0±2.89, 39.0±1.16, 52.3±7.23 aphids of *L. erysimi* respectively in first generation while the corresponding figures in second generation were 11.5±2.02, 27.0±2.89, 51.0±5.78, 60.3±9.54 aphids. Singh *et al.*, (2002) observed the larval consumption of *C. transversalis* as 413.8±58.7 aphids of *L. erysimi* whereas in the present investigation number of consumed *L. erysimi* were recorded as 249.8±10.60 aphids by the grub of same predator. Omkar and James (2004) examined the prey consumption of *C. transversalis* on six aphid species of which *A. gossypii*, *A. craccivora*, and *L. erysimi* are also included. Total consumption of aphids during the whole larval period of *C. transversalis* were recorded as 665.30 ± 5.75, 626.40 ± 3.53, 572.70 ± 2.99 aphids of *A. gossypii*, *A. craccivora*, and *L. erysimi* respectively. Total number of aphids consumed by male *C. transversalis* during their whole adult life were recorded as 4831.10 ± 123.54, 3883.70 ± 81.95, 3068.70 ± 130.50, aphids of *A. gossypii*, *A. craccivora*, and *L. erysimi* respectively but the corresponding figures for female adults were 5412.30 ± 94.51, 4494.00 ± 140.14, 3587.80 ± 61.49 aphids. Regarding larval and adult voracity of *C. transversalis,* results of Omkar and James (2004) is almost higher and relative prey suitability also varied from the present study.

Debaraj and Singh (1989) recorded the first, second third and fourth instar larval consumption of *C. transversalis* as 35.50, 68.40, 131.60 and 288.50 aphids of *A. craccivora.* The total number of aphids consumed by the larvae during its development ranged from 401 to 736 aphids with an average of 516.3 aphids. Among the larval instars the fourth instar larva was most voracious. Side by side the rate of consumption and developmental periods of first, second third and fourth instar larvae were also recorded as 8.0.20.1,26.7 and 40.9 aphids /day and 4.7, 3.9, 5.0 and 7.7 days respectively. During the experimental period, temperature and R. H. were ranging from 14°C-21°C and 43%-75% respectively. Results of the present study more or less in conformity with the findings of Debraj and Singh (1989) regarding gradual increase of prey consumption with the progression of developmental stages of the predator. Reddy *et al.*, (2001) recorded the larval stage of *Dideopsis aegrota* (Diptera:Syrphidae) consumed 505.80±13.81 aphids of *Macrosiphum rosae* (rose

aphid) during its development and the rate of consumption was 48.10±1.99 aphids/day and the larval period was recorded as 10.47±13.81 days (Reddy *et al.*, 2001).In terms of different aphid species as prey significant variation was observed in developmental stages of *M. discolor* (Hannan *et al.*, 1998).The incubation period, larval and pupal period of *M. discolor* were found to be 2.63,10.10 and 2.48 days respectively which were lower than the present results except the incubation period when bean aphid, *Aphis mediciginis* was used as prey(Hannan *et al.*, 1998). Prodhan *et al.*, (1995) stated that the egg, larva, prepupa and pupa of *M. discolor* took 2.9±0.23, 8.0±0.33, 1.2±0.13 and 3.0±0.21 days respectively on bean aphid,*A. craccivora*. However some variations of results revealed by different researchers might be due to the variations of nutritive quality of food and environmental differences.

CHAPTER 4 Integrated management of bean aphid, *Aphis craccivora* Koch

4.1. Introduction

4.1.1. Importance and cultivation of bean

Country bean, *Lablab purpureus* L. a crop of Indian origin (Chaudhury *et al.*, 1989) is an important annual as well as a perennial leguminous vegetable having twining, creeping or bushy habit. In Bangladesh it is popularly known as "Seem" and grown intensively all over the country in rabi season, although some varieties *viz.*, IPSA Seem-1 and IPSA Seem-2 developed by Bangabandhu Seikh Mujibur Rahman Agricultural University, Bangladesh can be grown year round including kharif season. Its green pods are used as vegetables and dry seeds as pulse. The dry seeds are also used for various vegetable preparations. The foliage of the crop provides hay, silage and green manure. Medicinal uses are also recorded. Its cultivation and use is so widespread here that it would be impossible to find a homestead in rural areas of Bangladesh which is lacking a bush of country bean in the winter. It is rich in nutritive value and per 100 gm edible portion of a green pod contains 86.1 g moisture, 6.7 g carbohydrate, 3.8 g protein, 0.7 g fat, 1.8 g fiber, 0.9 g mineral, 34.0 mg magnesium, 210.0 mg calcium, 68.0 mg phosphorus, 55.4 mg sodium, 1.7 mg iron, 74.0 mg potassium, 40.0 mg sulphur, 312I.U. vitamin A, 0.06 mg riboflavin, 0.1 mg thiamine, 0.7 mg nicotinic acid and 9.0 mg vitamin C respectively (Aykroid, 1963). During 2000-2001 crop season in our country it covered about 27130 acres of land and the production was about 49795 metric tons and its production is increasing gradually (B.B.S., 2004). It is sown in June-August and marketable green pods are harvested from November and continued up to March. Because of its photo/ and or thermo sensitive behavior the beans remain available only in the winter months when a lot of other vegetables are also available in the market.

4.1.2. Pest complex of country bean

High incidences of the insect pests result in low yield and poor quality of the country bean. Although no accurate statistical records are available, conservative estimate of the yield loss in country been due to insect pests is reported to be about 12-30% (Hossain, 1990). Country bean is attacked by different pests at different

stages of its growth and the method of infestation is also varied. According to Alam (1969), nine different insect species and one species of mite attack country bean. Among them attack by one aphid species, *A. craccivora* is frequently severe and it is the most destructive pest of bean and other vegetables in oriental countries (Sing, 1978; Thakur *et al.,* 1984; Shrivastava and Sing, 1986). According to Ahamed *et al.*,(2003),country bean (*Dolichos lablab*) is attacked by seven insect pests of which aphid (*A. craccivora*) and pod borer (*Maruca testulalis* Geyer) were the most serious while others were of minor importance. The incidence of aphid was the highest, followed by pod borer.

4.1.3. Ecology of bean, *Lablab purpureus* L.

Lablab purpureus L.is grown as a dry land crop. The field crop is drought resistant and can be grown in areas with a low rainfall. It can tolerate poor soils, provided they are well drained. In India and Burma it is often grown on sandy river banks exposed when the monsoon subside.The crop can be grown from sea level to 7.00 feet in Asia. It is photo periodic and both long and short day varieties are said to occur. Short-day varieties in India take 6-17 weeks to flower according to the sowing date.

4.1.4. Black aphid, *Aphis craccivora* Koch

The aphids are soft bodied pear-shaped shiny black or dark brown insects each measuring1.0-1.5mm with two appendages at the abdomen. Initially they are found on the lower surface of the leaves but move to the upper surface, stem and flower when they increase in enormous number. They multiply by parthenogenesis instead of reproducing through eggs. The immature insects develop into adult aphid within a weak and start producing next generation.

4.1.5. Morphology of *Aphis craccivora* Koch

Morphological characters of *A. craccivora* are highly variable and associated with the species of host with microclimate condition(Ruiz-Montoya *et al.*,2005).This aphid generally occurs as in both wingless (apterous viviparous female) and winged(alate viviparous female) morphs. Nymphs are wingless, dark or dusty brown and fairly rounded in body shape.

4.1.6. Nature of damage by *Aphis craccivora* Koch

Both nymphs and adults of aphid, *A. craccivora* damage bean crop from vegetative to fruiting stages and may cause up to 100% yield loss of different species of legumes (Attia *et al.,* 1986). *A. craccivora* is most dangerous for new plantings where excessive sap removal is more likely to affect general plant vigor. In vegetative stage, it sucks the sap from tender leaves and shoots. Flowers and flower buds fell of. *A. craccivora* draws sap from the phloem tissue of host plants using piercing-sucking type of mouth parts. Phloem sap is rich in sugars but poor in amino acid which are essential for growth. They inject toxic salivary secretions into plants during feeding. In fruiting stage mature and immature pods were infested severely and yield was adversely affected.York (1992) observed that the aphid fed on the underside of young leaves of country bean. When plants are heavily infested, leaf distortion and stunting are common resulting in poor fruit setting. In Asian countries, 20 to 40% yield loss is caused by this aphid (Sing and Allen, 1980). *A. craccivora* transmits about 20 viruses non-persistently including broad bean mossaic virus, Iranian strain virus etc., in many places of the world (Kaiser and Danesh, 1971; Kaiser, 1979; Thottappilly and Rossel, 1985).

4.1.7. Distribution and host plants of *Aphis craccivora* Koch

A. craccivora is widespread in warm temperate, subtropical and tropical regions. But some authorities believe that they are present worldwide and particularly well distributed in the tropics (Sing, 1978; Raychaudhuri, 1980; Blackman and Eastop, 1984). A large number of fruits, vegetables, agronomic and ornamental plants as well as many weeds are infested by *A. craccivora.* Raychaudhuri (1980, 1983) mentioned about 100 plant species under 13 families as the hosts of *A. craccivora.* Of these *A. craccivora* lives mainly on leguminosae but especially under drought conditions will colonize irrigated crops or succulent members of other families. In subtropical and tropical regions weeds are favored as summer hosts but in places where winter is more severe, the shrubs serve as primary host plants. In our country *A. craccivora* has been reported from 14 different plant species by Das (2002), out of which 10 species *viz., Arachis hypogea* L., *Cucurbita maxima* Duch., *Glycine max* L., *Lablab purpureus* L., *Lanegera leucantha* (Duch), *Lens esculenta* Moench, *Momordica*

charantea (B.) Rob, *Moringa olcifera* Lamk, *Phascolus mungo* L. and *Vigna sinensis* Endl. are vegetables and crops, one species *viz., Ricinus communies* L. is an oil producing plant and the remaining three are weeds *viz., Amaranthus spinosus* L. *Amaranthus* sp. and *Chenopodium album* L.

4.1.8. Natural enemies of *Aphis craccivora* Koch

A number of authors reported predators, parasitoids and fungi of *A. craccivora* from time to time. Some of them are as as follows:

A. Predators:

i. Coccinellidae:Coleoptera

Adonia variegata Goeza: Saxena *et al.*, 1970; Hamid *et al.*,1977;Patro and Behura,1993.

Cheilomenes lunata (Fabr.):Booker, 1963; Don and Pedro,1980;Ofuya,1997.

ii. Staphylinidae:Coleoptera

Paederus sp.:Sathpathi and Mondol,2006.

iii. Syrphididae:Diptera

Allograpta nasuta (Macquart):Booker, 1963.

Episyrphus balteatus (de Geer):Saxena *et al.*,1970; Hamid *et al.*,1977; Patro and Behura,1993.

Ischiodon scutellaris (Fabr.): Saxena *et al.*, 1970; Hamid *et al.*,1977;Patro and Behura,1993.

Melangyna viridiceps(Macquart):Waterhouse and Sands,2001.

Paragus borbonicus(Macquart): Booker ,1963; Don and Pedro,1980.

Paragus logiventris Loew: Booker, 1963; Don and Pedro,1980.

Paragus serratus(Fabr.): Booker ,1963; Saxena *et al.*,1970; Tao and Chiu,1971; Hamid *et al.*,1977; Don and Pedro,1980.

Paragus tibialis(Fllen.): Saxena *et al.*,1970; Hamid *et al.*,1977;Patro and Behura, 1993.

Simosyrphus grandicornis (Macquart): Waterhouse and Sands, 2001.

iv.Chamaemyiidae:Diptera

Leucopis formosana Hennig: Waterhouse and Sands, 2001.

v. Chrysopidae:Neuroptera

Chrysoperla carnea(Stephens): Saxena *et al.*,1970; Hamid *et al.*,1977;Patro and Behura,1993

B. Parasitoids

i. Braconidae:Hymenoptera

Adialytus salicaphis (Fitch): Hamid *et al.*, 1977; Selim *et al.*, 1987.

Aphidius colemani Viereck: Waterhouse and Sands, 2001.

Aphidius absinthii Marshall: Hamid *et al.*, 1977; Selim *et al.*,1987.

Aphidius ervi Haliday:Stary, 1979.

Aphidius funebris Mackauer: Stary, 1979.

Aphidius ribis Haliday: Stary, 1979.

Aphidius salicis Haliday: Stary, 1979.

Bindodoxys acalephae(Marshall):Rakhshani *et al.*, 2005

Bindodoxys angelicae Haliday: Rakhshani *et al.*, 2005

Bindodoxys indcus Subba Rao and Sharma:Agarwala *et al.*, 1981; Das, 2002.

Ephedrus nacheri Quilis:Takada,1968.

Ephedrus persicae Froggatt: Stary, 1979; Agarwala *et al.*,1981.

Ephedrus plagiator(Nees): Takada,1968.

Lipolexis gracialis Foerster: Tao and Chiu, 1971.

Lipolexis scuellaris Mackauer: Tao and Chiu,1971; Agarwala *et al.*,1981.

Lysiphlebia japonica (Ashmead): Takada, 1968; Tao and Chiu, 1971.

Lysiphlebus confusus Tremblayand Eady: Rakhshani *et al.*, 2005

Lysiphlebus delhiensis Subba Rao and Sharma:Paik, 1975.

Lysiphlebus fabarum(Marshall): Waterhouse and Sands,2001;Rakhshani *et al.*,2005.

Lysiphlebus testaceipes(Cresson): Waterhouse and Sands,2001;Rakhshani *et al.*,2005.

Trioxys acalephae (Marshall): Stary, 1979.

Trioxys angelicae Haliday: Stary, 1979.

Trioxys asiaticus Haliday: Stary, 1979.

Trioxys auctus Haliday: Stary, 1979.

Trioxys centaureae Haliday: Stary, 1979.

Trioxys cirsii(Curtis): Stary,1979.*Trioxy scomplanatus* Quilis: Stary,1979.

ii. Aphelinidae:Hymenoptera

Aphelinus gossypii Timberlake: Waterhouse and Sands, 2001.

Aphelinus abdominalis (Dalman): Hamid *et al.*, 1977.

C. Fungi

i. Neozygitaceae:Entomopathorales

Neozygites fresenii (Nowak): Ofuya, 1997.

Predation and parasitism by natural enemies are most important in pest management but to control pests sufficiently biological control needs to be combined with other control methods which are not harmful to them (Soerjani and Morallo-Rjesus, 1980).

4.1.9. Significance of integrated management of *Aphis craccivora* Koch

The need of control of the said pest is immense from the context of socio-economic development of Bangladesh. During implementation of any IPM programme, it requires many diverse information through research works both from laboratories and fields. But it is true that significant research work on IPM of aphids has not yet been undertaken in our country. So to control aphids, our farmers have to rely only on the insecticide spray in spite of its hazardous effect on the environment. In fact successful cultivation of crops must include efficient management of pests including aphids (Chhabra and Kaur, 1994) and successful pest control depends on the application of appropriate strategies and tactics (Youdeowei and Service, 1983). Thus in order to develop such strategies or tactics especially in the case of mysterious group of insects like aphids (Behura, 1994), field trials on various parameters of IPM are of great importance. Accordingly, effect of some components of IPM not all *viz.*, variety, sowing time, insecticides, botanicals, natural enemies, various indigenous materials like kerosinized ash were evaluated separately or in combination with one

another on the population of *A. craccivora* and ultimately on yield of bean. The findings of this type of research may be helpful to develop such strategies and tactics. These are the objectives of the present work.

4.2. Materials and Methods

In order to evaluate the impact of some parameters of IPM independently or in combination with one another on bean aphid population and finally on the yield of bean, an experiment was conducted at Rajshahi University Campus, Rajshahi from the month of July 2003 to February 2004. Certified seeds of two bean varieties (BARI Seem-1 and BARI Seem-2) were collected from BARI, Joydebpur, Gazipur . Seeds of two collected varieties were sown in experimental earthen tubs of 120 cm diameter and 40 cm deep on three different dates *viz.,* 31.07.2003, 15.08.2003 and 31.08.2003. On the basis of sowing date altogether one hundred and eighty tubs of both varieties were divided into six fields *viz.*, Field A (Var.BARI Seem-1) and B (Var.BARI Seem-2), (early sowing); Field C (Var.BARI Seem-1)and D(Var.BARI Seem-2), (mid sowing) and Field E (Var.BARI Seem-1) and F (Var.BARI Seem-2), (late sowing). Each experimental field was divided into six blocks (T_1 to T_6), i.e. five tubs comprised as a block. After germination excess plants were uprooted from the tubs. Finally one bean plant per tub was allowed to grow. Bamboo sticks were inserted in tubs to support the plants. Required moisture level was maintained by regular irrigation in the soil of the tubs. Block to block distance was 2.0 meters and between the tubs 1.5 meters. Each of the blocks of experimental fields was used for specific type of treatment and assigned as:

Treatment block T_1 = Two times insecticide spray (first round and second round).

Treatment block T_2 = One time spray of insecticide (first round) and one time spray of botanical (second round).

Treatment block T_3 = Two times release of natural enemies (first round and second round)

Treatment block T_4 = One time release of natural enemies (first round) and one time spray of botanical (second round).

Treatment block T_5 = One time dusting of kerosinized ash (first round) and one time botanical spray (second round).

Treatment block T_6 = Two times spray of water only (first round and second round) **(Controlled).**

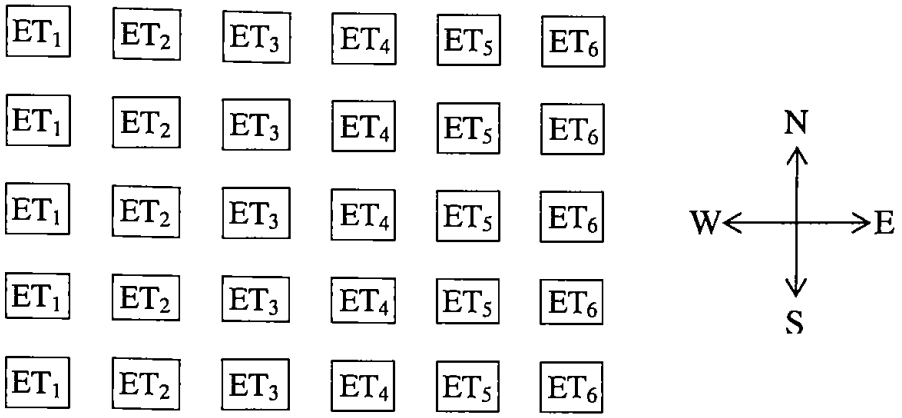
The bean plants of each of the blocks were checked regularly to detect the infestation of *A. craccivora* on them. With the beginning of heavy infestation in the first week of December 2003, application of aforementioned treatment parameters were started at 20 days intervals.

For the application of insecticide, botanical and water (for controlled blocks) a plastic bodied South Korean made Knaps-ack type lever operated hand sprayer of 18 liters capacity brand name (Manseok) was used. The sprayer was thoroughly washed and dried before use. Procedure of application including calibration of insecticide was followed mainly as per Mathews (1988). Calibration was made to ensure application of right dose of insecticide on experimental plants. The sprayer was operated with full stroke to raise optimum air pressure. Spraying was done on the experimental blocks with sufficient time to ensure optimum deposit. The walking speed was maintained @20 m/minute through the block to ensure optimum coverage. A hollow cone type of nozzle was used. The output was checked by collecting and measuring the spray liquid sprayed for 1 minute. A pressure gauge was fitted as close to the nozzle, the lever was operated evenly with a full stoke and uniform pressure as possible was maintained. This was practiced before the actual spray on the experimental crop. To ensure optimum deposit of spray volume on the plant surface the spray was checked by spraying on water sensitive paper. The desired droplet diameter (Vmd) was 100μm and the number of droplets that spread uniformly on the paper per square centimeter was around 20. Having determined the output from the nozzle in liters per minute, the rate per unit area was treated and calculated for knowing the swath width and walking speed.

