INCIDENCE OF INSECT PESTS COMPLEX OF BARI MOTOR -1 (*PISUM SATIVUM*) AND THEIR MANAGEMENT

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BY

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*This is to certify that thesis entitled **"INCIDENCE OF INSECT PESTS COMPLEX OF BARI MOTOR -1 (PISUM SATIVUM) AND THEIR MANAGEMENT"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **MOHAMMAD SAIFUL ISLAM, Registration no. 14-06350** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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INCIDENCE OF INSECT PESTS COMPLEX OF BARI MOTOR -1 (*PISUM SATIVUM*) AND THEIR MANAGEMENT

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ABSTRACT

The experiment was conducted in the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from November, 2014- March, 2015 to incidence of insect pest complex of BARI motor -1 and their management and their impact on natural enemies. The experiment was laid out in a Randomized Complete Block Design with three replications and five treatments applied at 7 days interval. The treatments were T_1: Mechanical and Cultural practices at 7 days interval, T_2: Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval, T_3: Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval, T_4: Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval and T_5: Untreated control. The result reveled that among different treatments Mechanical control and spraying of Ripcord 10EC @ 1.0 ml//L of water at 7 days interval was most effective in reducing the incidence of insect pests of BARI motor-1 and leaves infestation by white fly, aphid, and epilachna beetle (5.73 , 4.76 and 5.39%respectively) and in reducing pod infestation by number at early, mid and and late pod development stage caused by pod borer the lowest infestation (3.06, 4.23 and 5.00 % respectively) whereas the highest infestation (11.97, 13.75 and 14.81% respectively) was observed in $T_{5.}$ As the best treatment, it reduced the highest level of pod infestation conversely it increased the maximum level of plant and pod related yield attributes, that is T_2 increased the maximum height (cm), number of pods/plant, number of seeds/pod, and weight of 100-seeds (g) (50.94, 50.47, 5.27 and 17.15 respectively) of pea over control followed by Spraying Suntaf 50SP @ 1.5 g/L of water (49.04, 47.53, 5.07 and 16.63 respectively) and Topgan 10EC @ 1.0 ml/L of water (49.67, 48.47,5.13and 16.22 respectively). T_2 also had the highest pod yield (2.09 t/ha) followed by $T_{1,}$ $T_{3,}$ and T_4 (2.00, 2.02.and 1.987 t/ha).Considering the impact of management practices on the population of natural enemy, T_2 had adversely affected and reduced the highest population of adult ladybird beetle and field ant (83.10% and 80.00% respectively) over control followed by T_3 (73.70% and 78.60%) Though, T_2 reduced the highest level of insect pests infestation of BARI motor-1 and including other chemical treatments, conversely they mostly harmful to the beneficial arthropod biodiversity in the pea ecosystem by reducing the maximum level of the natural enemy population than any other newer insecticides which were comparatively safe, and would be fit well into the management of insect pests of BARI motor-1.

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CHAPTER I

INTRODUCTION

Pea *(Pisum sativum* L) is one most of the important pulse crops, belongs to the family Papilionaceae. There are two main kinds of cultivated peas today, among them; vegetable pea can be eaten as green peas. Pea is highly nutritive containing high percentage of digestible protein (83-92%) along with carbohydrates and vitamins Protein content varies 20-30% in different pulse varieties. It is also very rich in minerals (Coolong, 2012). It is an excellent food for human consumption, taken either as a vegetable or in soup.

Green pea can be considered as vegetable crop as it can also be grown without competition with cereal crops. The present consumption of pulse in Bangladesh is only about 10g/h/d against the recommended uptake of about 45g/h/d (BBS, 2010). Per head pulse consumption is less in Bangladesh due to lack of production. In Bangladesh, usually production of pulse is 383030 metric tons, among them garden pea production is 13540 metric tons (BBS, 2012), which is far less than the annual requirement. High production potential if exploited properly can minimize this situation. Production of pulses can be increased by enhancing both area productions and HYV (High Yielding Variety). Now a day the acreage and production of pea in Bangladesh has drastically reduced.