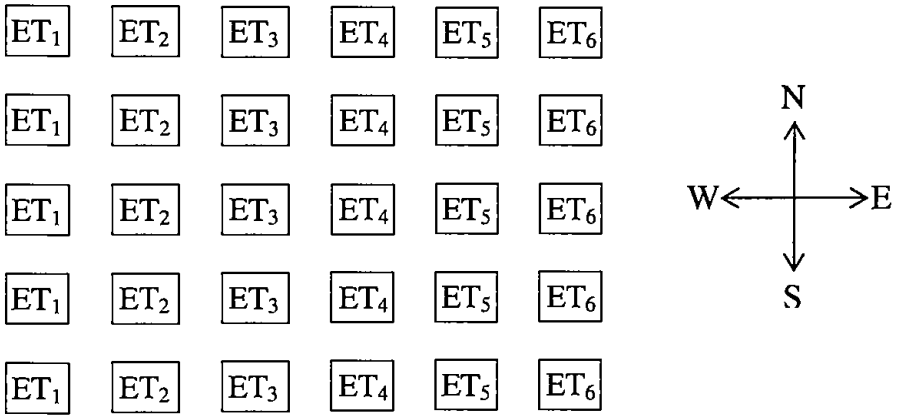
Following Mathew's (1988), with a swath of 1 meter and walking at 20m/ min and flow rate of 0.45 liters/min., volume of spray per square meter was:

$$\frac{0.45 \text{ lit/min}}{1\text{m} \times 20\text{m/min}} = 0.02225 \text{ liters/m}^2 = 225\text{lit/hectare}$$

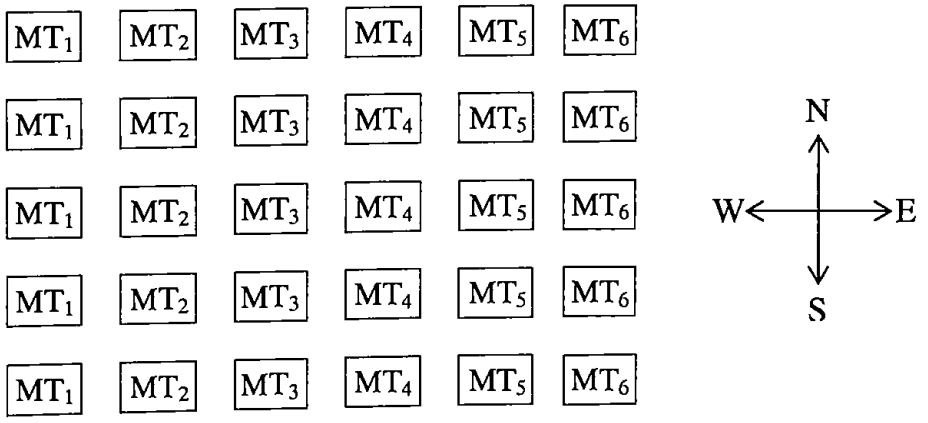
LAYOUT OF THE FIELD EXPERIMENT



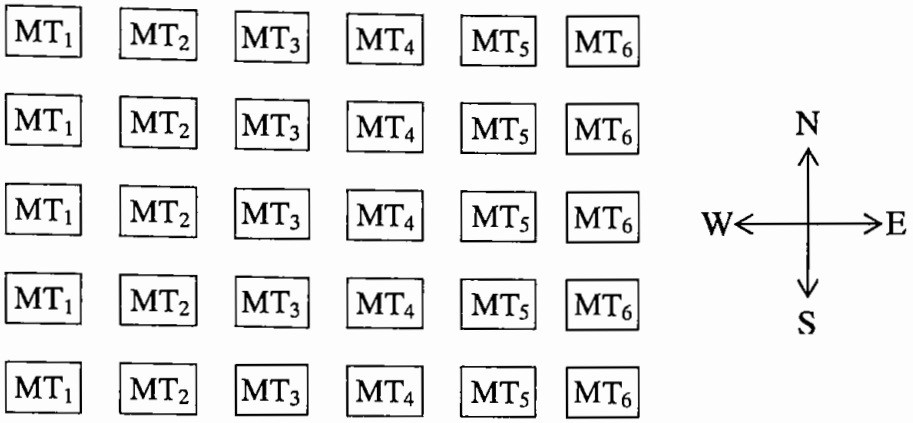
Field A (early sowing) – 31st July 2003(Var.BARI-Seem -1)



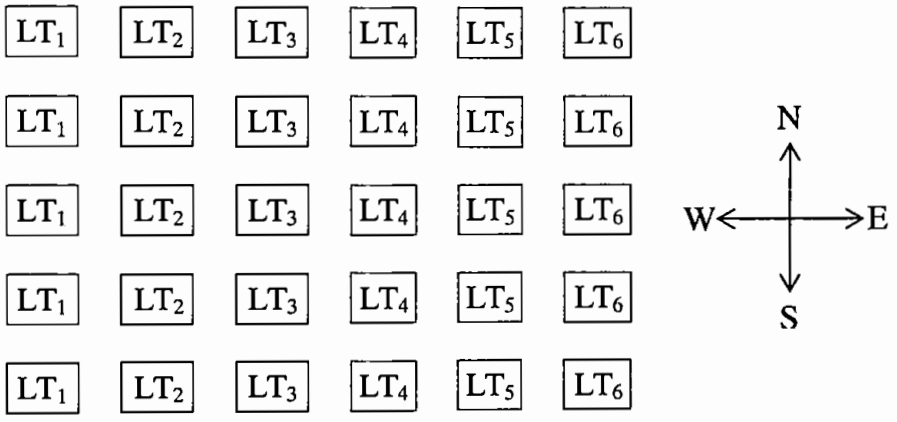
Field B (early sowing) – 31st July 2003(Var.BARI-Seem -2)



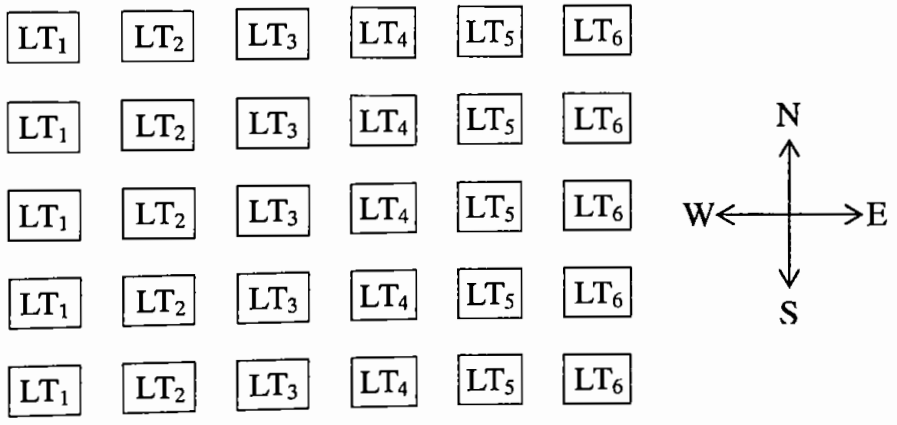
Field C (mid sowing) – 15th August 2003(Var.BARI-Seem -1)



Field D (mid sowing) – 15th August 2003(Var.BARI-Seem -2)



Field E (late sowing) – 31st August 2003(Var.BARI-Seem -1)

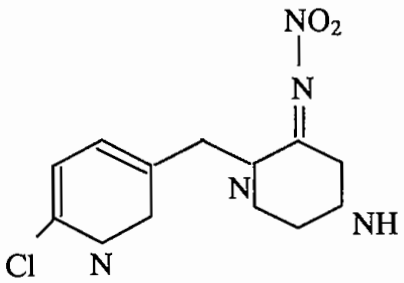


Field F (late sowing) – 31st August 2003(Var.BARI-Seem -2)

Because of the different sowing date, treatment schedule varied from field to field. For the convenience of counting of aphid population Field A and B were treated on 08.12.2003 (first round) and 29.12.2003 (second round). Similarly Field C and D were treated on 13.12.2003 (first round) and 03.01.2004 (second round). But in case of late sowing Field E and F, first and second round application were done on 18.01.2004 and 08.02.2004 respectively.

Insecticide:

A very common systemic insecticide, Imidacloprid ($C_9H_{10}ClN_5O_2$) of Bayer Crop Science, commercially marketed as Admire 200 SL frequently used to control aphids including other sucking insect pests in Bangladesh was selected for this purpose. The prescribed dose rate of Admire 200SL is 1 ml / L water against bean aphid and thus 50 ml/ha. Insecticide was sprayed in blocks T_1 (first and second round) and T_2 (first round only) of each field.



Chemical structure of Imidacloprid.

Tobacco leaf extract (botanical):

Nicotine is an effective pesticide and highest concentration of nicotine is present in stalks and leaf ribs of Tobacco (*Nicotina tabacum* L.) plant (Ghosh, 2000). Collected mature green leaves of Tobacco were chopped with a sharp knife to very small chips. The chips were soaked in normal water at room temperature for 10 days. The proportion of plant material and water was 1:10 (w/v). After soaking for the stipulated time, the plant materials were squeezed manually to extract the active ingredient as much as possible. The solution was then screened through fine mesh nylon cloth to obtain the extract free from plant residue or darts. The tobacco leaf extracted water was poured into the sprayer and sprayed in block T_2, T_4 and T_5 (second round) of each experimental field.

Natural enemies:

Both the larval and adult stages of many coccinellid species are promising biological control agents of many crop pests including aphids (Haque and Islam, 2008). Of these, *C. transversalis* (Fabr.) is an important one in preventing bean aphid, *A. craccivora* population (Patro and Sontakke, 1994). Hence, third instar larvae of *C. transversalis* were obtained from the stock culture in plastic container (6 cm height × 6.5 cm diameter). The mouth of the containers were covered with thin cloths, secured with rubber bands to permit aeration. The larvae were released at the rate of five larvae per plant with a soft brush (0 size) on scheduled date around the infested twigs of bean plant in block T_3 (first round and second round) and T_4 (first round only) . Small quantity of Vaseline was placed around the base of the predator treated bean plants to avoid escaping of predator larvae.

Kerosinized ash:

This method is recommended as a preventive measure and quite effective against sucking type of insects like aphids (Stoll, 1998). Six teaspoon of kerosene were mixed with 1 kg of wood ash and applied manually by throwing in block T_5 (first round) of each field.

The control blocks T_6 of each field were also sprayed with water only at the time of treatment made on other blocks of respective field.

Aphid population counts were taken using hand lens on randomly selected leaves (old, mature and young), twigs of 5 cm in length, pods (if infested) from each of the five tubs of six blocks of an individual field. In case of thick colonies aphids were dislodged carefully from the above mentioned plant parts by means of a camel hair brush (0 size) on white plastic plate, counted and thereafter they were placed back to same place of the plant. No distinction was made between the nymphs and adults since both the stages cause similar injury to the plants. The leaves and twigs observed once were not considered for further observation. Pretreatment data were taken 1 day prior to and post treatment data were obtained on 1, 3, 7 and 20 days after treatment. To compare yield with the controlled block, pods produced by per block were collected separately and recorded. Usually the very immature pods were not considered.

Statistical analysis:

For all the experiment, analysis of variance (ANOVA) was done to test the significance in difference among the treatments. Comparison of means was done by Duncan's Multiple Range Test (DMRT) at 0.05 level of significance. Statistical Software SPSS (Ver. 11.5) was used to carry out the analysis.

4.3. Results

Color of bean pod of both BARI Seem-1 and BARI Seem-2 is although green but their size and weight is different. Size of each matured bean pod of BARI Seem-1 is 10-11cm long and 2.0-2.5cm wide while it is 10-13cm long and 1.5-2.0cm wide for BARI Seem-2.Weight of each matured bean pod of BARI Seem-1 is 10-11gm whereas the weight of each matured bean pod of BARI Seem-2 is 7-8 gm. Life span of the variety BARI Seem-1 is 200-220 days but the life span of BARI Seem-2 is 190-210 days. Under various control parameters, field and block wise pretreatment and post treatment data on aphid population of *A. craccivora* Koch along with yield of bean are presented in Table 9-14 and it is observed that aphid population before the application of the first round treatment was much higher in all the treatment blocks. It is also evident from the experiment two times insecticidal treatment proved more effective in all the fields as compared to the remaining treatments in terms of aphid population reduction and finally increase in yield. After the initiation of first round treatment, aphid numbers started to decrease sharply up to 7^{th} days but on the 20^{th} day aphid incidence increased slightly in some treatment blocks. Just after the second round treatment aphid population again decreased whereas the population of controlled blocks (water sprayed) remained more or less same from the beginning to the end of different counting date. In the Table 9, the highest yield was obtained from the treatment block T_1 that was treated with two times by an insecticide Admire 200SL @ 1 ml per liter water and it was statistically higher from other treatments. Minimum yield 1.14 kg/plant was recorded from the untreated control block (T_6) of field A which had the highest number of aphids during different counting date. More or less similar trend was also observed in Table 10-14. The increase in yield over control in various treatments ranged from 28.07 to 193.36%, 47.22 to 469.44%, 22.00 to 210.00%, 25.00 to 250.00%, 29.55 to 256.82% and 35.29 to 358.82% in field

Table 9. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of bean aphid, *A. craccivora* Koch and yield of bean in field A (Var.BARI Seem-1).

Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								Yield (kg/ plant) Mean ±S.E.
			Pre-treatment	First round treatment (08.12.2003)				Second round treatment (29.12.2003)			
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT	
A 31.7.03 (Early sowing)	ET_1	Admire 200 SL@ 1 ml/L water (first round and second round)	53±4.63	25±2.23	3.6±1.80	1.4±0.51	5.4±1.71**cd**	0.2±0.20	1.6±0.09	3.6±1.77	10±2.94**b**	3.35±0.19 **a**
	ET_2	Admire 200 SL@ 1 ml/L water (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	53±7.18	22±6.03	5.6±5.86	0.4±0.09	1.4±0.51**d**	0.2±0.20	5±0.20	18±2.56	19.8±1.65**b**	2.74±.18 **b**
	ET_3	Larvae of *C. transversalis* (first round and second round)	48.6±6.39	22±4.05	41±3.31	40±3.53	21.2±2.43**bc**	16±1.87	24±1.41	19±2.93	17.8±2.24**b**	1.78±.15 **c**
	ET_4	Larvae of *C. transversalis* (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	57.6±5.63	18.8±1.84	27.6±2.87	32±6.62	25±3.53**b**	28.6±8.12	19±5.56	22±2.55	16±3.67**b**	1.60±.09 **c**
	ET_5	Kerosinized ash (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	52±4.63	15±1.97	24±5.33	23.2±4.33	22±5.82**bc**	10.6±1.96	15±2.23	30±6.11	14±4.29**b**	1.46±.22 **cd**
	ET_6	Control, spray water only (first round and second round)	51±8.70	44±10.28	59±6.39	65±4.99	56±12.06**a**	23±5.36	27±6.62	37±8.87	56±9.26**a**	1.14±0.06 **d**
							P=.000 F=10.795				P=.000 F=12.614	P=.000 F=45.973

- All figures are mean of five replications
- DAT – Days after treatment
- Means having the same letter(s) in a column are not significantly different at 0.05 probability level by DMRT.
- Average canopy size 0.87 square meter/plant.

Table 10. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of bean aphid, *A. craccivora* Koch and yield of bean in field B (Var.BARI Seem-2).

Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								Yield (kg/plant) Mean±S.E.
			Pre-treatment	First round treatment (08.12.2003)				Second round treatment (29.12.2003)			
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT
B 31.7.03 (Early sowing)	ET_1	Admire 200 SL@ 1 ml/L water (first round and second round)	60.20± 5.16	32.00± 6.04	17.00± 4.36	1.60± 0.93	3.80± 0.66**c**	0.00± 0.00	0.20± 0.20	0.40± 0.24	0.80± 0.37**c**	2.05±0.12 **a**
	ET_2	Admire 200 SL@ 1 ml/L water (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	64.00± 9.67	39.00± 10.50	10.80± 2.42	4.00± 0.71	5.60± 0.75**c**	9.20± 1.02	10.60± 1.17	12.60± 1.25	24.00± 1.87**b**	1.45±0.12 **b**
	ET_3	Larvae of *C. transversalis* (first round and second round)	64.00± 8.12	61.00± 6.78	52.00± 4.90	44.60± 3.70	43.00± 4.36**b**	35.60± 2.80	29.60± 3.27	19.00± 3.32	24.00± 2.92**b**	0.95±0.28 **c**
	ET_4	Larvae of *C. transversalis* (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	80.00± 6.52	74.60± 3.76	53.60± 3.44	61.00± 5.10	41.00± 8.12**b**	37.60± 3.71	24.00± 5.79	22.60± 2.69	16.60b± 2.93**b**	0.55±0.05 **cd**
	ET_5	Kerosinized ash (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	90.60± 6.66	78.60± 3.31	63.00± 6.63	52.20± 3.93	38.60± 6.00**b**	32.60± 3.91	37.00± 6.25	27.60±3 .36	22.80± 4.05**b**	0.53±0.06 **cd**
	ET_6	Control, spray water only (first round and second round)	86.00± 4.30	81.00± 3.32	76.00± 1.87	61.00± 4.00	70.00± 4.47**a**	64.60± 2.48	74.00± 5.79	72.00±3 .74	100.00± 7.58**a**	0.36±0.04 **d**
							P=.000 F=26.755				P=.000 F=76.565	P=.000 F=22.266

- All figures are mean of five replications
- DAT – Days after treatment
- Means having the same letter(s) in a column are not significantly different at 0.05 probability level by DMRT.
- Average canopy size 0.87 square meter/plant.

Table 11. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of bean aphid, *A. craccivora* Koch and yield of bean in field C (Var.BARI Seem-1).

Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								Yield (kg/plant) Mean±S.E.
			Pre-treatment	First round treatment (13.12.2003)				Second round treatment (03.01.2004)			
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT
C 15.8.03 (Mid sowing)	MT_1	Admire 200 SL@ 1 ml/L water (first round and second round)	57±5.14	17± 3.74	2.80±0.66	.80±0.58	5.40±1. 50**d**	0.00± 0.00	3±1.09	1.20±0.58	5.60± 1.50**c**	3.10±0.09 **a**
	MT_2	Admire 200 SL@ 1 ml/L water (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	59±6.19	24± 3.99	2.20±0.58	1.80± 0.19	6.60± 1.82**d**	0.40± 0.24	1.80± 0.37	13±1.99	21± 2.24**b**	2.72±0.44 **b**
	MT_3	Larvae of *C. transversalis* (first round and second round)	54±6.58	30± 0.00	31±2.45	29±4.29	19.60±2 .76**bc**	16±2.91	23±4.35	20.80± 0.80	19.20± 2.03**b**	1.48±0.14 **c**
	MT_4	Larvae of *C. transversalis* (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	62±5.36	31.20 ± 5.18	24±2.91	33±6.62	26± 4.29**b**	19±3.67	20±1.58	24±2.45	20± 3.86**b**	1.46±0.05 **c**
	MT_5	Kerosinized ash (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	58±3.74	30± 7.06	21±2.45	13± 1.10	13.60± 2.10**cd**	15± 2.23	22± 2.55	20±5.23	21± 10.48**b**	1.22±0.06 **cd**
	MT_6	Control, spray water only (first round and second round)	5±9.12	45± 11.16	52±6.03	37± 3.74	47± 2.99**a**	41± 7.47	57± 4.89	47±7.98	36± 6.58**a**	1.0±0.03 **d**
							P=.000 F=32.285				P=.001 F=6.417	P=.000 F=89.769

- All figures are mean of five replications
- DAT – Days after treatment
- Means having the same letter(s) in a column are not significantly different at 0.05 probability level by DMRT.
- Average canopy size 0.87 square meter/plant.

Table 12. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of bean aphid, *A. craccivora* Koch and yield of bean in field D (Var.BARI Seem-2).

Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								Yield (kg/plant) Mean±S.E.
			Pre-treatment	First round treatment (13.12.2003)				Second round treatment (03.01.2004)			
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT
D 15.8.03 (Mid sowing)	MT_1	Admire 200 SL@ 1 ml/L water (first round and second round)	71.60±6.68	45.60± 4.17	17.00± 3.39	7.60± 1.94	8.60± 2.25**c**	6.60± 1.89	1.20± 0.58	10.00± 2.83	19.20± 2.06**c**	1.40±0.10 **a**
	MT_2	Admire 200 SL@ 1 ml/L water (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	83.00±5.39	48.00± 6.04	30.00± 1.58	10.00± 0.71	4.60± 1.36**c**	4.40± 0.51	9.80± 2.15	21.40± 5.52	12.40± 3.75**c**	1.25±0.08 **a**
	MT_3	Larvae of *C. transversalis* (first round and second round)	92.00±2.25	81.00± 3.32	77.00± 3.39	62.00± 8.60	73.00± 2.55**a**	65.10± 2.24	57.00 ±5.39	57.00± 3.39	56.60± 3.94**b**	0.80±0.05 **b**
	MT_4	Larvae of *C. transversalis* (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	79.00±4.30	72.60± 3.57	61.00± 2.92	51.00± 4.30	48.00± 4.64**b**	36.00± 3.67	23.00 ±3.39	15.60± 3.92	24.00± 6.78**c**	0.52±0.02 **c**
	MT_5	Kerosinized ash (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	101.00±6.40	84.00± 4.30	75.00± 2.74	58.00± 6.04	50.00± 5.70**b**	30.00± 5.70	47.00 ±4.90	23.00± 4.36	19.00± 4.92**c**	0.50±0.03 **c**
	MT_6	Control, spray water only (first round and second round)	109.00±23.60	74.00± 19.40	69.00± 23.90	65.00± 10.00	61.60± 12.10**ab**	53.00± 10.90	52.00 ±9.03	63.00± 7.68	74.00± 5.10**a**	0.40±0.06 **c**
							P=.000 F=22.169				P=.000 F=32.540	P=.000 F=44.690

- All figures are mean of five replications
- DAT – Days after treatment
- Means having the same letter(s) in a column are not significantly different at 0.05 probability level by DMRT.
- Average canopy size 0.87 square meter/plant.

Table 13. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of bean aphid, *A. craccivora* Koch and yield of bean in field E (Var.BARI Seem-1).

Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								Yield (kg/plant) Mean±S.E.
			Pre-treatment	First round treatment (18.01.2004)				Second round treatment (08.02.2004)			
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT
E 31.8.03 (Late sowing)	LT_1	Admire 200 SL@ 1 ml/L water (first round and second round)	62±4.89	18±2.54	5.20± 1.06	2±0.70	2.40± 0.50**b**	00±00	.20±. 20	1.80±0. 37	4.60± 1.32**c**	3.14±0.17 **a**
	LT_2	Admire 200 SL@ 1 ml/L water (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	61±4.57	19±3.99	5±1.41	1.40± .60	2.80± 1.31**b**	1.60±. 51	9.40± 1.77	4.80±1. 49	6.60± 2.56**c**	2.62±o.10 **b**
	LT_3	Larvae of *C. transversalis* (first round and second round)	58±5.82	35±2.23	31.60± 2.46	20.60± 3.98	28±2. 55**a**	19±3. 31	24.80 ±3.67	32±2.55	24±2.91 **b**	1.28±0.19 **c**
	LT_4	Larvae of *C. transversalis* (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	70±3.52	35.40± 3.87	30.80± 2.62	22± 5.13	26±1. 86**a**	14±1. 86	16± 1.86	13.6±2. 11	23±2.55 **b**	1.18±0.07 **cd**
	LT_5	Kerosinized ash (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	63±3.73	33±9.93	39± 3.31	15± 2.23	16±3. 99**a**	11.6± 2.65	24± 4.86	41±6.39	15.80± 5.20**bc**	1.14±0.05 **cd**
	LT_6	Control, spray water only (first round and second round)	54±8.98	52±5.82	67± 3.74	31± 10.03	25±8. 41**a**	23±5. 37	36± 3.9	20±6.51	51±5.56 **a**	0.88±0.05 **d**
							P=.000				P=.000	P=.000
							F=7.614				F=20.862	F=63.271

- All figures are mean of five replications
- DAT – Days after treatment
- Means having the same letter(s) in a column are not significantly different at 0.05 probability level by DMRT.
- Average canopy size 0.87 square meter/plant.

Table 14. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of bean aphid, *A. craccivora* Koch and yield of bean in field F (Var.BARI Seem-2).

Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								Yield (kg/plant) Mean±S.E.
			Pre-treatment	First round treatment (18.01.2004)				Second round treatment (08.02.2004)			
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT
F 31.8.08 (Late sowing)	LT_1	Admire 200 SL@ 1 ml/L water (first round and second round)	96.00±4.30	34.00± 5.10	5.80± 1.28	0.40± 0.24	5.80± 1.43**c**	0.40± 0.24	2.60± 0.93	6.40± 3.06	6.40± 1.89**c**	1.56±0.02 **a**
	LT_2	Admire 200 SL@ 1 ml/L water (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	97.00±9.17	31.00± 6.00	3.60± 0.93	2.40± 0.51	5.00± 1.48**c**	0	9.60± 1.50	17.00± 2.28	15.00±0. 71**bc**	1.50±0.16 **a**
	LT_3	Larvae of *C. transversalis* (first round and second round)	106.20±6.33	93.60± 2.23	76.60± 3.40	57.00± 5.61	57.00± 3.00**b**	37.00± 4.36	36.60± 10.20	28.20± 5.85	40.60± 8.08**a**	1.05±0.09 **b**
	LT_4	Larvae of *C. transversalis* (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	144.00±22.90	114.00± 14.70	76.00± 5.10	52.00± 7.18	43.00± 5.39**b**	30.00± 5.70	28.00± 8.00	25.60± 4.99	25.00±2. 24**b**	0.48±0.01 **c**
	LT_5	Kerosinized ash (first round) and Tobacco leaf extract @ 1:10 W/V (second round)	166.00±10.80	146.00± 11.70	104.00± 5.10	76.00± 5.10	60.00± 7.07**b**	51.00± 4.00	24.60± 2.48	12.00± 1.22	26.00±1. 87**b**	0.46±0.05 **c**
	LT_6	Control, spray water only (first round and second round)	167.00±10.70	114.00± 8.12	122.00± 9.70	108.00± 7.35	96.00± 10.30**a**	41.00± 6.40	23.00± 5.39	28.20± 8.90	18.00± 0.95**b**	0.34±0.02 **c**
							P=.000 F=36.979				P=.000 F=10.340	P=.000 F=47.799

- All figures are mean of five replications
- DAT – Days after treatment
- Means having the same letter(s) in a column are not significantly different at 0.05 probability level by DMRT.
- Average canopy size 0.85 square metre/plant.

Table 15. Yield (Mean ±S.E.) of bean (kg/ plant)in terms of date of sowing ,variety and treatments.

Date of sowing	Crop variety	Treatments					
		T_1	T_2	T_3	T_4	T_5	T_6
Early sowing 31.07.2003	BARI Seem-1	3.35±0.09**a**	2.74±0.18**a**	1.78±0.15**a**	1.60±0.09**a**	1.46±0.22**a**	1.14±0.06**a**
	BARI Seem-2	2.05±0.12**b**	1.45 ±0.12**b**	0.95±0.28**c**	0.55±0.05**c**	0.53±0.06**c**	0.36±0.04**c**
Mid sowing 15.08.2003	BARI Seem-1	3.10 ± 0.09**a**	2.72±0.44**a**	1.48± 0.14**ab**	1.46±0.05**a**	1.22±0.06**b**	1.0±0.03**b**
	BARI Seem-2	1.40±0.10**c**	1.25±0.08**b**	0.80±0.05**c**	0.52±0.02**c**	0.50±0.03**c**	0.40±0.06**c**
Late sowing 31.08.2003	BARI Seem-1	3.14±0.17**a**	2.62 ± 0.10**a**	1.28±0.19**bc**	1.18±0.07**b**	1.14±0.05**b**	0.88±0.05**b**
	BARI Seem-2	1.56 ±0.02**c**	1.50±0.16**b**	1.05 ±0.09**bc**	0.48±0.01**c**	0.46 ±0.05**c**	0.34±0.02**c**
		P=.000 F=45.97	P=.000 F=28.99	P=.002 F=5.27	P=.000 F=77.80	P=.000 F=74.06	P=.000 F=60.24

- All figures are mean of five replications
- Means having the same letters in a column are not significantly different at P<0.01 and P<0.001 level by DMRT
- Detailed description of treatments(T_1.T_6) were already mentioned in Table(9-14)

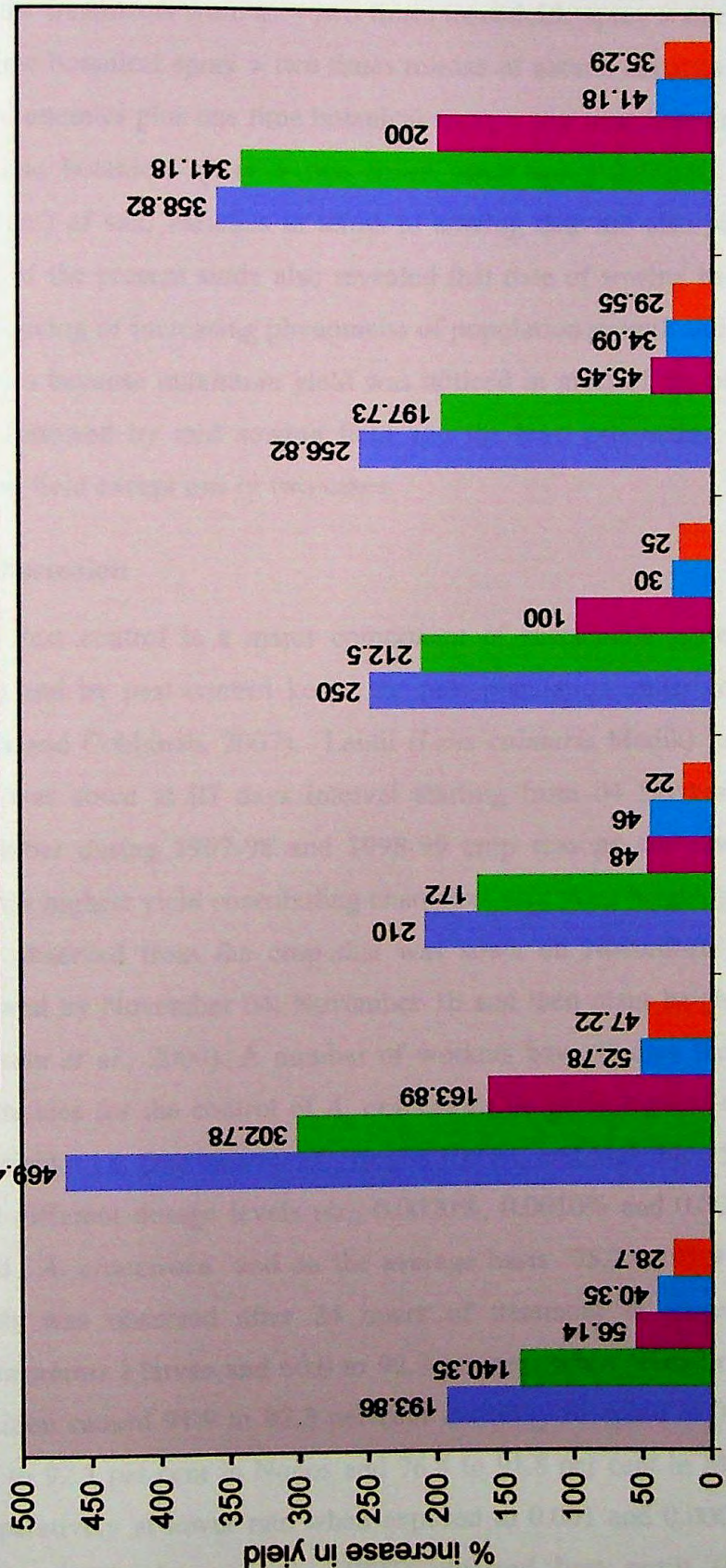


Figure 6: Percent increase in yield over control (T_6) in various treatments for BARI Seem-1 and BARI Seem-2.

A,B,C,D,E and F respectively (Fig.6). Thus in order of increasing efficacy on yield of bean the treatments were as – two times insecticide spray > one time insecticide plus one time botanical spray > two times release of natural enemies > one time release of natural enemies plus one time botanical spray > one time kerosinized ash dusting plus one time botanical spray > two times water spray (control). Besides mean yield (kg/plant) of said varieties in terms of sowing date are also plotted in Table15.The result of the present study also revealed that date of sowing has immense impact on the reducing or increasing phenomena of population growth and yield of bean in both varieties because maximum yield was noticed in most of the blocks of early sowing field followed by mid sowing field and the least production was recorded in late sowing field except one or two cases.

4.4. Discussion

Pest control is a major component of sustainable agriculture (Zhang *et al.*, 2005) and by pest control keeps the pest population under economic injury levels (Ofori and Cobbinah, 2007). Lentil (*Lens culinaris* Medik) a very related crop of bean was sown at 07 days interval starting from 04 November continued till 09 December during 1997-98 and 1998-99 crop seasons and lowest aphid infestation visa-vis highest yield contributing characters *viz.*, plant height, pods/plant, grain yield were observed from the crop that was sown on November 11 in both the years followed by November 04, November 18 and then plant height gradually decreased (Hossain *et al.,* 2000). A number of workers have studied the efficacy of different insecticides for the control of *A. craccivora* on grain legume crops. Three common insecticides i.e. Diazinon 60 EC, Nogos 100 EC and Malathion 57 EC were sprayed at three different dosage levels *viz.*, 0.0020%, 0.0010% and 0.0005% AI against bean aphid , *A. craccivora* and on the average basis 75.7 to 91.9 per cent mortality of aphids was observed after 24 hours of treatment in presence of predator (*M. sexmaculatus*) larvae and 60.0 to 92.7 per cent when predator adults were present . Diazinon caused 91.9 to 92.3 per cent mortality of aphid at 0.02% AI followed by 87.1 to 92.3 per cent in Nogos and 76.4 to 91.8 per cent in Malathion. Aphids died comparatively at lower rate when exposed to 0.001 and 0.0005% doses (Islam and Sardar, 1997). Jena *et al.*, (1997) obtained best result (83.70% reduction of

infestation) by using Dimethoate 30 EC to control *A. craccivora* on groundnut at Bhubaneswar, India. Sarup *et al.,* (1974) assessed the biological efficacy of six insecticidal granular formulations *viz.,* Lindane, Phorate, Disulfoton, Aphidan, Dimethoate and Phosmamidon against some important predators and pest of pea cops including *A. craccivora* and recorded Disulfoton to be the most effective. Bari and Sardar (1998) worked on the control strategy of bean aphid, *A. craccivora* with predator *Menochilus sexmaculatus* (Fabr.) and insecticides Diazinon 0.002% AI and Malathion 0.002% AI and observed that Malathion was comparatively better than Diazinon and *M. sexmaculatus* had adequate reductive impact on *A. craccivora* particularly at low density. Lokhande and Mohan (1990) recorded each larva of *M. sexmaculatus* consumed on an average 8.50 adults and 73.52 nymphs of *A. craccivora* /day and the adult member of the predator consumed 24.34 adult aphids and 176.15 nymphs /day. Thakur *et al.,* (1984) carried out an experiment to determine the effectiveness of six insecticides against *A. craccivora* on lentil and observed that all the insecticides were effective against the pest as compared with untreated blocks. The most effective of the compounds 72 hour after treatment were Dimethoate and Phosmamidon while Dimeton-Methyl and Fenvalerate had an early knockdown effect. According to Khurana and Kaushic (1991), Monocrotophos (0.025%) and Endosulphan (0.05%) were very effective against *A. craccivora.* Abate and Ampofo (1996) worked on the management of insect pest of beans in Africa through the use of a traditional IPM approach that consists of appropriate sowing dates , varietals mixtures, intercropping , good crop husbandry , locally available materials, natural biological controlled and obtained a very excellent result. Ogenga-Latigo *et al.,*(1999) reported reduced aphid (*Aphis fabae* Scop.) infestation and damage when beans were intercropped with densely populated older maize. From the study of Shah *et al.,* (2001) on relative susceptibility of dolichos bean *Lablab purpureus* L. to black bean aphid, *A. craccivora* , it was found that lowest aphid population in genotype AC-120 followed by AC-134, AC-351 and AC-354. The maximum aphid population was recorded in S-27, (most susceptible genotype).

From the result of present observation it is evident that two times insecticidal treatments irrespective of sowing date gave an excellent result in reducing aphid population which in turn resulted in higher yields of bean. Next effective result was

found from the treatment by one time insecticide spray plus one time botanical spray. But in the past no one took this sort of pest control measure using IPM concept to control *A. craccivora* infesting bean plant in Bangladesh. Das (2001) conducted an experiment on IPM of aphid pest on egg plant and concluded that the population of *A. gossypii* on the egg plant could be kept under economic threshold level by sowing date manipulation with minimum insecticide use and release of the effective natural enemies. Phadke and Prasad (1987) studied the effect of sowing date on aphid incidence in some varieties of rapeseed and mustard and mentioned that delayed sowings made the plants to suffer from higher injury at a younger crop stage. Results of the present study thus confirmed the findings of Phadke and Prasad (1987), Hossain *et al.*, (2000) and Das (2001) who strongly suggested that early sowing would be very effective to escape aphid infestation.

However in order to reduce the use of insecticide, 'one time insecticide spray plus one time botanical spray' or 'two times release of natural enemies' or 'one time release of natural enemies plus one time botanical spray' or 'one time dusting of kerosinized ash plus one time botanical spray' may be applied to control *A. craccivora* in the field. One time release of natural enemies plus one time botanical spray technique may be selected to control *A. craccivora* since this is harmless to the environment and less expensive.