Garden pea is sporadically cultivated in urban areas for fulfilling their needs. The demand of green pea is increasing day by day especially in high cost modern restaurant. It is also used for cooking Biriani and Polao as well as salad. It provides cash income to our national economy through selling within the country and exporting them. With a view to creating genetic variability having desired traits like early maturity, high yield, sugar content and softness of pod for high market value, a sound breeding programme should be adopted. Thus, there is a great scope for pulse production in Bangladesh (BARI, 2013).

The quality of green pea as vegetable depends on sugar content in seed and softness of pod. The protein and vegetable deficiency can be overcome by developing high yielding garden pea. Any early maturing pea varieties will fit well easily in existing intensive cropping system. As per capita land is shrinking gradually, it is needed of developing early maturing variety in Bangladesh. Unfortunately, pulses are infested by a number of insect pests, which are considered to be the significant obstacles for its economic production. Among them, aphid and thrips are the major pests responsible for considerable damage of BARI Mator-1 (BARI, 2013). In spite of being a prospective crop, high incidences of insect pests already effect the yield and reduce the quality. Farmers in our country faced various problems including the availability of quality seeds, fertilizer and manures, irrigation facilities, modern information in the fields of technical and instrumental inputs, insect pests and diseases in cultivation of the crop (Rahman, 2006). Among these, insect pets are the most important and cause enormous quantity of yield losses in every season and every year. Although no regular statistical records are kept, as per conservative estimate the yield loss in BARI Mator-1 due to insect pest. In most cases, the farmers either forgot the instructions or did not care to follow those instructions and went on using toxic insecticides at their own choice or experience. Therefore, the effective control of insect pest in BARI Mator-1 deserves some new approaches which are eco-friendly, economically viable and socially acceptable.

OBJECTIVES:

1) To study the incidence of insect pests and determine infestation level of BARI Mator-1 during the growing season.
2) To find out efficacy of the management practices against insect pests complex of BARI Mator-1.
3) To evaluate the effect of management practices on the natural enemies during the study period.

CHAPTER II

REVIEW OF LITERATURE

2 Pea (*Pisum sativum* ssp. Hortense)

The pea *(Pisum sativum* ssp. Hortense*)* is an annual herbaceous legume belonging to the family Papalionaceae grown for its edible seeds and seedpods. One of the subdivisions of this family, *Viciae,* includes the genera *Pisum.* Within the genus *Pisum* Linnaeus distinguished *two* species *Pisum sativum* ssp. *arvense*, the field pea, and *Pisum sativum* ssp. *sativum*, the garden pea (Muehlbauer and Tullu, 1997).

2.1 Origin and Distribution

The garden pea is grown for its green succulent seeds, which are used as vegetables. salad and also dahl for food while the field pea is grown for forage or for its dry, mature seeds, which are used as food or feed The origin and progenitor of pea are obscure, but it is one of the oldest cultivated plaits Four centers of origin based on genetic diversity were listed by Myers *et al.* (2006). Muehlbauer and Tullu (1997) indicated that the principal center of genetic diversity is the Mediterranean gene center with secondary centers in the Near as and Ethiopia.

2.2 Botany

Pea is an annual herbaceous plant. It has a tap root system. Stems are slender, usually single, and upright in growth. Leaves are pinnately compound with two to several leaflets. The rachis terminates in a simple or branched tendril. There are large stipules clasping the stem. The flowers are typical apilionacepus . It has green calyx comprising of five united sepals, five petals (one standard, two wings and two keels). The stamens are in diadelphous (9 +1) condition. The gynoecium is monocarpellary, with ovules up to 13) alternately attached to the two placentas. Stigma is ellipticall and sticky. The pea plant can be bushy or climbing; with slender stems which attach to a substrate using tendrils. Each leaf has 1–3 pairs of oval leaflets and can reach 1–6 cm in length. The plant produces white, red or purple flowers and swollen or compressed green seedpods which can be straight or curved. The pods can range in size from 4 to 15 cm long and 1.5–2.5 cm wide. Each pod contains between 2 and 10 seeds, or peas. The pea plant is an annual plant, surviving only one growing season and can reach 30–

150 cm in height. Pea may also be referred to as garden pea, English pea or green pea and likely originates from Southwest Asia (Coolong, 2012).