CHAPTER 5 Integrated management of brinjal aphid, *Aphis gossypii* Glover

5.1. Introduction

5.1.1. Importance and cultivation of brinjal

Eggplant, *Solanum melongena* L. a solanaceous vegetable popularly known as brinjal and extensively cultivated during both the rabi and kharif season in Bangladesh (Rahman *et al.*,2003).The name of egg plant derives from the fruit of some varieties which look like chicken eggs (Chen *et al.*, 2002). It is one of the most common and important vegetable sources in our country and occupy second highest place in terms of production following potato (Anonymous, 1994).Only in rabi 2000-2001 crop season, 103875 acres of land were under brinjal cultivation where the production was 269790 metric tons with the average yield of 2.60 metric tons/acre (B.B.S., 2004) . In rural areas it is grown for home consumption in almost all families near the homestead. In many localities this vegetable is grown commercially. A number of cultivars are grown throughout the country depending upon yield, consumers preference about the color, size and shape of the various cultivars. The brinjal is of much importance in the warm areas of Fareast being grown in India, Pakistan, China and the Philippines. It is also popular in France, Italy and USA.

Brinjal has been a staple vegetable in our diet since ancient times. It is liked by both poor and rich contrary to the common belief; it is quite high in nutritive value and can well be compared with tomato (Chaudhury, 1976). Per hundred gram edible portion of a brinjal contains 92.7 gm moisture,1.4 gm protein, 0.3 gm fat, 0.3 gm minerals , 1.3 gm fiber, 4.0 gm carbohydrate, 18 mg calcium, 16 mg magnesium, 18 mg oxalic acid, 47 mg phosphorous, 0.9 mg iron, 3.0 mg sodium, 2.0 mg potassium, 0.17 mg copper, 44.0 mg sulphur, 52.0mg chlorine, 1249.4 vitamin A, 0.04 mg thiamine, 0.11 mg riboflavin, 0.09 mg nicotinic acid and 12.0 mg vitamin C respectively (Aykroid, 1963). The unripe fruit is primarily used as a cooked vegetable and it has got much potential as raw material in pickle making and dehydration industries (Sing *et al.*, 1963). It is supposed to contain medicinal properties and acts as an excellent remedy for those suffering from diabetes and liver complaints (Chauhan, 1981).

5.1.2. Diseases and pests of brinjal

The brinjal is subjected to the attack of bacterial, virus and fungal diseases affecting roots, leaves, steams and fruits. The severity in any particular disease depends on the season and the region in which the crop is grown. Insect pest infestation is one of the most limiting factors for accelerating yield potential of brinjal. The crop brinjal suffers from the damage due to pests of about two dozen different insect species, out of which *A. gossypii* has been considered as major one (Gapud ,1992).

5.1.3. *Aphis gossypii* Glover:Homoptera:Aphididae

The aphids are soft bodied yellowish insects each measuring 1.0-1.5mm with two cornicles at the abdomen. Initially they are found on the lower surface of the leaves but move to the upper surface, stem and flower when they increase in enormous number. They multiply by parthenogenesis instead of reproducing through eggs. These immature insects develop into adult aphid within a weak and start producing next generation.

5.1.4. Nature of damage by *Aphis gossypii* Glover

After transplantation, the seedlings of brinjal put forth new succulent leaves and grown vigorously and it is the succulent sappy tender leaves of young plants that are preferred by *A. gossypii* as against harden leaves of brinjal. Nymphs and adults are found to suck sap from the ventral surface of the leaves. The infested leaves, become curled up or wrinkled and the affected portion fade and gradually the whole twig becomes more or less blighted, thus causes great damage to the plant (Alam, 1969). Moreover, this aphid transmits many plant viruses which are also responsible for the loss of crop. The most interesting thing is *A. gossypii* leads anholocyclic life-cycle in Bangladesh and for this reason they are available in brinjal field throughout the year. *A. gossypii* reproduces partheno-genetically and give birth to young ones. Male morph of this species has yet not been reported from Bangladesh. Apterae, alatae, alatoid and normal nymphs are the general member of an aphid colony on brinjal in this country. The proportion of alatoid nymphs increase rapidly within short period of time offer the initiation of *A. gossypii* on brinjal. As a result, the entire brinjal plant of the field are severerely affected. The damage reaches its speak during mid to late winter.

5.1.5. Distribution and host plants of *Aphis gossypii* Glover

A. gossypii is a cosmopolitan polyphagous aphid and attacks about 220 host plants belonging to 46 families throughout the world (Roy and Behura, 1983). Ebert and Cartwright (1997) reported over 90 plant families in which at least one species was listed as a host. *A. gossypii* is wide spread in tropical and warm temperate regions (Schmutterer, 1978) and it is a polyphagous species occurring throughout the year on different host plants all over Bangladesh (Karim *et al.*, 2002). Das (2002), mentioned *A. gossypii* is distributed all over Bangladesh and infests 12 crops and 8 ornamental plants during winter season. These are : *Abelmoschus esculentus* L., *Capiscum annum* L., *Corchorus capsularis* L., *Coriaudrum sativum* L., *C. maxima, Cucurbita pepo* Dc, *Gossypium arboreum* L., *G. herbaceum* L., *Lagenaria leucantha* (Duch), *Rusby, M charantea, Solanum melongena Wall, S. tuberosum* L., *and Bellis perenms* L., *Cestrum nocturnum* L., *Chrysanthemum coronarium* L., *Codiaeum variegatum* Bl., *Hibiscus rosasinensis* L., *Rosa ceutifolia* L., *Tagetes patula* L., *Zinnia elegans* L. respectively. According to him few trees *viz.*, *Cassia alata* L., *C. fistual* L., *Lagerstromoea thorelli* Sm., *Ppsidium guajava* L. and one medicinal plant, *viz.*, *Eclipta alba* L. are also attacked by this aphid species.

5.1.6. Natural enemies of *Aphis gossypii* Glover

Eleven predators and two parasitoids are encountered in the *A. gossypii* infested crop fields in Bangladesh (Das, 1994). These are as follows:

Predators of *Aphis gossipii* Glover:

I) *Anatis sp.*

II) *Cocinella septempunctata* L.

III) *Coccinella transversalis* (Fabr.)

IV) *Cheilomenes sexmaculata*(Fabr.)

V) *Ischiodon scutellaris* (Fabr.)

VI) *Micraspis discolor* (Fabr.)

VII) *Scymnus pyrochellus* Mulsant

VIII) *Synharmonia octomaculata* (Fabr.)

IX)*Orius sp.*

X)*Paragus sp.*

XI)*Brumoids suturalis*

Parasitoids of *Aphis gossypii* Glover:

I) *Binodoxyrs indicus* (Subba Rao and Sharma)

II) *Aphelinus mali* (Haldmann)

5.1.7. *Aphis gossypii* Glover and IPM

Brinjal is the most common and important vegetable in Bangladesh. The production of this vegetable is seriously affected by two dozen insect pests, out of which *A. gossypii* has been considered as major one (Gapud, 1992). The aphid *A. gossypii* harm not only by direct feeding damage but also transmits many plant viruses which are also responsible for the loss of crop. So to control this aphid species, farmers of our country have to rely only on the insecticide spray in spite of its hazardous effect on the environment. In order to minimize this hazardous effect there is no other alternative of IPM. But an integrated pest management approach to control *A. gossypii* was not available in Bangladesh. Accordingly evaluation of impact of insecticides, botanicals, natural enemies, various indigenous materials either separately or in combination with one another on the population of *A. gossypii* and on yield of brinjal were carried out. The findings of this type of research may be helpful to develop an IPM package against a specific aphid species. These are the objectives of the present work.

5.2. Materials and Methods

The experiment was carried out at Rajshahi University Campus during rabi 2004-2005. The entire research work was divided into following heads.

Preparation of seed bed:

Seed beds were prepared by harrowing, followed by ploughing, cross ploughing and leveling since a sandy loam soil that is fertile, deep and well drained is ideal for egg plant. The size of each bed was 4m long and 1m wide. Cow dung @ 15 ton urea, TSP and MP @ 250, 150, 125 kg respectively per hectare were applied as recommended by Rashid (1993).

Seedling production and transplanting:

Certified seeds of two BARI brinjal cultivar, Nayantara and Kazla were collected from BARI, Joydebpur, Gazipur. Seeds of each cultivar were sown in three seedling beds at three different dates *viz.*, 1st September (Early sowing), 16th September (Mid sowing) and 1st October (Late sowing). A seedling of forty day-old (3/4 leaf stage) from each bed were transplanted in the soil of experimental earthen tubs of 120 cm diameter and 40 cm deep. Transplanting were done during late afternoon in order to minimize the transplanting shock. Besides, immediately after transplanting soil surface of the tubs were irrigated sufficiently to establish a good root to soil contact. Eighteen tubs were prepared by the seedling of each cultivar and each sowing date respectively and divided them further into six blocks (T_1 –T_6) i.e. three tubs comprised as a block. Tubs were arranged in such a manner that plant spacing were maintained as 60 cm between plants and 1 meter between rows. In order to ensure green and healthy conditions of plants, fertilizers including cow dung and irrigation were applied into the soil of the tubs as and when necessary throughout the investigation period.

Counting of aphids:

The brinjal plants of each block were checked regularly to observe the aphid infestation. Sampling of aphids were done just after immediate notice of *A. gossypii* in the field. Altogether three types of leaf (young, mature and old) from each plant of all the blocks were considered for the counting of aphids. The plants observed once were not taken for subsequent observation. In case of thick colonies aphids were taken carefully on a white plastic plate from the infested leaves by means of a soft camel hair brush (0 size), counted and thereafter they were placed back to the same place of the plant. Counts were taken before and after 1, 3, 7 and 20 days of treatment.

Details of treatments :

The experiment comprising six treatments including a control and treatments were done considering both the sowing date and age of plant. Hence treatment schedule varied from field to field. Sprays operations were conducted when wind velocity was normal and dew drops dried up to avoid insecticidal drift. The gap in

between first round and second round treatment was twenty days in each. Each block of the experimental fields of respective sowing date was used for specific type of treatment.

Treatment block T_1 = Nimbicidine (0.03% EC Azadirachtin) @ 4ml/L water (1^{st} round and 2^{nd} round).

Treatment block T_2 = Nimbicidine (0.03% EC Azadirachtin) @ 4ml/L water (1^{st} round) and Bankalmi leaf extract @1:10 W/V (2^{nd} round).

Treatment block T_3 = Larvae of *C. transversalis* (1^{st} round and 2^{nd} round).

Treatment block T_4 = T_3 (1^{st} round) and Bankalmi leaf extract @1:10 W/V (2^{nd} round).

Treatment block T_5 = Kerosinized ash (1^{st} round) and Bankalmi leaf extract @1:10 W/V (2^{nd} round).

Treatment block T_6 = Control, spray water only (1^{st} round and 2^{nd} round).

Nimbicidine (Insecticide):

Nimbicidine is only an organic phyto based insecticide in Bangladesh marked by ACI Crop Care widely used to control rice and vegetable pests. It is systemic in nature and derived from the extract of neem (*Azadirachta indica* Juss) and each liter of Nimbicidine contains 0.03% EC Azadirachtin. It is safe to beneficial and fits thereby excellent to IPM programs. The insecticide was diluted as 4ml: 1000ml @ 2 liter per hectare.

Bankalmi leaf extract (botanical):

Leaves of the plant Bankalmi, *Ipomoea* spp. (Family Convolvulaceae) collected from Rajshahi University Campus were air dried at room temperature (20-34^0 C) and then made into fine powder by a hand grinder. The leaf powder was dissolved in normal water at room temperature for 10 days. The proportion of plant material and water was 1:10 (w/v). The dissolved material was then passed through a fine mesh nylon cloth to separate the extract from the plant debris. The extracted water was then poured into the sprayer and sprayed in block T_2, T_4 and T_5 (Second round) of each experimental field.

Natural enemies release :

Five third instar larvae of *C. transvresalis*, (Omker and Parvez, 2000) were released per plant in block T_3 (First round and second round) and T_4 of each field (First round only) with soft brush (0 size).

Kerosinized ash :

Certain mineral oils are well known to reduce aphid colonization on plants and thus the transmission of virus diseases (Simons and Zitter, 1980). Accordingly six tea spoon of kerosene were mixed with 1 kg of wood ash and applied manually by throwing in block T_5 (First round) of each field.

The control block T_6 of each field were also sprayed with water only at the time of treatment made on other blocks of respective field.

Yield counting :

The number of brinjal per plant from all the blocks were collected and their weight was recorded. Usually the very immature and abnormal brinjal were not recorded.

Data recording and analysis :

Data base upon both the number of aphids (Nymphs and adults) and crop yield per plant was averaged and presented in Table 16-21. Mean data expressed in counting aphids density and crop yield was analyzed statistically by analysis of variance (ANOVA) to test the significance in difference among the treatments. Mean separation was done by Duncan's Multiple Range Test (DMRT) at 0.05 probability level. All statistical works were done with the help of Statistical Software, SPSS (Ver. 11.5).

5.3. Results

Nayantara brinjal is rounded in shape and its color is bright purple. On an average twenty to thirty brinjals were produced by a single plant and weight of each brinjal varies from 120 gm to 130 gm. First harvesting were done within eighty to eighty five days of sowing. The shape of Kazla brinjal on the other hand is moderately elongated and blackish purpled colored. Seventy to eighty brinjals produced per plant

and weight of each brinjal varies from 55 gm to 60 gm. After sowing, ninety to ninety five days are needed to produce brinjal by the variety Kazla. Effect of various treatments on the mean member of aphids per plant during 1, 3, 7 and 20 days of treatment and finally on yield in two varieties under three sowing dates have been plotted in Table 16-21. Among all the treatments, highest aphid population and minimum yield per plant were recorded in controlled block (T_6) irrespective of varietal difference and sowing date. However two times insecticide spray provided better effect on aphid population reduction and consequently on highest yield in early, mid and late sowing fields of two varieties compared to other treatments. Insecticide plus botanical treated block (T_2) stood in second position in aphid population reduction. Two times treatment by natural enemies (block T_3), one time natural enemies plus one time botanical treated block (block T_4) and one time kerosinised ash plus one time botanical treated block (block T_5) reduced aphid numbers and produced significantly different yield in comparison to untreated (controlled) blocks.

In case of early sowing fields of the variety Nayantara as shown in Table 16, highest yield of brinjal (3.17±0.17 kg/plant) was found in two times insecticide treated blocks (ET_1) and it was 89.82% increase in yield over control. This was followed by 79.64%, 54.49%. 49.70% and 19.76% (Fig.7) in the blocks having treatment by one time insecticide plus one time botanical treated block (ET_2),two times natural enemies treated block (ET_3), one time natural enemies plus one time botanical treated block (ET_4) and one time kerosinised ash plus one time botanical treated block (ET_5) respectively. Similar trends of yield of brinjal may be noticed in mid and late sowing fields of the same variety that have been depicted in Table 18 and 20.

On the other hand highest production (2.10±0.06 kg/plant) of Kazla brinjal was recorded from two times insecticide treated block (Table 17) of early sowing field (ET_1) followed by one time insecticide plus one time botanical treated block (ET_2), two times natural enemies (ET_3), one time natural enemies plus one time botanical (ET_4) and one time kerosinised ash plus one time botanical (ET_5) respectively. Regarding yield the mid and late sowing fields of the same variety also produced similar results (Table 19 and 21).Statistical analysis also revealed that yield of brinjal differed significantly ($P<0.01$ and $P<0.001$) within specific treatment blocks of early, mid and late sowing fields of both varieties (Table 22). From the pretreatment count,

Table 16. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of brinjal aphid, *Aphis gossypii* Glover after two treatments and yield of brinjal in field A (Var. Nayantara).

Plot/Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E)/plant								yield (kg/block) Mean ± S.E.
			Pre-treatment DBT	First round treatment (01.12.2004)				Second round treatment (22.12.2004)			
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT	
A 01.09.04 (Early sowing)	ET_1	Nimbicidine @ 4ml/L water (First round and second round)	7.33± 3.17	7.00± 1.00	5.67± 0.33	3.00± 1.73	7.00± 0.58**b**	3.00± 1.73	1.00± 1.00	0.00± 0.00	6.00± 3.00**a**	3.17± 0.17**a**
	ET_2	Nimbicidine @ 4ml/L water (First round and Bankalmi leaf extract @1:10 W/V (second round)	11.67± 2.19	8.33± 0.88	6.67± 4.06	5.00± 2.00	6.00± 0.00**b**	5.33± 1.20	5.00 ± 2.00	6.00± 0.00	10.00± 0.58**a**	3.00 ± 0.00**ab**
	ET_3	Larvae of *C. transversalis* (First round and Second round)	12.00± 0.58	10.00± 1.00	9.33± 2.85	10.00± 0.58	11.67± 2.40**ab**	12.00± 6.25	15.00± 5.00	20.00± 5.77	16.07± 3.33**a**	2.58± 0.30**abc**
	ET_4	ET_3 (First round) and Bankalmi leaf extract @ 1:10 W/V (Second round)	8.33± 1.20	10.00± 0.00	9.33± 2.91	2.67± 1.76	5.33± 2.73**b**	5.00± 1.15	5.33± 2.33	6.00± 1.15	15.00± 5.00**a**	2.50± 0.02 **bc**
	ET_5	Kerosinized ash (First round) and Bankalmi leaf extract @ 1:10 W/V (Second round)	11.67± 4.37	5.33± 0.33	5.00± 0.00	5.00± 2.52	8.33± 3.33**b**	5.00± 2.89	5.33± 2.91	6.00± 2.31	13.33± 8.33**a**	2.00± 0.29 **cd**
	ET_6	Control, Spray water only (First round and second round).	13.33± 3.33	11.67± 3.33	15.00± 2.89	16.67± 4.41	20.00± 5.00**a**	22.67± 7.42	20.00± 7.64	27.00± 6.51	24.67± 8.35**a**	1.67± 0.17 **d**

- All figures are mean of three replications. P=.030 P=.323 P=.001
- DBT – Day before treatment. F=3.669 F=1.312 F=8.612
- Means having the same letter (s) in a column are not significantly different at 0.05 probability level by DMRT.
- DAT –Days after treatment.

Table 17. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of brinjal aphid, *Aphis gossypii* Glover after two treatments and yield of brinjal in field B (Var. Kazla).

Plot/Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								yield (kg/block) Mean ± S.E.
			Pre-treatment DBT	First round treatment (01.12.2004)				Second round treatment (22.12.2004)			
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT	
B 01.09.04 (Early sowing)	ET_1	Nimbicidine @ 4ml/L water (First round and second round)	6.67± 2.40	8.33± 3.53	5.00± 2.89	6.67± 1.20	6.67± 1.45**a**	5.00± 2.00	11.67± 6.01	13.33± 4.41	18.33± 1.20**a**	2.10± 0.06 **a**
	ET_2	Nimbicidine @ 4ml/L water (First round and Bankalmi leaf extract @1:10 W/V (second round)	13.33± 3.33	8.67± 1.33	8.33± 1.20	5.33± 0.88	6.67± 1.20**a**	8.33± 1.67	13.33± 3.33	6.67± 1.76	8.33± 2.03**a**	2.00 ± 0.00 **a**
	ET_3	Larvae of *C. transversalis* (First round and Second round)	10.00± 0.00	10.00± 6.08	9.33± 1.86	8.33± 1.20	13.33a ±.82**a**	10.00± 2.65	16.67± 9.28	16.67± 1.20	20.00± 7.64**a**	1.75± 0.14 **ab**
	ET_4	ET_3 (First round) and Bankalmi leaf extract @ 1:10 W/V (Second round)	8.33± 2.33	8.33± 1.86	10.33± 0.67	6.67± 3.33	6.67± 3.33**a**	6.67± 0.33	6.67± 0.33	6.67± 2.91	10.00± 0.58**a**	1.42± 0.22 **bc**
	ET_5	Kerosinized ash (First round) and Bankalmi leaf extract @ 1:10 W/V (Second round)	11.67± 4.26	6.67± 3.38	5.33± 2.73	5.00± 0.00	10.00± 3.21**a**	8.33± 4.41	6.67± 3.33	6.67± 1.20	13.33± 2.60**a**	1.17± 0.08 **c**
	ET_6	Control, Spray water only (First round and second round).	11.67± 4.26	11.67± 4.18	13.33± 3.84	6.67± 3.33	16.67± 4.37**a**	20.00± 10.40	20.00± 5.77	20.00± 6.43	16.67± 3.53**a**	1.10± 0.10 **c**

- All figures are mean of three replications. P= .526 P=.241 P=.000
- DBT – Day before treatment. F= .875 F=1.571 F=12.212
- Means having the same letter (s) in a column are not significantly different at 0.05 probability level by DMRT.
- DAT –Days after treatment.

Table 18. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of brinjal aphid, *Aphis gossypii* Glover after two treatments and yield of brinjal in field C (Var. Nayantara).

Plot/Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								yield (kg/block) Mean ± S.E.
			Pre-treatment DBT	First round treatment (16.12.2004)				Second round treatment (06.01.2005)			
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT	
C 16.09.04 (Mid sowing)	MT_1	Nimbicidine @ 4ml/L water (First round and second round)	23.33± 7.69	17.67± 4.33	16.67± 0.67	18.67± 1.33	22.33± 5.36**ab**	11.00± 2.08	19.33± 1.76	26.00± 3.06	27.50± 10.20**a**	2.97± 0.03 **a**
	MT_2	Nimbicidine@ 4ml/L water (First round and Bankalmi leaf extract @1:10 W/V (second round)	40.00± 5.77	21.67± 6.01	18.67± 3.18	17.00± 9.07	15.00± 2.89**b**	21.67± 4.41	12.67± 2.91	10.00± 4.00	11.67± 2.85**a**	2.67 ± 0.33 **ab**
	MT_3	Larvae of *C. transversalis* (First round and Second round)	26.67± 1.67	16.67± 4.41	18.33± 7.22	18.33± 3.84	26.67± 8.11**ab**	15.00± 8.66	20.00± 5.00	23.33± 8.41	30.00± 8.66**a**	2.50± 0.00 **ab**
	MT_4	ET_3 (First round) and Bankalmi leaf extract @ 1:10 W/V (Second round)	10.00± 1.15	12.00± 3.46	10.00± 0.00	15.33± 2.91	16.67± 8.82**ab**	13.33± 3.33	10.00± 2.89	22.67± 3.71	35.00± 8.66**a**	2.33± 0.17 **abc**
	MT_5	Kerosinized ash (First round) and Bankalmi leaf extract @ 1:10 W/V (Second round)	13.33± 3.38	6.67± 3.76	13.33± 1.67	20.00± 5.77	36.67± 6.01**a**	20.00± 10.40	13.33± 4.37	15.00± 0.00	28.33± 1.67**a**	2.17± 0.17 **bc**
	MT_6	Control, Spray water only (First round and second round).	11.67± 2.03	13.33± 3.33	20.00± 2.89	26.67± 6.67	28.33± 1.67**ab**	33.33± 3.33	36.67± 1.67	43.33± 6.01	40.00± 20.00**a**	1.67± 0.33 **c**

- All figures are mean of three replications. P=.194 P=.483 P=.018
- DBT – Day before treatment. F=1.768 F=.953 F= 4.291
- Means having the same letter (s) in a column are not significantly different at 0.05 probability level by DMRT.
- DAT –Days after treatment.

Table 19. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of brinjal aphid, *Aphis gossypii* Glover after two treatments and yield of brinjal in field D (Var. Kazla).

Plot/Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								yield (kg/block) Mean ± S.E.
			Pre-treatment DBT	First round treatment (16.12.2004)				Second round treatment (06.01.2005)			
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT	
D 16.09.04 (Mid sowing)	MT_1	Nimbicidine @ 4ml/L water (First round and second round)	21.67± 4.41	13.33± 1.67	6.67± 1.45	15.67± 6.74	20.00± 2.89**ab**	10.00± 2.89	13.33± 3.38	3.33± 2.85	30.00± 11.50**a b**	2.00± 0.00 **a**
	MT_2	Nimbicidine @ 4ml/L water (First round and Bankalmi leaf extract @1:10 W/V (second round)	33.33± 4.41	23.33± 6.01	20.00± 5.77	10.00± 0.58	13.33± 3.53**b**	20.00± 5.00	10.00± 0.58	3.33± 2.40	21.67± 3.33**ab**	1.77 ± 0.12 **b**
	MT_3	Larvae of *C. transversalis* (First round and Second round)	21.67± 6.01	13.33± 1.67	20.00± 0.00	18.33± 6.01	26.67± 4.41**a**	15.00± 2.89	21.67± 4.41	13.33± 3.84	13.33± 4.06**b**	1.57± 0.03 **bc**
	MT_4	ET_3 (First round) and Bankalmi leaf extract @ 1:10 W/V (Second round)	5.00± 2.00	10.00± 1.15	10.00± 0.58	13.33± 3.33	13.33± 2.40**b**	11.67± 2.03	5.00± 2.52	10.00± 1.00	15.00± 2.89**ab**	1.37± 0.03 **c**
	MT_5	Kerosinized ash (First round) and Bankalmi leaf extract @ 1:10 W/V (Second round)	13.33± 1.76	2.67± 1.76	6.67± 1.20	6.67± 0.88	13.33± 2.40**b**	11.67± 1.45	20.00± 11.50	23.33± 6.01	36.67± 7.27**a**	1.33± 0.03 **c**
	MT_6	Control, Spray water only (First round and second round).	13.33± 3.84	13.33± 1.67	13.33± 1.67	13.33± 3.33	20.00± 2.89**ab**	16.67± 1.67	18.33± 1.67	30.00± 5.77	36.67± 7.27**a**	1.07± 0.12 **d**

- All figures are mean of three replications. P=.057 P=.103 P=.000
- DBT – Day before treatment. F=2.957 F=2.370 F=20.752
- Means having the same letter (s) in a column are not significantly different at 0.05 probability level by DMRT.
- DAT –Days after treatment.

Table 20. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of brinjal aphid, *Aphis gossypii* Glover after two treatments and yield of brinjal in field E (Var. Nayantara).

Plot/Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								yield (kg/block) Mean ± S.E.
			Pre-treatment DBT	First round treatment (31.12.2004)			Second round treatment (21.01.2005)				
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT	
E 01.10.04 (Late sowing)	LT_1	Nimbicidine @ 4ml/L water (First round and second round)	25.00± 2.89	16.67± 3.33	18.33± 6.01	20.00± 5.77	26.67± 1.67**ab**	13.33± 3.84	26.67± 6.01	33.33± 14.50	40.00± 5.77**ab**	2.53± 0.03 **a**
	LT_2	Nimbicidine @ 4ml/L water (First round and Bankalmi leaf extract @1:10 W/V (second round)	46.67± 6.67	23.33± 4.41	20.00± 2.89	16.67± 3.33	16.67± 3.33**b**	26.67± 6.67	26.67± 6.67	30.00± 5.00	35.00± 2.89**ab**	2.17 ± 0.17 **ab**
	LT_3	Larvae of *C. transversalis* (First round and Second round)	25.00± 7.64	20.00± 5.77	23.33± 2.27	20.00± 5.77	33.33± 3.33**ab**	20.00± 5.77	26.67± 6.01	30.00± 10.00	45.00± 15.00a **b**	2.33± 0.33 **a**
	LT_4	ET_3 (First round) and Bankalmi leaf extract @ 1:10 W/V (Second round)	13.33± 3.33	13.33± 1.67	13.33± 4.41	20.00± 5.77	28.33± 7.27**ab**	20.00± 2.89	8.33± 1.67	20.00± 5.00	30.00± 5.00**b**	2.33± 0.09 **a**
	LT_5	Kerosinized ash (First round) and Bankalmi leaf extract @ 1:10 W/V (Second round)	15.00± 7.64	10.00± 0.00	16.67± 3.33	26.67± 6.67	40.00± 5.77**a**	26.67± 8.82	20.00± 7.64	30.00± 5.77	43.33± 8.82**ab**	2.07± 0.07 **ab**
	LT_6	Control, Spray water only (First round and second round).	20.00± 5.77	20.00± 5.77	20.00± 5.00	26.67± 6.01	33.33± 6.01**ab**	40.00± 5.77	53.33± 12.00	46.67± 3.33	70.00± 17.30**a**	1.63± 0.32 **b**

- All figures are mean of three replications. P=.085 P=.200 P=.111
- DBT – Day before treatment. F=2.555 F=1.739 F=2.291
- Means having the same letter (s) in a column are not significantly different at 0.05 probability level by DMRT.
- DAT –Days after treatment.

Table 21. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population ofbrinjal aphid, *Aphis gossypii* Glover after two treatments and yield of brinjal in field F (Var. Kazla).

Plot/Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								yield (kg/block) Mean ± S.E.
			Pre-treatment DBT	First round treatment (31.12.2004)				Second round treatment (21.01.2005)			
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT	
F 01.10.04 (Late sowing)	LT_1	Nimbicidine @ 4ml/L water (First round and second round)	26.67± 3.33	20.00± 5.77	13.33± 3.33	10.00± 1.15	30.00± 2.89**ab**	20.00± 5.77	21.67± 6.01	23.33± 8.82	30.00± 11.50**a**	1.93± 0.07 **a**
	LT_2	Nimbicidine@ 4ml/L water (First round and Bankalmi leaf extract @1:10 W/V (second round)	40.00± 5.77	26.67± 7.27	23.33± 4.41	30.00± 11.50	40.00± 5.77**a**	20.00± 2.89	28.33± 6.01	28.33± 4.41	30.00± 11.50**a**	1.90 ± 0.06 **a**
	LT_3	Larvae of *C. transversalis* (First round and Second round)	20.00± 5.29	20.00± 2.89	20.00± 5.77	16.67± 3.53	20.00± 5.77**bc**	18.33± 6.01	21.67± 9.28	30.00± 11.50	46.67± 8.82**a**	1.70± 0.06 **b**
	LT_4	ET_3 (First round) and Bankalmi leaf extract @ 1:10 W/V (Second round)	10.00± 5.77	6.67± 3.33	13.33± 3.33	13.33± 3.33	18.33± 6.01**bc**	10.00± 5.77	10.00± 0.00	11.67± 3.84	20.00± 5.77**a**	1.60± 0.06 **b**
	LT_5	Kerosinized ash (First round) and Bankalmi leaf extract @ 1:10 W/V (Second round)	8.33± 4.41	5.00± 2.89	6.67± 3.33	10.00± 0.00	13.33± 3.33**c**	5.00± 2.89	10.00± 2.89	11.67± 1.67	30.00± 5.77**a**	1.60± 0.06 **b**
	LT_6	Control, Spray water only (First round and second round).	8.33± 1.20	3.33± 3.33	10.00± 0.58	16.67± 4.41	36.67± 4.41**a**	13.33± 3.33	15.00± 2.89	18.33± 4.41	50.00± 20.20**a**	1.07± 0.07 **c**

- All figures are mean of three replications. P=.011 P=.476 P=.000
- DBT – Day before treatment. F=4.914 F=.965 F=26.400
- Means having the same letter (s) in a column are not significantly different at 0.05 probability level by DMRT.
- DAT –Days after treatment.

Table 22. Yield (Mean ± S.E.) of brinjal (kg/plant)in terms of date of sowing, variety and treatments.

Date of sowing	Crop variety	Treatments					
		T_1	T_2	T_3	T_4	T_5	T_6
Early sowing 01.09.2004	Nayantara	3.17±0.17**a**	3.00±0.00**a**	2.58±0.30**a**	2.50±0.02**a**	2.00±0.29**ab**	1.67±0.17**a**
	Kazla	2.10±0.06**c**	2.00±0.00**b**	1.75±0.14**bc**	1.42±0.22**b**	1.17±0.08**c**	1.10±0.10**a**
Mid sowing 16.09.2004	Nayantara	2.97±0.03**a**	2.67±0.33**a**	2.50±0.00**a**	2.33±0.17**a**	2.17±0.17**a**	1.67±0.33**a**
	Kazla	2.00± 0.00**c**	1.77±0.12**b**	1.57±0.03**c**	1.37±0.03**b**	1.33±0.03**c**	1.07±0.12**a**
Late sowing 01.10.2004	Nayantara	2.53±0.03**b**	2.17±0.17**b**	2.33±0.33**ab**	2.33±0.09**a**	2.07±0.07**ab**	1.63±0.32**a**
	Kazla	1.93±0.07**c**	1.90± 0.06**b**	1.70±0.06**c**	1.60±0.06**b**	1.60±0.06**c**	1.07±0.07**a**
		P=.000 F=43.818	P=.001 F=8.898	P=.008 F=5.349	P=.000 F=18.145	P=.001 F=8.207	P=.115 F=2.255

- All figures are mean of three replications
- Means having the same letters in a column are not significantly different at P<0.01 and P<0.001 probability level by DMRT
- Detailed description of treatments(T_1-T_6) were already mentioned in Table(16-21)

Figure-7: Percent increase in yield over control (T_6) in various treatments for BARI brinjal, Nayantara and Kazla.

it is also observed that early sowing plants received the least aphid infestation in both the varieties. Aphid population was comparatively higher in mid and late sowing field than that of early sowing.

Percent increase in yield over control in various treatments are also shown in Figure 7. *A. gossypii* attack the lower surface of the leaves and it's number was comparatively higher in matured leaves those received less sun light.

5.4. Discussion

This study has demonstrated that aphid incidence and the associated yield affected variously because of various IPM treatments. Das (2001) carried out an experiment on IPM of aphid pest on eggplant but his experiment was confined within only two treatments *viz.*, two sprays of recommended insecticide and one spray of insecticide plus one time release of natural enemies along with sowing date alteration. A significant ($p<0.001$) difference was observed between controlled and treated crops but no difference could be recognized between two sprays and one time release of natural enemies (Das, 2001). Certain plant products *viz.*, leaf extract of *Datura alba*, *Pongomia pinnata*, *Parthenium hysterophorus*, *Ipomea carnea*, flower extract of *Calotropis procera*, flesh extract of *Agave americana*, seed extract of *Datura alba* and Neem oil at 1, 3, 1, 10, 5, 2.5, 1 and 1 percent concentrations respectively were sprayed three times at 15 days intervals against *A. gossypii* infesting brinjal (Var. LAR 5166) at experimental farm of Annamalai University, Tamil Nadu, India. Among the treatments the neem oil gave the maximum mean percentage reduction of 47.87, 53.37 and 47.08 aphids and *C. procera* flower extract gave the least control of 19.49, 21.25 and 23.07 aphids in the first, second and third trails respectively (Veeravel and Jeganathan, 2006).Butler *et al.*,(1988) tested soybean and cotton seed oils against *A. gossypii* in green house condition and reported that foliar sprays of the oils reduced nymphal and adult populations remarkably. Fiume (1993) tested biological and integrated control methods against *A. gossypii* on peppers and obtained best results with integrated control which combined chemical (Methomyl) and biological (*Verticililum spp.*) methods which is in good agreement with the present findings. From the residual toxicity test of eight insecticides using *A. gossypii* on cotton, Nagia *et al.*, (1989) revealed that Cypermethrin, Fenvalerate, Deltamethrin and Permethrin remained active for about 10 days and giving aphid mortality between

61-86%. Monocrotophos, Endosulphan, Chlorpyriphos and Methyl Paration were effective for 14, 10, 8 and 4 days giving insect mortality of 96.4%, 79.3%, 62.9% and 83.3% respectively. Semada *et al.*,(1993) have shown that *A. gossypii* attacked the lower surface of unfurled leaves, especially in lower regions of the plants and was present for 8 and 5 weeks with 62.7 and 30.3 aphids/ square inch on maize crops planted on May 15 and June 15 respectively. The reason for more aphids in matured leaves in the lower part of the plant is probably due to the favorable microclimate for an aphid not for its natural enemies (Coaker, 1987).

Water and nitrogenous compounds are relatively high in young leaves and decline with leaf maturation (Scriber, 1984). Monophagous and oligophagous herbivores often show a strong preference for the more nutritious younger tissues that are also high in toxins, whereas polyphagous herbivores demonstrate a strong preference for the less nutritious mature leaves (Evans, 1984). Therefore, the highest population of *A. gossypii* on matured leaves might also be due to its polyphagous nature. Besides, the present observation was close to the observation of Raupp and Denno (1983) who reported that plant leaves under full sunlight are generally less attractive to aphids than those in shade though the nitrogen content may be higher. Webb (1994) did an experiment for the protection of squash from *A. gossypii* through various control measures and found that mineral oil in combination with Bifenthrin was very effective. Nagia *et al.*,(1994), suggested from their experiment , Dimethoate 30 EC and Oxydemeton methyl 25 EC may used either alone or in combination for the control of *A. gossypii* and *Myzus persicae* (Sulz.) when they occur simultaneously on potato. Jarande and Dethe (1994) carried out an experiment on brinjal sucking pests and showed that imidacloprid was highly effective in reducing the incidence of aphids, whiteflies and jassids on brinjal and increasing in seedling height and total leaf chlorophyll over those of untreated plants. However results of the present study tend to agree with the results of previous studies conducted by Das (2001) who reported that population of *A. gossypii* was significantly ($p<0.05$) lower on the early sowing transplanted egg plants than those of mid and late sowing plants. Finally it could be concluded that in combination of appropriate sowing time with minimum insecticide plus botanical or natural enemies release technique may be applied to control the population of *A. gossypii* in the field under economic threshold level and higher economic return.

CHAPTER 6 Integrated management of mustard aphid, *Lipaphis erysimi* (Kalt.)

6.1. Introduction

6.1.1. Importance and cultivation of mustard

Mustard and rapeseed are important oil seed crops in Bangladesh. The national economy of Bangladesh suffers from an acute shortage of edible oils in terms of domestic production. Nearly two-thirds of the total edible oil consume in the country are imported (Hossain, 1991). One of the reasons for such low yield is the constraint put up by the insect pests of these crops. Of the various oil seeds grown in the country, the mustard occupies the top position in respect of total yield and acreage. During 1996-97 crop season, only mustard cultivation covered about 336 thousand hectares of land in our country and the production was about 249 thousand metric tones (B.B.S., 1998). Mustard crop is conventionally grown for edible vegetable oil and green leaves are used both for human food and animal fodder (Nasir *et al.*, 1998). The residual cake of mustard is used as fish and cattle feed and as fertilizers (Haque *et al.*, 1979). According to Huxley and Levy (1992) this crop has ornamental and medicinal value.