2.3 Floral Characteristics

Usually the pea is considered to be self-pollinated; however, cross pollination can be quite extensive with some genotypes and environments. *Pisum sativum* is essentially self- pollinated but out crossing ranging from 0.09 to 94. 5% has been reported by different workers (Drost, 2010). The amount of out crossing varies with variety, location, climatic conditions and population of pollinating agents. The proportion generally reported with commercial cultivars is less than l%. The preponderance of self fertilization in the pea is due primarily to its cleistogamous nature. Pollination takes place approximately 24 hours before the flower opens (Kraft and Pfleger, 2001). Pollen placed on the stigma germinates in about 8 to 12 hours, and fertilization occurs about 24 to 28 hours after pollination (Myers *et al.,* 2006).

The inflorescence of the pea is a raceme arising from the axil of a leaf The peduncle may vary greatly in length and often elongates from 1 cm when first exposed to 6 cm or more when fully elongated. Bracts may or may not develop at the base of the pedicel. There are usually one to three flowers per raceme, though some genotypes have more. The number of flowers per peduncle may vary form one to several on the same plant (Razzaque, 2000).

Chlorophyll content

Chlorophyll and carotenoid pigments from six cultivars of processed green peas were extracted with 100% acetone and analysed by reversed-phase HPLC (Gowda and Kaul 1982). A number of pigments were identified in the pea cultivars including chlorophyll b and chlorophyll a related compounds. The efficiency of different extraction procedures using 100% acetone showed that initial extraction followed by three reextractions without holding time between gave a higher extraction yield than no reextraction and 30 or 60 minutes holding time all six cultivars contained the same pigments, but the concentration of each pigment varied significantly. On average of the two years, the chlorophyll a concentration varied from 4800 to 7300 ig/l00 g fresh weight, the chlorophyll b concentration from 2100 to 2800 ug/l00 g fresh weight in the processed pea cultivars. These differences in pigment concentration between the investigated cultivars are discussed in relation to nutritional, product color and nutritional quality.

Kinetic measurements of the light-harvesting chlorophyll a/b complex (LHCIIb) were performed by Jha *et al.* (1997) to determine the effects of chlorophyll a and b, extracted from pea leaves, on the in vitro assembly of LHCIIb.

Harries (1968) observed that chloroplasts isolated from protoplasts and purified on a Percoll gradient were highly import-competent, with little non specific binding of the precursor, and a high yield of intact chloroplasts (0.1 mg chlorophyll/g FW).

Etiolated pea plants were exposed to intermittent light (cycles of 2 mm white light and 118 mm dark) for *2-5* days ((IMl plants) or to 1 ms saturating white light flashes after every 15 min darkness for 10-15 days (FL plants) (Saxena, 1988).

Sugar content

Singh (1983) conducted studies in India, with seven genotypes of peas during the rabi season revealed that the number of pods per plant, pod girth and total sugars exhibited significant association with pod yield per plant. *Pisum sativum* contents soluble protein, ascorbic acid and sulfur. A thesis work on yield attributes and sugar content in vegetable pea *(Pisum Sativum* L.) to measure the variability and character association among eleven genotypes of vegetables pea. He concluded that highest genotypic variability vas observed from biological yield followed by green seed yield. Sugar content showed the highest genotypic co-efficient of variation Sugar content (percentage) also showed high heritability.

Tiwari (1985) reported highly significant differences among genotypes for pod number, node at which 1st fruit appeared, harvest index, height, pod length, protein content, total yield and total soluble sugar content.

Khan *et al.* (1982) worked on total and partial correlations between yield and protein and sugar contents En peas and reported that at the green pod stage significant negative correlations were found between sugar and both dry matter and alcohol-insoluble solid contents.