6.1.2. Pests of mustard

Insects-pests are one of the major limiting factors influencing the production of mustard. About two dozen insects pests have been associated with this crop (Rai, 1976), only three are regarded as major pests. They are mustard saw fly, *Athalia proxima* Klug., the painted bug, *Bagrada cruciferarum* Kiru., and the mustard aphid, *L. erysimi* The first two pests occur only in the early stages of crop growth, but the mustard aphid appears on the crop for a considerable period of plant growth and incurs serious loss even up to 90-95 percent. Besides *L. erysimi*, another two species of mustard aphids are *Myzus persicae* Sulzer and *Brevicoryne brassicae* L. However of all the pests of mustard in Bangladesh, *L. erysimi* is most devasting (Alam *et al.*, 1964; Ahmed *et al.*, 1977; Haque *et al.*, 1979) which reduces the yield of mustard considerably.

6.1.3. Aphid, *Lipaphis erysimi* (Kalt.) : Homoptera, Aphididae.

This aphid is soft bodied yellowish green, grey green or olive green insect with a white waxy body coating measuring 1.2-2.4 mm (apterae female) and 1.4-2.2 mm (alatae forms) long (Blackman and Eastop, 1984). After emerging from the last moult, 1-2 days pass before the adult females begin producing young. They continue producing young for 13-20 days followed by a 2-3 day post reproductive stage. The total duration of the adult stage is 26-37 days (Sachan and Bansal, 1975). They also reported that wingless females produce 70-87 young in their life time. While winged females produce 31-40 young. Male aphids are considerably smaller than females and measure approximately 1.20-1.35 mm in length (Kawada and Murai, 1979).

6.1.4. Common names of *Lipaphis erysimi*(Kalt.):

Lipaphis erysimi (Kalt.) has many common names, *viz,* Mustard aphid, cabbage aphid, false cabbage aphid, safflower aphid, turnip aphid, canola aphid (English); loodkleurige bladluis (Dutch); afido del repollo, pulgon del nabo (Spanish); nise-daikon-aburamusi (Japanese); puceron du navet (French) and Senf-Blattlaus (German).

6.1.5. Biology of *Lipaphis erysimi* (Kalt.)

In *L. erysimi*, although holocyclic forms have been observed, anholocycly predominates in warmer climates (Blackman and Eastop, 1989). It has two modes producing young: fertilization of females by males resulting in the production of eggs (sexual reproduction) and the birthing of live female nymphs by adult females without fertilization by males (parthenogenesis). Reproduction through parthenogenesis seems to be the norm as males are very rare and females are almost exclusively viviparous (birth live young) throughout the year and males have only been observed in the cooler months (Kawada and Murai, 1979).

Eggs (sexual reproduction) are laid along the veins of leaves (Kawada and Murai, 1979). There are four nymphal stages (instars). The general appearance of each stage is similar except for increase in size during subsequent instars. Minor variations in the duration of instars occur between winged and wingless forms when raised on cabbage, cauliflower, mustard and radish (Sachan and Bansal, 1975).

6.1.6. Nature of damage by *Lipaphis erysimi* (Kalt.)

L. erysimi is one of the most important pests of Brassicas leafy vegetables world wide (Blackman and Eastop, 1984) including Taxes (Yue and Liu, 2000). The aphids may stunt or kill plants in early stages of growth and later on their contamination reduces the market values, causing them to curl, forming pockets and folds that offer shelter to the aphids thus enabling them to escape insecticide treatment. *L. erysimi* feed on growing shoots, inflorescence and under side of the leaves. In severe infestation entire crop plants are densely covered with aphids causing stunting growth and poor pod formation (Malti *et al.*, 1988). Heavily attacked crop becomes week and exhausted and does not bear any seed (Hazarika, 1951).

In a recent study it was observed that the yield loss due to the infestation of *L. erysimi* in mustard ranged from 35.4 to 91.3% (Brar *et al.,* 1987; Sing and Sachan, 1994). Sometimes high incidence of this pest can cause complete loss of the crop (Rouf and Kabir, 1997). It was reported that the yield loss due to aphid attack ranged from 8.9 to 77.5% (Prasad and Phadke, 1983) and 8.6 to 57.5% (Vir and Henry, 1987). But in a recent investigation in Bangladesh it was found that the yield loss due to infestation in mustard by *L. erysimi* ranged from 87.16 to 98.16% (Anonymous, 1995). Both adults and nymphs feed on leaves, inflorescences and pods, which results in pale and curled leaves and consequently plant growth and development of flowers and pods is adversely affected. The yield may decrease up to 80% in case of severe infestation (Atwal, 1976). Besides, disease producing turnip mosaic virus is also carried by this species.

6.1.7. Distribution and host plants of *Lipaphis erysimi* (Kalt.)

L. erysimi is distributed in Bangladesh, Pakistan, India, U.S.A and many other countries of the world (Husain and Shahajahan, 1997). Cruciferous plants are the chief host plants of *L. erysimi* of which mustard (*Brassica campestris* L.), turnip (*Brassica rapa* L.) and reddish (*Raphanus sativus* L.) are most remarkable (Aslam and Ahmed, 2001). Besides *Brassica alba* Hook; *Brassica integrifolia* (West.) Schulz, *Brassica napus* L., *Brassica nigra* L., *Brassica oleracea* var. *Agrotis*, *Brassica oleracea* L. var. *Capittata*, *Brassica rugosa* Prain, var. *Cuneifolia*, *Lactuca sativa* L. are note worthy as host plants of *L. erysimi* in Bangladesh (Das, 1994).

6.1.8.Natural enemies of *Lipaphis erysimi* (Kalt.)

Predators:

i. Coccinellidae: Coleoptera

Brumoides suturalis (Fabricius): Agarwala and Bhattacharya (1999); Singh *et al.* (2003).

Cheilomenes sexmaculata (Fabricius): Tao and Chiu (1971); Agarwala and Bhattacharya (1999); Singh *et al.* (2003); Omkar and Bind (2004).

Coccinella repanda Thunberg: Tao and Chiu (1971); Saharia (1984); Agarwala and Bhattacharya (1999).

Coccinella septempunctata L.: Tao and Chiu (1971); Singh and Singh (1994a); Agarwala and Bhattacharya (1999); Singh *et al.* (2003); Srivastava and Srivastava (2003).

Coccinella transversalis Fabricius: Agarwala and Bhattacharya, (1999); Omkar and James (2004).

Coccinella tranversoguttata Faldermann: Agarwala and Bhattacharya (1999).

Coccinella undecimpunctata L.: Agarwala and Bhattacharya (1999); Solangi et al. (2007).

Coccinella octopunctata Müller: Tao and Chiu (1971); Agarwala and Bhattacharya (1999).

Harmonia octomaculata (Fabricius): Agarwala and Bhattacharya (1999)

Harmonia (Leis) dimidiata (Fabricius): Tao and Chiu (1971).

Hippodamia variegata (Goeze): Singh and Singh (1994); Agarwala and Bhattacharya (1999).

Lemnia biplagiata (Schwartz): Tao and Chiu (1971); Yu and Chen (2002).

Lemnia swinhoei (Crotch): Tao and Chiu (1971).

Micraspis discolor (Fabr.): Agarwala and Bhattacharya (1999); Hossain *et al.* (2001); Das (2002).

Pania luteopustulata (Mulsant): Agarwala and Bhattacharya (1999).

Propylea dissecta (Mulsant): Omkar and Pervez (2004); Mishra *et al.* (2005).

Propylea japonica (Thunberg): Tao and Chiu (1971).

Scymnus (Pullus) pyrocheilus Mulsant: Agarwala and Bhattacharya (1999).

Scymnus xerampelinus Mulsant: Agarwala and Bhattacharya (1999).

Scymnus spp.: Das (2002).

Synonycha grandis (Thunberg): Tao and Chiu (1971).

ii. Syrphidae:Diptera

Allograpta javana (Wiedemann): Agarwala and Bhattacharya (1999);

Singh *et al.*, (2003).

Betasyrphus serarius (Wiedemann): Agarwala and Bhattacharya (1999).

Dideopsis aegrota (Fabricius): Agarwala and Bhattacharya (1999).

Episyrphus balteatus (De Geer): Agarwala and Bhattacharya (1999);

Bisht *et al.* (2006); Samuel *et al.* (2005).

Episyrphus alternans Macquart: Agarwala and Bhattacharya (1999);

Kumar *et al.*, (1987).

Episyrphus viridaureus (Wiedmann): Agarwala and Bhattacharya (1999).

Eupeodes corollae (Fabricius) (=*Metasyrphus corollae* (Fabricius): Tao and Chiu (1971).

Ischiodon scutellaris (Fabricius): Tao and Chiu (1971); Agarwala and Bhattacharya (1999);

Kumer *et al.* (1987); Das (2002); Singh *et al.* (2003); Bisht *et al.* (2006).

Lasiopticus seleniticus Meigen: Bisht *et al.* (2006)

Melanostoma orientale (Wiedemann): Tao and Chiu (1971); Agarwala and Bhattacharya (1999).

Melanostoma univittatum Wiedemann: Tao and Chiu (1971); Bisht *et al.* (2006).

Metasyrphus confrater (Wiedemann): Kumer *et al.* (1987).

Metasyrphus latilunulatus (Collin): Kumer *et al.* (1987).

Paragus crenulatus Thomson: Agarwala and Bhattacharya (1999).

Paragus serratus (Fabricius): Tao and Chiu (1971); Agarwala and Bhattacharya (1999).

Paragus tibialis (Fallén): Tao and Chiu (1971); Agarwala and Bhattacharya (1999).

Scaeva albomaculata (Macquart): Agarwala and Bhattacharya (1999).

Scaeva latimaculata (Brunetti): Kumer *et al.* (1987).

Scaeva pyrastri (Linaeus): Agarwala and Bhattacharya (1999).

Scaeva selentica Meng: Bisht *et al.* (2006).

Sphaerophoria indiana Bigot: Kumer *et al.* (1987); Agarwala and Bhattacharya (1999).

Sphaerophoria scripta (Linnaeus): Agarwala and Bhattacharya (1999); Bisht *et al.,* (2006).

Sphaerophoria spp.: Das (2002).

Sphaerophoria vockerothi Joseph: Agarwala and Bhattacharya (1999).

Syrphus confrater Wiedemann: Das (2002).

Syrphus corollae Fabricius: Bisht *et al.* (2006).

Syrphus isaaci Bhatia: Bisht *et al.* (2006).

Syrphus spp.: Bisht *et al.* (2006).

iii. Chrysopidae: Neuroptera

Chrysoperla carnea (Stephens): Agarwala and Bhattacharya (1999); Liu and Chen (2001a); Singh *et al.* (2003).

Chrysopa septempunctata Wesmael: Tao and Chiu (1971).

Chrysoperla rufilabris (Burmeister): Liu and Chen (2001a).

iv. Anystidae: Prostigmata

Anystis spp.: Tao and Chiu (1971).

Parasitoids:

i Aphelinidae: Hymenoptera

Aphelinus spp. nr. *flavipes* Kurdy: Agarwala and Bhattacharya (1999).

ii. Braconidae: Hymenoptera

Aphidius avenae Haliday: Subhrani *et al.* (2006).

Aphidius colemani Viereck: Subhrani *et al.* (2006).

Aphidius gifuensis Ashmead: Agarwala and Bhattacharya (1999); Subhrani *et al.*, (2006).

Aphidius hortensis Marshall: Subhrani *et al.* (2006).

Aphidius matricariae Haliday: Agarwala and Bhattacharya (1999); Kavallieratos *et al.* (2001).

Diaeretiella rapae (M'Intosh): Agarwala and Bhattacharya (1999); Kavallieratos *et al.* (2001); Olmez and Ulusoy (2003); Singh *et al.* (2003);

Biradar and Dhanorkar (2004); Subhrani *et al.* (2006).

Ephedrus minor Stelfox: Subhrani *et al.* (2006).

Ephedrus plagiator (Nees): Agarwala and Bhattacharya (1999); Subhrani *et al.* (2006).

Fungi:

iAncylistaceae: Entomophthorales

Conidiobolus obscurus (Hall and Dunn): Scorsetti *et al.* (2007).

ii. Entomophthoraceae: Entomophthorales

Entomophthora planchoniana Cornu: Scorsetti *et al.* (2007).

Entomophthora spp.: Agarwala and Bhattacharya (1999).

Pandora neoaphidis (Remaud. and Hennebert): Scorsetti *et al.* (2007).

Zoophthora radicans (Brefeld): Scorsetti *et al.* (2007).

iii. Neozygitaceae: Entomophthorales

Neozygites fresenii (Nowak): Scorsetti *et al.* (2007).

iv. Niessliaceae: Hypocreales

Cephalosporium aphidicola Petch: Agarwala and Bhattacharya (1999).

6.1.9. Importance of the present study

In Bangladesh, mustard aphid is generally controlled by using insecticides (Alam *et al.*, 1964; Ahmed *et al.*, 1977; Haque *et al.*,1979). But the use of insecticides is hazardous as they leave many undesirable side effects such as (i) development of resistance in pest populations, (ii) destruction of beneficial species, (iii) resurgence, (iv) outbreaks of secondary hosts, (v) residues in feeds, foods and the environment and (vi) hazards to humans and the environment (Luckman and Metcalf,1975; Husain and Begum, 1984). Highly toxic insecticides with long residual effect are believed to hamper pollination in mustard and cause seed sterility. On the other hand, less toxic insecticides are found less effective in controlling aphids when the incidence becomes very high. Moreover, the insecticides and spraying equipments are very costly, hence sometimes it becomes quite unaffordable for our farmers to purchase these materials (Husain, 1984). In addition the insecticides are lipophilic in nature and may leave hazardous residues in oils. Thus it is urgently required to find out an effective,

cheapest and environmentally safe alternative in place of insecticidal control which will strengthen the bases of integrated pest management (IPM) programme. But till today no body did any work for the integration of different control techniques *viz.*, cultural, biological, chemical, botanical in Bangladesh. So there is enough scope to explore the impact of these on mustard aphid, *L. erysimi.*

6.2. Metarials and Methods

The experiment was conducted during October 2005 to March 2006 at Rajshahi University Campus, Rajshahi a northwestern district of Bangladesh. The investigation was aimed to assess the impact of some IPM parameters either alone or in combination with one another on the population abundance of mustard aphid, *L. erysimi* and on the yield of mustard. Accordingly seeds of two mustard cultivars, BARI sharisha-6 (*Brassica campestris*) and BARI Sharisha-7 (*Brassica napus*) were sown at three different dates *viz.*, 16.10.2005 (Early sowing), 01.11.2005 (Mid sowing) and 16.11.2005 (Late sowing) on separate plots. The research trial was laid out in randomized block design with six treatments including a control and replicated thrice, each having the size of 1.5 × 1 meters. Thus eighteen blocks were made from each cultivar and each sowing date respectively. The spacing were maintained as 30 cm and 15 cm for rows and plants respectively. Usual irrigation and weeding were done whenever necessary. The chemical fertilizers were applied at the rate 84:66:34 kg/ha of N:P:K. respectively (Anonymous, 1987). Half of nitrogen and total amount of P(phosphate) and K (murate of potash) were applied at the time of final land preparation. The rest of the nitrogen was applied just before flowering. The experimental plots were visited regularly to detect the arrival of *L. erysimi* and application of under mentioned treatment parameters was started as soon as their incidence was noticed. The interval in-between first round and second round treatment was 20 days. For the application of watery solution like insecticide, botanical and water (for controlled block) Manseok Sprayer was used and procedure of application including calibration of insecticide was followed as per Mathews (1988).

Each of the blocks of experimental plots was used for specific type of treatment and named as-

Treatment block T_1 = Two times insecticide spray (Classic 20 EC @ 2ml/L Water (First round and second round)

Treatment block T_2 = One time spray of insecticide (Classic 20 EC @ 2ml/L water (first round) and one time spray of botanical (Dhutura leaf extract) @ 1:10 W/V (Second round).

Treatment block T_3 = Two times release of natural enemies (Larvae of *C. transversalis* (First round and second round).

Treatment block T_4 = One time release of natural enemies (Larvae of *C. transversalis* (First round) and one time spray of botanical (Dhutura leafextract) @ 1:10 W/V (Second round).

Treatment block T_5 = One time dusting of kenosinized ash (first round) and one time botanical spray (Dhutura leaf extract) @ 1:10 W/V (second round)

Treatment block T_6 = Two times spray of water only (first round and second round).

Insecticide (Chloropyriphos) :

Chloropyriphos is a organophosphorus compound forms an important class of pesticide. It is commercially marketed as Classic 20 EC by ACI crop care in Bangladesh and indicated for the control of wide variety of pests specially aphids and other sucking insects. This insecticide has a contact, stomach and fumigant action. The chief advantage of this insecticide is highly toxic against target organism and non-toxic to vertebrate and do not accumulate in the animal body. The prescribed dose rate of Classic 20 EC is 2ml/L water against aphids and thus 100 ml/ha.

Botanical (Dhutura leaf extract) :

Datura metel L. (Family Solanaceae) is a genus of herbaceous plant which includes 10 to 12 species of plants. They are distributed throughout the tropical and temperate regions in both the old and new worlds. In Bangladesh they grow wild in waste places and roadsides all over the country. Fully grown plant of the *Datura metel* L. attains height of 2-6 feet. Principal chemical constituents of the plant are a large number of alkaloids including hyoscyamine, hyoscine, scopolamine, atropine and

vitamin C (Gupta *et al.*, 1992; Mahmood *et al.*, 1998; Sharma 2003). Dhutura leaves have narcotic, antispasmodic and anodynic properties. They are smoked to relieve spasmodic asthma and used in rheumatic swellings, lumbago, sciatica, neuralgia, painful tumors and also in earache. These promising attributes led the author to evaluate the potential use of *D. metel* leaf extract against *L. erysimi* in the present investigation.

Fresh leaves Dhutura plant were collected from the botanical garden and roadsides of Rajshahi University Campus. The collected leaves were washed and cleaned with tap water. The plant materials were then cut in small pieces with sharp knife and dried in shade. The shade dried materials were ground into powder by a hand grinder. The leaf power was dissolved in normal water and kept at room temperature (20^0C-34^0C) for 10 days. The proportion of plant material and water was 1:10 (W/V). It was then filtered to separate the extract from the plant debris. The extracted was then sprayed in experimental block T_2, T_4 and T_5 (Second round) of each plot.

Natural enemies :

Agarwala and Bhattacharya (1999) emphasised the importance of *Coccinella transversalis* (Fabr.) (=*Coccinella repanda* Thunb.) and *Micraspis discolor* (Fabr.) as potential predator of mustard aphid with other natural enemies. Accordingly five third instar larvae of *C. transversalis* were taken from the stock culture and released them on scheduled date in experimental block T_3 (first round and second round) and T_4 (first round of each plot).

Kerosinized ash :

Uses of ash and sand as mechanical control method of insect pests has a history of many years (Hossain *et al.*, 1994; Hossain *et al.*, 2003). Six tea spoon of kerosine were mixed with 1kg of wood ash and applied it manually by throwing in block T_5 (first round) of each plot.

Counting of aphids and yield:

For counting the number of aphids, three plants were randomly selected per variety/per sowing date /per block. Aphids were counted before and after 1, 3, 7 and

20 days of treatment from the top of 5 cm apical twig and three types of leaf (young, mature and old) from each of the selected plants. In case of thick colonies, magnifying glass was used in counting procedure. The plants observed once were not taken for subsequent observation. Seed yield from each treatment was weighed after the harvest and finally converted in quintal per hectare.