2.4 Aphids (Pea aphid):

Common name: Aphids

Scientific name: *Acyrthosiphon pisum*

2.4.1 Systematic position of Aphids:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Homoptera

Family: Aphididae

Genus: *Acyrthosiphon*

Species: *pisum*

Source: (Gungali and Roychaudhuri, 1984).

2.4.2 Distribution

Aphids are distributed worldwide, but are most common in temperate zones. Aphid species diversity is much lower in the tropics than in the temperate zones. They can migrate great distances, mainly through passive dispersal by riding on winds, for example, the currant-lettuce aphid. Aphids have also been spread by human transportation of infested plant material. Aphid (*Aphis craccivora* Koch) is a polyphagous insect with marked preference to legumes. Amongst legumes, mungbean along with cowpea and groundnut are most damaged by this pest (Gungali and Roychaudhuri, 1984).

2.4.3 Biology

Adult aphids are black or dark brown, shiny, abdomen with large, dark, practically solid dorsal plate. Winged parthenogenetic females are 1.5 to 2.0 mm long, dark dorsal abdominal plate. Antennae are about two third as long as the body. Nymphs are wingless, dark with fairly rounded body 0.12 mm shape. Nymphs appear on the crop soon after germination from adults having over wintered or spent dry season on near by leguminous plants. In tropics only females, winged or wingless, are found, and parthenogenetic reproduction occurs throughout the year. The aphid is ovoviviparous, with females retaining eggs inside their bodies and giving birth to small nymphs. Males are winged and sexual forms are occasionally found. The optimal development temperature is 24-28.5°C and relative humidity 65%. The optimal day length for nymphal development is 16 hours light and 8 hours of darkness (Abdel *et al.*, 1982).

2.4.5 Nature of damage

Young aphids cluster over tender shoots and occasionally young pods of mungbean and suck plant sap-from these plant parts. Heavy infestation weakens the plant and entire plant can be destroyed. Severe attack at the time of flowering and seed formation affects yield and produce wilt symptoms. In addition, abnormalities due to virus diseases rosetting, stunting, mosaic, mottle etc can be observed. The greatest damage results from virus diseases which are transmitted by *A. craccivora*, especially in groundnut. Among the virus vectored by this aphid in various crops are alfalfa mosaic, bean commo mosaic, bean yellow mosaic, cowpea aphid-borne mosaic, cowpea banding mosaic, cowpea mild mottle, bean leaf roll and chickpea stunt virus. In mungbean, it transmits at least three viruses; green mosaic, leaf curl browning and little leaf (Rai, 1994).

Small soft bodied insects on underside of leaves and/or stems of plant; usually green or yellow in color, but may be pink, brown, red or black depending on species and host plant (Drost, 2010). if aphid infestation is heavy it may cause leaves to yellow and/or distorted, necrotic spots on leaves and/or stunted shoots; aphids secrete a sticky, sugary substance called honeydew which encourages the growth of sooty mold on the plant (Coolong, 2012).

2.4.6 Yield loss due to aphid

During cultivation of cowpea the farmers face a serious problem with bean aphid as it is one of the most destructive pests of worldwide distribution and is one of the limiting factors in the cultivation of country bean (Rai, 1994). Bean aphid is polyphagous, with marked preference for leguminosae ((Jayappa and Lingappa, 1988). Cowpea was found to be the most preferred crop by a *craccivora* (Parker and Dutcher, 2006). A *Craccivora* is the most damaging species causing significant damage throughout the world and resulting 100% yield loss in different varieties of country bean (*L. purpureus*), barbati (*Vigna sesquipendalis*), black gram (*V. mungo*), mung bean (*V. radiata*) and cow-pea (*V. unguiculata*) in different places (Ganguli and Roychaudhury, 1984). In Bangladesh small, shiny black coloured bean aphid is known as *A. medicaginis* but in India this species is called *A. craccivora* (Verdcourt, 1970). The bean aphid, *A. craccivora* Koch is the most serious pest of bean plants from seedling to pod bearing stage, causing considerable yield losses Hagedorn and Walker (1954). Aphid causes damage directly by sucking cell sap of plant and indirectly by transmitting several vital diseases. The losses are colossal and irreparable (Cane *et al.*, 1988).

Both the nymphs and adults cause damage by sucking sap from flowers, buds, pods and tender shoots of the plants and reduce the vitality of the bean and leguminous crops (Thakur and Kashyap, 1989). In severe cases, plants fail to give flowering and pods resulting 20-40% yield loss (Singh and Allen, 1980). These aphids also secrete abundant sticky honeydew which enhance the growth of shooty mold fungus and reduces photosynthetic efficiency of the plant (Sultana *et al.,* 2009). The aphids are peculiar insects for their biology and adaptation to agro-ecosystem. They are perhaps the most prolific insects, due to their rapid growth and telescoping of generations rather than to the number of young per female (Harries, 1968). There are many exceptions in the different species, but in general the aphids over-winter in the egg stage, and the hatching nymphs become stem mothers which produce living young in succeeding generations during the summer. These may be both wingless and winged agamic viviparous forms. In the fall winged males may appear which mate with the females to complete the cycle. In warmer climates the sexual part of the cycle may be entirely eliminated. *A. craccivora* is a soft bodied prolific breeder and produces offsprings, parthenogenetically (Singh and Taylor, 1978).

Due to its parthenogenetic viviparity, short developmental period, high fecundity and polymorphic nature this insects soon build up a high population and thus causes a considerable damage to bean p1ant (Walker and Snyder, 1933).

Hagedorn (1984) studied the life history of *Aphis craccivora* at 20°C, 50% RH and LD 168 h and showed the presence of four instars. Aphid infestation without control may account for more than 1000 million aphids per acre. On the other hand, yield, protein and carotene content of bean may be reduced to half due to aphid infestation. It injects a toxin through salivary secretion into the plant during feeding, which causes vitality and reduction of growth (Rahman *et al.*, 1981).

From the economic standpoint the control of bean aphid is vital for successful bean production. The factors influencing its multiplication and colonization to host crop need to study before adopting control measures. In severe cases, plants fail to give flowering and pods resulting 20-40% yield loss (Thakur and Kashyap, 1989).

2.4.7 Control Measures

2.4.7.1 Biological control

Most natural enemies of aphids are polyphagous attacking wide range of aphid species in a particular habitat. Therefore, important natural enemies attacking particular aphid species on crops tend to be different according to crop species and climate. This is especially true of aphid species such as *A. craccivora*, attacking a range of crop over large geographical areas. In addition, many natural enemies, especially parasitoids are members of species complexes, morphologically very similar but with different host preferences and geographical distribution. Some of the important parasitoids of *A. craccivora* are *Thioxysindicus, Lysiphlebus fabarumand* L, *Tesaceipes* (Nayar *et al.*, 1976).

Singh (1983) found 9.4% parasitism by *T. indicus* shortly after appearance of *A. craccivora* on pigeon pea, in India. The peak rate of 64.6% was observed in later stages of infestation which was sufficient to suppress aphid populations on pigeonpea. Important predators include coccinellid beetles, e.g. *Cheilomenessex maculate* and *Coccinella septempunctata*, neuropteran larvae, e.g. *Micro mustimidus and* predatory diptera, e.g. *Aphidoletes aphidimyza* and a syrphid, *Ischiodon scutellaris*. Use of chemical insecticides however, suppresses activityof all these beneficial arthropods. To conserve these natural enemies' insecticides that are least toxic to predators and parasites that too only cases of absolute necessity.