Data recording and analysis:

To compare yield among the treatments, data were pooled, analyzed statistically using an analysis of variance (ANOVA) procedure and significantly (0.05) different means were separated by Duncun's (1951) Multiple Range Test (DMRT) with the help of Statistical Software SPSS (Ver. 11.5).

6.3. Results

Plant height of the variety BARI Sharisha-6 is comparatively longer than the variety BARI-7. Flower color of BARI –6 is yellow but in case of BARI Sharisha-7 it is white colored. Yield attributing characters like branches per plant, seeds per siliqua is more in BARI Sharisha–6 than in BARI Sharisha-7. Seeds of both varieties become mature within ninety five days from the date of sowing. The population of mustard aphid, *L. erysimi* was reduced in all the blocks of early, mid and late sowing plots of both varieties just after the introduction of first round treatment. Thereafter the population increased slightly towards the end of first round treatment. The population of mustard aphid again started to decrease after the initiation of second round treatment. The polled data on the aphid counts of two varieties after 1, 3, 7 and 20 days of treatment along with yield of mustard in different blocks/ plot based on sowing date are presented in Table 23-28. Pretreatment counts were done just one day before treatment in all cases. Within a plot, two times insecticide treated blocks had the lowest aphid population followed by one time insecticide plus one time botanical treated blocks when compared with the population recorded on controlled blocks. Among all the treatments of early sowing plots, two times insecticide treated block (ET_1) provided the maximum increased seed yield of mustard 9.76 q/ha for BARI Sharisha-6 and 9.14 q/ha for BARI Sharisha-7, while one time insecticide plus one time botanical treated block (ET_2), two times natural enemies treated block (ET_3), one

Table 23. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of mustard aphid, *Lipaphis enysimi* (Kalt.) after two treatments and yield of mustard in plot A (Var.BARI Sharisha-6).

Plot/Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								yield (kg/ block)	Average yield q/ hectare
			Pre-treatment	First round treatment (08.12.2005)				Second round treatment (29.12.2005)				
			DBT	I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT	Mean ± S.E.
A 16.10.2005 (Early sowing)	ET_1	Classic 20 EC @ 2ml/L water (First round and second round)	98.33± 41.11	36.67± 12.03	9.00± 00.58	5.33± 1.77	14.00± 2.31**d**	.67± 00.67	1.67± .33	4.00± 1.16	6.67± 2.41**c**	.48± 0.01 **a**	9.76
	ET_2	Classic 20 EC@ 2ml/L water (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	133.33± 48.13	22.33± 4.34	24.67± 4.38	6.33± 2.73	12.67± 1.77**d**	4.00± 1.16	5.67± 1.77	6.33± 1.77	11.00± 1.16**c**	.44 ± 0.01 **ab**	8.94
	ET_3	Larvae of *C. transversalis* and (First round and Second round)	126.67± 43.77	43.33± 8.83	50.00± 5.78	46.67± 8.82	50.00± 5.78**bc**	18.33± 6.01	18.33± 6.01	40.00± 11.56	80.00± 5.78**b**	.39± 0.00 **b**	7.92
	ET_4	Larvae of *C. transversalis* (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	123.33± 41.82	43.33± 3.33	50.00± 15.29	40.00± 5.78	43.33± 8.88**c**	31.66± 9.29	56.67± 14.55	76.67± 8.83	70.00± 5.78**b**	.36 ± 0.00 **c**	7.32
	ET_5	Kerosinized ash (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	153.33± 12.03	70.00± 5.78	40.00± 5.78	56.67± 21.88	68.33± 9.29**b**	56.67± 17.65	46.67± 12.03	35.00± 2.89	53.33± 167.65**b**	.32 ± 0.01 **c**	6.50
	ET_6	Control, Spray water only (First round and second round).	83.33± 31.84	93.33± 17.66	126.67 ± 3.33	135.00 ± 2.89	143.66± 3.18**a**	152.00± .58	130.00± 35.16	90.00± 26.49	146.67± 8.83**a**	.20± 0.01 **d**	4.07

- All figures are mean of three replications. P=.000 P=.000 P=.000
- Size of each experimental block 1.5 × 1 meters F=64.917 F=34.473 F=49.571
- DBT – Day before treatment.
- Means having the same letter (s) in a column are not significantly different at 0.05 probability level by DMRT.
- DAT –Days after treatment

Table 24. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of mustard aphid, *Lipaphis erysimi* (Kalt.) after two treatments and yield of mustard in plot B (Var. BARI Sharisha -7).

Plot/Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								yield (kg/block) Mean ± S.E.	Average yield q/hectare
			Pre-treatment DBT	First round treatment (08.12.2005)			Second round treatment (29.12.2005)					
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT	
B 16.10.2005 (Early sowing)	ET_1	Classic 20 EC @ 2ml/L water (First round and second round)	35.00± 2.89	5.00± 5.01	0.00± 0.00	3.00± 1.53	4.00± 3.06**c**	0.00± 0.00	0.00± 0.00	0.00± 0.00	6.33± 2.03**c**	.45±0.03 **a**	9.14
	ET_2	Classic 20 EC@ 2ml/L water (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	50.00± 5.78	6.67± 3.34	11.00± 2.08	15.00± 2.89	30.00± 5.78**ba b**	2.33± 0.88	0.00 ± 0.00	1.00± 0.57	5.67± 1.45**c**	.42 ± 0.02 **ab**	8.53
	ET_3	Larvae of *C. transversalis* (First round and Second round)	58.33± 43.77	15.00± 8.83	16.67± 5.78	30.00± 8.82	33.33± 5.78**ab**	36.66± 6.01	13.33± 6.01	15.00± 11.56	13.33± 5.78**bc**	.39 ± 0.00 **b**	7.92
	ET_4	Larvae of *C. transversalis* (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	100.00± 50.39	23.33± 4.41	28.33± 6.01	35.00± 2.89	36.67± 6.67**ab**	20.00± 5.78	9.67± 2.73	3.33± 1.77	9.33± .67**c**	.33 ± 0.02 **c**	6.71
	ET_5	Kerosinized ash (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	116.67± 43.77	53.33± 23.54	30.00± 2.89	31.67± 13.66	43.33± 8.83**ab**	11.67± 9.29	7.33± 3.85	5.67± 2.19	20.00± 2.89**b**	.26 ± 0.00 **d**	5.29
	ET_6	Control, Spray water only (First round and second round).	120± 36.09	123.33 ± 21.88	90.00± 37.90	113.33 ± 27.32	55.00± 7.65**a**	93.33± 6.67	70.00± 5.78	73.33± 6.01	90.00± 5.78**a**	.16± 0.00 **e**	3.25
							P=.006 F=5.786				P=.000 F=107.981	P=.000 F=42.822	

- All figures are mean of three replications.
- Size of each experimental block 1.5 × 1 meters
- DBT – Day before treatment.
- Means having the same letter (s) in a column are not significantly different at 0.05 probability level by DMRT.
- DAT –Days after treatment.

Table 25. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of mustard aphid, *Lipaphis erysimi* (Kalt.) after two treatments and yield of mustard in plot C (Var. BARI Sharisha-6).

Plot/Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								yield (kg/block) Mean ± S.E.	Average yield q/ hectare
			Pretreatment DBT	First round treatment (13.12.2005)			Second round treatment (03.01.2005)					
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT	
C 01.11.2005 (Mid sowing)	MT_1	Classic 20 EC @ 2ml/L water (First round and second round)	126.67± 23.36	30.00± 5.78	6.67± 3.34	2.67± 2.67	8.00± 1.16**d**	00± 00	1.00± 0.58	3.00± 0.58	9.33± 0.67**c**	.41± 0.01 **a**	8.33
	MT_2	Classic 20 EC@ 2ml/L water (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	120.00± 41.68	26.00± 4.93	25± 7.65	6.67± 3.34	19.33± 0.67**d**	8.00 ± 1.56	6.00± 1.56	8.67± 0.67	13.33 ± 1.67**c**	.39± 0.01 **a**	7.93
	MT_3	Larvae of *C. transversalis* (First round and Second round)	116.67± 16.68	46.67± 9.29	33.33± 3.34	46.67± 8.82	56.67± 6.02**bc**	15.00± 2.89	18.33± 6.02	43.33± 10.15	65.00± 25.69**b**	.37 ± 0.01 **a**	7.52
	MT_4	Larvae of *C. transversalis* (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	226.67± 37.16	46.67± 1.67	53.33± 13.66	43.33± 6.01	46.67± 9.29**c**	53.33± 16.93	78.33± 4.41	73.33± 4.41	80.00± 5.78**b**	.38 ± 0.01 **a**	7.72
	MT_5	Kerosinized ash (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	123.33± 49.84	33.33± 23.36	41.667 ± 4.41	50.00± 15.29	70.00± 7.65**b**	60.00± 18.95	50.00± 10.42	36.67± 4.41	63.33± 19.24**b**	.32 ± 0.01 **b**	6.50
	MT_6	Control, Spray water only (First round and second round).	216.67± 44.15	150.00 ± 00	135.00 ± 7.65	140.00 ± 00	148.33 ± 6.02**a**	153.33 ± 1.67	135.00 ± 35.16	106.67 ± 17.65	146.67 ± 8.83**a**	.19± 0.01 **c**	3.86
						P=.000 F=68.279				P= .000 F=13.281	P=.000 F=51.094	

- All figures are mean of three replications.
- Size of each experimental block 1.5 × 1 meters
- DBT – Day before treatment.
- Means having the same letter (s) in a column are not significantly different at 0.05 probability level by DMRT.
- DAT –Days after treatment.

Table 26. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of mustard aphid, *Lipaphis erysimi* (Kalt.) after two treatments and yield of mustard in plot D (Var. BARI Sharisha-7).

Plot/Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error((S.E.)/plant								yield (kg/block) Mean ± S.E.	Average yield q/hectare
			Pre-treatment DBT	First round treatment (13.12.2005)				Second round treatment (03.01.2005)				
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT	
D 01.11.2005 (Mid sowing)	MT_1	Classic 20 EC @ 2ml/L water (First round and second round)	48.33± 8.34	11.67± 1.67	11.67± 1.67	16.67± 4.41	25.00± 2.89**b**	2.00± 1.16	5.33± 1.77	6.00± 2.65	8.00± 0.58**c**	.39± 0.01 **a**	7.92
	MT_2	Classic 20 EC@ 2ml/L water (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	53.33± 6.02	10.00± 00	11.67± 1.67	16.67± 4.41	31.67± 4.41**b**	4.00 ± 1.16	7.33± 2.9	5.33± 2.34	7.67± 1.45**c**	.37± 0.01 **a**	7.52
	MT_3	Larvae of *C. transversalis* (First round and Second round)	76.67± 14.55	15.00± 00	20.00± 2.89	33.33± 8.82	40.00± 6.02**b**	38.33± 2.89	16.67± 6.02	16.67± 10.15	21.66± 25.69**b**	.33 ± 0.01 **b**	6.71
	MT_4	Larvae of *C. transversalis* (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	81.67± 10.15	23.33± 3.34	31.667 ± 4.41	40.00± 7.65	23.33± 3.34**b**	11.67± 1.67	11.00± 2.08	10.00± 00	11.00± 2.08**c**	31 ± 0.01 **c**	6.30
	MT_5	Kerosinized ash (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	123.33± 12.03	40.00± 5.78	31.67± 4.41	50.00± 5.78	46.67± 10.15**b**	18.33± 6.01	13.33± 3.33	11.66± 1.67	26.67± 2.27**b**	.29 ± 0.01 **c**	5.89
	MT_6	Control, Spray water only (First round and second round).	123.33± 37.16	116.67 ± 16.69	156.67 ± 14.55	113.33 ± 17.66	73.33± 12.03**a**	60.00± 11.56	73.33± 7.27	75.00± 5.00	100.00 ± 00**a**	.18± 0.01 **d**	3.65
							P=.011 F=4.943				P=.000 F=107.324	P= .000 F=85.606	

- All figures are mean of three replications.
- Size of each experimental block 1.5 × 1 meters
- DBT – Day before treatment.
- Means having the same letter (s) in a column are not significantly different at 0.05 probability level by DMRT.
- DAT –Days after treatment.

Table 27. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of mustard aphid, *Lipaphis erysimi* (Kalt.) after two treatments and yield of mustard in plot E (Var. BARI Sharisha-6).

Plot/Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								yield (kg/block) Mean ± S.E.	Average yield q/hectare
			Pre-treatment DBT	First round treatment (18.12.2006)				Second round treatment (08.02.2006)				
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	XX DAT	
E 16.11.2005 (Late sowing)	LT_1	Classic 20 EC @ 2ml/L water (First round and second round)	113.33± 13.35	31.67± 6.02	26.67± 6.67	11.67± 1.67	19.33± 0.67**c**	2.00± 2.00	00± 00	4.00± 1.16	10.00± 1.16**c**	.35±0.01 **a**	7.11
	LT_2	Classic 20 EC@ 2ml/L water (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	126.67± 62.35	28.33± 4.41	30.00± 7.65	18.33± 1.65	19.33± 0.67**c**	10.00 ± 0.00	.33± 0.33	3.00± 0.58	18.33 ± 1.67**c**	.34±0.01 **ab**	6.91
	LT_3	Larvae of *C. transversalis* (First round and Second round)	123.33± 14.55	46.67± 9.29	35.00± 2.89	50.00± 10.01	53.33± 6.67**bc**	11.67± 1.67	00± 00	8.33± 3.67	68.33± 24.58**b**	.32 ± 0.01 **b**	6.50
	LT_4	Larvae of *C. transversalis* (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	223.33± 29.67	46.67± 3.34	61.67± 19.24	60.00± 00	46.67± 6.67**bc**	55.00± 12.60	70.00± 2.89	75.00± 2.89	83.33± 8.83**b**	.28 ± 0.01 **c**	5.69
	LT_5	Kerosinized ash (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	116.67± 16.69	60.00± 20.23	43.33± 4.41	53.33± 13.66	73.33± 1.67**b**	61.67± 15.91	53.33± 8.83	36.77± 1.67	70.00± 15.29**b**	.25 ± 0.01 **d**	5.08
	LT_6	Control, Spray water only (First round and second round).	233.33± 44.15	60.00± 11.56	91.67± 36.37	140.00 ± 5.78	140.00 ±30.59 **a**	126.67 ±37.16	103.33 ±3.34	90.00± 5.78	156.67 ±21.89 **a**	.18± 00 **e**	3.66
							P=.000 F=11.811				P=.000 F=11.977	P=.000 F=62.451	

- All figures are mean of three replications.
- Block size 1.5 × 1 meters
- DBT – Day before treatment.
- Means having the same letter (s) in a column are not significantly different at 0.05 probability level by DMRT.
- DAT –Days after treatment.

Table 28. Effect of insecticide, botanical, natural enemies and kerosinized ash on the population of mustard aphid, *Lipaphis erysimi* (Kalt.) after two treatments and yield of mustard in plot F (Var. BARI Sharisha-7).

Plot/Field based on sowing date	Tr. block	Treatments	Mean number of aphids with standard error(S.E.)/plant								yield (kg/block) Mean ± S.E.	Average yield q/ hectare
			Pre treatment DBT	First round treatment (18.01.2006)				Second round treatment (08.02.2006)				
				I DAT	III DAT	VII DAT	XX DAT	I DAT	III DAT	VII DAT	2XX DAT	
F 16.11.2005 (Late sowing)	LT_1	Classic 20 EC @ 2ml/L water (First round and second round)	60.00± 11.56	11.67± 1.67	15.00± 2.89	16.67± 6.67	33.33± 3.34**b**	6.00± 2.31	3.33± 2.41	6.67± 2.41	9.33± 0.67**c**	.34± 0.01 **a**	6.91
	LT_2	Classic 20 EC@ 2ml/L water (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	76.67± 8.83	11.67± 1.67	13.33± 1.67	16.67± 4.41	33.33± 3.34**b**	5.33 ± 1.77	7.33± 2.67	6.33± 2.19	10.00 ± 0.00**c**	.34± 0.01 **a**	6.91
	LT_3	Larvae of *C. transversalis* (First round and Second round)	85.00± 8.67	16.67± 4.41	21.66± 4.41	36.67± 3.33	43.33± 18.58**b**	36.67± 13.35	20.00± 0.00	20.00± 0.00	25.00± 2.9**bc**	.30 ± 0.01 **b**	6.1
	LT_4	Larvae of *C. transversalis* (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	130.00± 5.78	30.00± 5.78	33.33± 3.34	45.00± 7.65	26.67± 3.34**b**	11.67± 1.67	15.00± 2.89	14.33± 3.48	13.33± 1.67**c**	.27 ± 0.01 **c**	5.49
	LT_5	Kerosinized ash (First round) and Dhutura leaf extract @ 1:10 W/V (Second round)	146.67± 27.32	43.33± 8.83	33.33± 3.34	51.67± 4.41	48.33± 11.68**b**	25.00± 5.01	15.00± 5.00	13.33± 3.34	31.67± 10.15**b**	.24± 0.01 **c**	4.88
	LT_6	Control, Spray water only (First round and second round).	136.67± 18.58	110.00 ±20.84	153.33 ±3.34	133.33 ±16.69	86.67± 6.67**a**	61.67± 2.27	78.33± 9.29	78.33± 4.41	106.67 ±6.67 **a**	.15±0.01 **d**	3.5
							P=.010 F=5.068				P=.000 F=52.661	P=. 000 F=49.441	

- All figures are mean of three replications.
- Size of each experimental block 1.5 × 1 meters
- DBT – Day before treatment.
- Means having the same letter (s) in a column are not significantly different at 0.05 probability level by DMRT.
- DAT –Days after treatmen

Table 29. Yield (Mean ±S.E.) of mustard (kg/block)in terms of date of sowing ,variety and treatments.

Date of sowing	Crop variety	Treatments					
		T_1	T_2	T_3	T_4	T_5	T_6
Early sowing 16.10.2005	BARISharisha -6	.48±0.01**a**	.44 ±0.01**a**	.42±0.00**a**	.36±0.00**ab**	. 32±o.o1**a**	..20±0.01**a**
	BARISharisha -7	.45±0.03**a**	.42±0.02**ab**	.39±0.00**ab**	.33± 0.02**bc**	.26±0.00**bc**	.16±0.00**b**
Mid sowing 01.11.2005	BARI Sharisha-6	.41±0.01**b**	.39±0.01**bc**	.37± 0.01**b**	.38±0.01**a**	.32±0.01**a**	.19±0.01**a**
	BARISharisha -7	.39±0.01**bc**	.37±0.01**cd**	.33±0.01**c**	.31±0.01**cd**	.29±0.01**ab**	.18±0.01**ab**
Late sowing 16.11.2005	BARI Sharisha-6	.35±0.01**cd**	.34±0.01**d**	.32±0.01**c**	.28±0.01**dc**	.25±0.01**bc**	.18±0.00**ab**
	BARISharisha -7	.34±0.01**d**	.34±0.01**d**	.30±0.01**c**	..27±0.01**e**	24±0.01**c**	.15±0.01**b**
		P=.000 F=16.74	P=.000 F=11.98	P=.000 F= 12.84	P=.000 F=14.584	P=.001 F=8.178	P=.018 F=4.292

- All figures are mean of three replications
- Means having the same letters in a column are not significantly different at P<0.05;P<0.01and P<0.001 probability level by DMRT
- Detailed description of treatments(T_1-T_6) were already mentioned in Table(23-28)

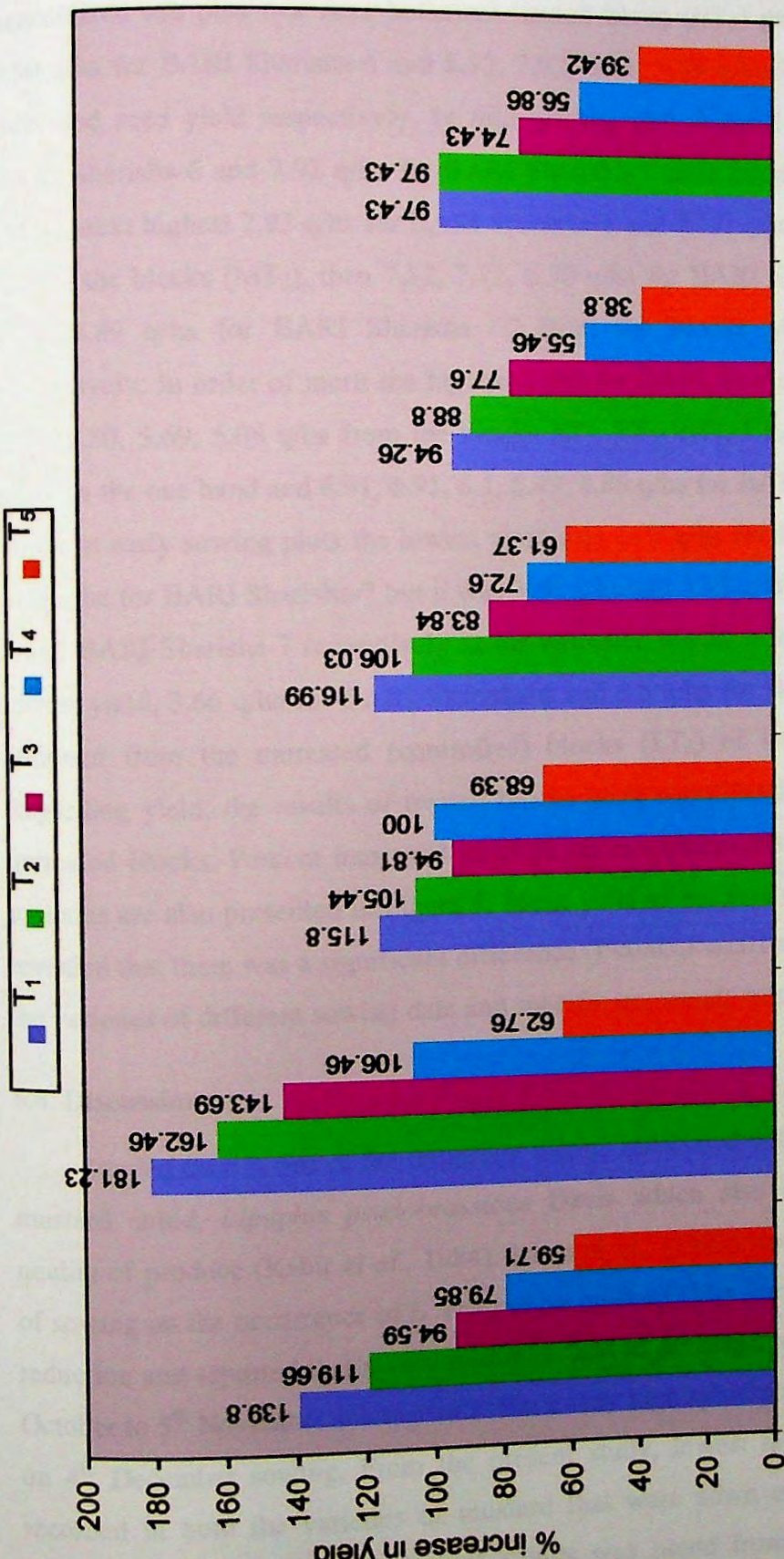


Figure 8: Percent increase in yield over control (T_6) in various treatments for BARI Sharisha-6 and BARI Sharisha-7.

time natural enemies plus one time botanical treated block (ET_4), one time kenosinized ash plus one time botanical treated block (ET_5) gave 8.94, 7.92, 7.32, 6,50 q/ha for BARI Sharisha-6 and 8.53, 7.92, 6.71, 5.29 q/ha for BARI Sharisha-7 increased seed yield respectively. In mid sowing plot, highest yield 8.33 q/ha for BARI Sharisha-6 and 7.92 q/ha for BARI Sharisha-7 were obtained from the blocks (MT_1), next highest 7.93 q/ha for BARI Sharisha-6 and 7.52, q/ha for BARI Sharisha-7 from the blocks (MT_2), then 7.52, 7.72, 6.50 q/ha for BARI Sharisha –6 and 6.71, 6.30, 6.89 q/ha for BARI Sharisha –7 from the blocks MT_3, MT_4 and MT_5 respectively. In order of merit the highest yield for BARI Sharisha – 6 were as 7.11, 6.91, 6.50, 5.69, 5.08 q/ha from the blocks LT_1, LT_2, LT_3, LT_4, LT_5 in late sowing plots on the one hand and 6.91, 6.91, 6.1, 5.49, 4.88 q/ha for BARI Sharisha –7 on the other. In early sowing plots the lowest yield was 4.07 q/ha for BARI Sharisha-6 and 3.25 q/ha for BARI Sharisha-7 but it was 3.86 q/ha and 3.65 q/ha for BARI Sharisha - 6 and BARI Sharisha-7 respectively in the untreated blocks of mid sowing plot. The lowest yield, 3.66 q/ha for BARI Sharisha-6 and 3.5 q/ha for BARI Sharisha-7 were obtained from the untreated (controlled) blocks (LT_6) of late sowing plot also. Regarding yield, the results of treated blocks were significantly superior above the untreated blocks. Percent increased yield in various treatments over control of both varieties are also presented in Figure 8. Mean yield of mustard (Kg/Block)(Table 29) revealed that there was a significant difference ($P<0.05$;$P<0.01$ and $P<0.001$) between the varieties of different sowing date and specific treatments respectively.

6.4. Discussion

Sowing time is one of the important factors associated with serious incidence of mustard aphid, *Lipaphis psudobrassicae* Davis which also affects the yield and quality of produce (Kabir *et al.*, 1984). Islam *et al.,* (1991) studied the effect of date of sowing on the occurrence of *L. erysimi* on mustard (Var.Tory 7) extent of its yield reduction and reported that a very minimum and or no aphid was recorded from 15th October to 5th November sowing time. But a very high aphid population was recorded on 4th December sowing. From the present study, lowest number of aphids were recorded in both the varieties of mustard that were sown on 16th October (early sowing). Increase in the number of aphids was noted from the mid sowing (1st

November) plots and the then highest aphid infestation was found in the crop sown on 16th November (Late sowing plots). So the results of the present study are in good agreement with the findings of Islam *et al.,* (1991) in spite of varietal difference. Miani (1985) and Bhattacharjee (1961) who strongly suggested that early sowing would be very effective to escape aphid infestation in mustard. Significant decrease in the seed yield of mustard was observed with successive delay in sowing from 08 October to 18 December at 10 days interval during all three years of study (1995-96, 1996-97 and 1997-98) even under protected condition (Patel *et al.,* 2004).On the mean basis sowing on 08 November produced seed yield of 1409 kg/ha that was 40.2, 63.4, 76.6 and 85.9 per cent higher than the seed yield sowing on 18 and 28 November and 08 and 18 December respectively.

Generally time of sowing varies with the climate of a region and the variety used. Reports regarding the effect of sowing time on the incidence of aphids of mustard and rape seed in Bangladesh is not adequate. Effect of four seeding dates (25th October, 4th November, 14th November and 24th November) on the aphid (*Lipaphis pseudobrassicae* Davis) infestation and seed yield of mustard (local Var. Rai 5) and rapeseed (BARI Var. SS-75 and Local Var. LS-14) showed that sowing on October and early November gave highest yield and low aphid infestation while sowing on mid and late November gave lowest yield and highest aphid infestation (Rahman *et al.,* 1989). High seed yield obtained in earlier sowing dates suggests that early sown crop escaped severity of aphid on slaught at its crucial period of flowering, since peak infestation is reached by the time flowering is over and most of the pods have been formed. With the delay in sowing date, growing stage and flowering period coincided with the peak infestation period (Sing *et al.,* 1984; Bhattacharjee, 1961). Few genotypes of *Brassica* cultivars *viz.*, Ys-Pb-24, Ys-B-9, Yss-8, BSH-1, BS-113, Pusa Kalyani, Sangam, RH-30 and Pusa bold that were sown on 10 days interval starting from 05 October continued till 15 November during 1978-79 and 1979-80 crop seasons manifested that delayed sowing exposed the crop to a high aphid infestation resulting in lower yield irrespective of varietal differences (Phadke and Prasad, 1987). From the experiment of Hussain and Shahjahan (1997) on susceptible Nap-check of ten *Brassica* varieties/ mutants against mustard aphid, it was found that Nap-3 was moderately susceptible; Tori-7,BS-5, Sangam highly susceptible; Sampad,

Agrani, SS-75, Safal, BINA-2, and Ys-52 were less susceptible to aphid *L. erysimi*. In order to minimize the attack of *L. erysimi* infesting oil seed Brassica crops, Singh and Sharma (2002) emphasized the need based use of safer insecticides along with cultural, biological, behavioral and biotechnological approach. Islam *et al.*, (1990) evaluated eight foliar insecticides *viz.*, Marshal 20 EC (Carbosulfun), Pillacron 100 EC (Phosphamidon), Sumicidin 20 EC (Fenvalerate), Maladan 57 EC (Malathion), Polygor 40 EC (Dimethoate), Metasystox 25 EC (Oxydemeton methyl), Benicron 100 WSC (Phosphamidon) and Hekthion 57 EC (Malathion) against *L. erysimi*. Among the insecticidal treatments, Hekthion 57 EC (Malathion) treatment gave the highest yield of mustard (63.11%) above the untreated crop yield. Imidacloprid 200SL @ 0.25ml/l water; Azadirachtin 5F @ 1.0ml/l water and Fenpropathrin 30EC @ at four different dosage levels *viz.*, 0.25 ml/l, 0.50 ml/l, 0.75 ml/l, and 1.0 ml/l were sprayed once in November-December 2003 and again in January-February, 2004 at Nadia, India against Mustard aphid (*L. erysimi*) and the highest reduction in aphid population was found in case of Fenpropathrin @ 1.0 ml/l water followed by Fenpropathrin @ 0.75 ml/l of water. Regarding seed yield, highest production (10.45 q/ha) was achieved from the treatment @ 1.0 ml/l and second highest (10.02 q/ha) from @ 0.75 ml/l of water respectively (Sahu *et al.*, 2006). Singh (2006) recorded the highest grain yield of mustard 8.85 q/ha in IPM field whereas it was 7.05 q/ha in farmers traditional field. The cost benefit analysis revealed that farmer's practices resulted cost benefit ratio of 1:7.34 whereas it was 1:18.32 in IPM adopted field. From the results of present investigation it was also observed that between the two varieties aphid infestation index was relatively more on BARI Sharish-6 than on BARI Sharisha-7. Besides, differences in yield were found to be very significant among the treatments of each plot. Thus it could be concluded that irrespective of varietal difference, mustard should be sown within mid October and treated with judicious use of pesticide in order to get maximum seed yield as well as higher environmental safety.

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APPENDICES

Plate-I. Experimental tubs with bean plants.

Plate-II. Infested twigs of bean plant by *Aphis craccivora* Koch.

Plate-III. Infested immature bean pod by *Aphis craccivora* Koch.

Plate-IV. Colony of *Aphis craccivora* Koch on bean pod.

Plate-V. Apterous morph of *Aphis craccivora* Koch.

Plate-VI. Alatae morph of *Aphis craccivora* Koch.

Plate-VII. Treatment materials including Manseok sprayer.

Plate-VIII. Spraying insecticide on a block by Manseok sprayer.

Plate-IX. Treated bean plants with insecticide.

Plate-X. Untreated bean plants (controlled).

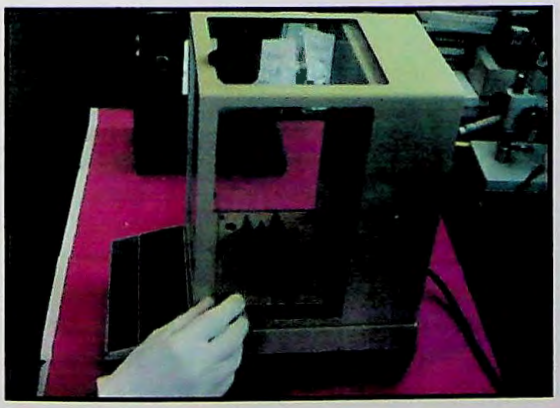

Plate-XI. Weighing of bean by electronic balance.

Plate-XII. Bean plants on scaffold.

Plate-XIII. Early sown brinjal plant (Var.Kazla).

Plate-XIV. Mid sown brinjal plant (Var. Nayantara).

Plate-XV. Late sown brinjal plant (Var. Kazla).

Plate-XVI. Plants with Kajla brinjal.

Plate-XVII. Adult of *Scymnus coccivora* Ayyar preying on *Aphis craccivora* Koch.

Plate-XVIII. Early sown mustard field (Var.BARI-Sharisha 6).

Plate-XIX. Early sown mustard field (Var.BARI-Sharisha 7).

Plate-XX. Dried leaves of Tobacco, Dhutura and Bankalmi.

Plate-XXI. Infested twig of mustard (BARI Sharisha-7).

Plate-XXII. Infested twig of mustard (BARI Sharisha-6).

Plate-XXIII. Adult of *Coccinella transversalis* (Fabr.).

Plate-XXIV. Mating of *Coccinella transversalis* (Fabr.).

Plate-XXV. Egg mass of *Coccinella transversalis* (Fabr.).

Plate-XXVI. Larva of *Coccinella transversalis* (Fabr.).

Plate-XXVII. Pupae of *Coccinella transversalis* (Fabr.).

Plate-XXVIII. An infested mustard twig was cased by a plastic container for functional response study.

Plate -XXIX. Larva of *Micraspis discolar* (Fabr.).

Plate-XXX. *Micraspis discolar* (Fabr.) on bean plant.

Plate-XXXI. Parasioid, *Tryoxys (Binodoxys) indicus* (SubaRao and Sharma).

Plate-XXXII. Searching behavior of *Tryoxys (Binodoxys) indicus.*

Plate-XXXIII. *Tryoxys (Binodoxys) indicus* ovipositing on aphid.

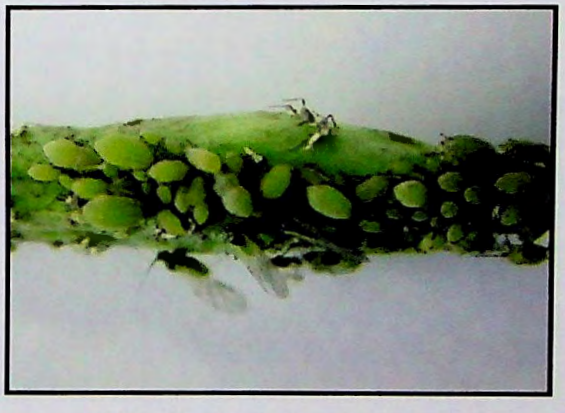

Plate-XXXIV. An infested mustard pod (Var.BARI Sharisha-6) by *Lipaphis erysimi*(Kalt.).

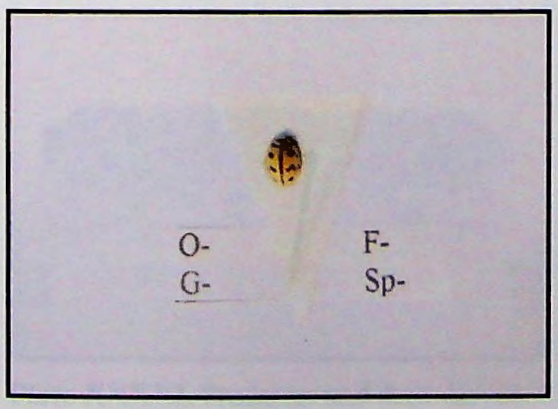

Plate-XXXV. *Cheilomenes sexmaculata* (Fabr.).

Plate-XXXVI. *Coccinella septempunctata* L.

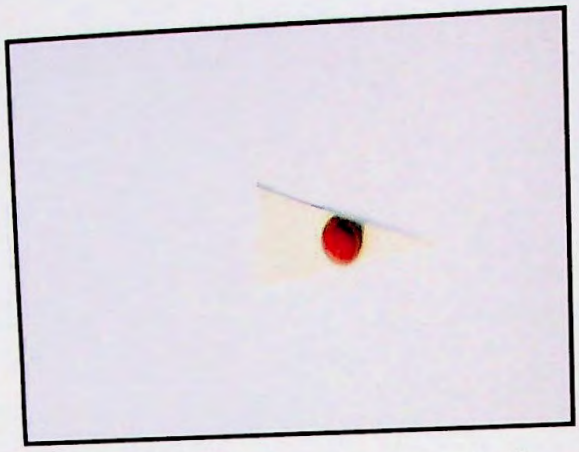

Plate-XXXVII. *Micraspis yasumatsui* Sasajii.

Plate-XXXVIII. *Ischiodon scutellaris* (Fabr.)

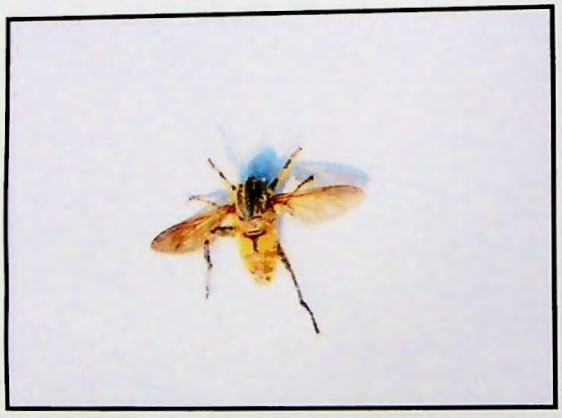

Plate-XXXIX. *Syrphus confracter* Wiedemann.

Plate-XXXX. Larva of *Syrphus confracter* on bean aphid colony.

Plate-XXXXI. Predators and their larvae rearing container.

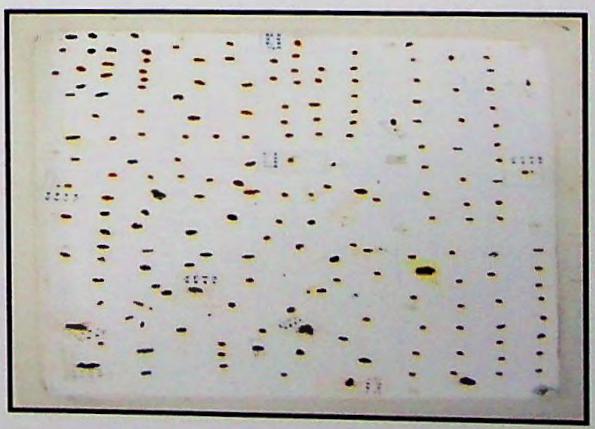

Plate-XXXXII. Insect preservation box.