2.4.7.2 Cultural control

Densely planted groundnut fields sown as soon as possible discourage colonization by aphids. Early sowing allows plants to start flowering before aphids appear, while dense sowing provide a barrier to aphids penetrating in from field edges. Sanitary measures are needed during the season and between seasons to prevent spread of viruses vectored by *A. craccivora*. Virus infected plants should be removed and any volunteer plants or weeds that could harbor viruses should be destroyed promptly. Insecticide applications were more effective in minimizing the incidence of *A. craccivora* when chickpeas were intercropped with barley or linseed. However, mungbean. Cowpea or ground nut are not suitable crops for intercropping due to the risk of spread of the insect between these favorable host-plants (Islam, 2006).

2.4.7.3 Chemical control

Most major groups of insecticides, especially organophosphorus and carbamates, have been tested and some of them found effective against wide variety of aphid on economically important crops. Pirimicarb a selective aphicideis widely used to control various species of aphids. Other chemicals include acephate, dimethoate, endosulfan, menazon, and thiometon which have been recommended for aphid control. Other sprays found promising on crops include neem and petroleum oil (Saxena, 1988). Cost of some of these sprays could, however, be prohibitive to subsistence farmers growing mungbean.

If aphid population is limited to just a few leaves or shoots then the infestation can be pruned out to provide control; check transplants for aphids before planting; use tolerant varieties if available; reflective mulches such as silver colored plastic can deter aphids from feeding on plants; sturdy plants can be sprayed with a strong jet of water to knock aphids from leaves; insecticides are generally only required to treat aphids if the infestation is very high - plants generally tolerate low and medium level infestation (Coolong, 2012). Insecticidal soaps or oils such as neem or canola oil are usually the best method of control; always check the labels of the products for specific usage guidelines prior to use (Drost, 2010).

2.4.7.4 Integrated pest management

Potential exist for the integrated control of *A. craccivora*. Combinations of selective insecticides, predators and parasites, cultural methods and resistant cultivars have potential of controlling the pest on a sustainable basis. In groundnut, monitoring pest populations to time insecticide spray application is combined with the use of cultural methods and resistant cultivars (Omo, 2010). In Bangladesh the IPM involving using malathion along with natural predation of *Menochilus sexmaculatus* was successful in controlling *A. craccivora* on beans (Ahmad *et al*., 1985).

During 1995-1996, a partial insecticide experiment was carried out on farms in Igalaland, Kogi State, Nigeria, to study the effects on the nature of insect pest attack of treating only a certain proportion (0, 25, 50, 75 or 100%) of the plants in a cowpea stand with a systemic insecticide (carbofuran as Furadan 3G, 3% a.i.) Numbers of both cowpea aphid (*Aphis craccivora*) and bean foliage beetles (*Ootheca mutabilis*) were determined and cowpea leaf damage was assessed. It was found that the greater the proportion of insecticide-treated plants in a plot, the lower the foliage pest infestation and damage on the susceptible (untreated) component. The reductions in leaf damage on untreated plants grown in admixture with insecticide-treated plants were often statistically significant although not as great as that achieved by the insecticide-treated plants them. It is concluded that the reduction of insect pests on the susceptible component was caused by a redistribution of pests, exposing them to toxins, after the initial infestation. A final set of experiments attempted to validate these results utilizing an aphid resistant variety of cowpea, but the results were inconclusive (Singh and Taylor, 1978).

2.5 Whitefly

Common name: White fly

Scientific name: *Bemisia tabaci*

2.5.1 Systematic position of whitefly (*Bemisia tabaci*)

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Homoptera

Superfamily: Aleyrodoidea

Family: Aleyrodidae

Subfamilies: Aleurodicinae, Aleyrodinae, Udamoselinae

Genus: *Bemisia*

Species: *tabaci*

(Martin and Mound, 2007).

2.5.2 Distribution

Whitefly is primarily a pest of cultivated plants in tropical and warm temperate regions of the world. It is found throughout the southern United States and can overwinter outdoors as far north as South Carolina. It is found infesting greenhouses in more northern latitudes in the United States and Canada. It is widely distributed throughout the Caribbean Islands, Central and South America, and Mexico. It is present throughout much of southern Europe, Africa, India, and has recently moved into Australia (Martin and Mound, 2007).

2.5.3 Biology

Whiteflies get their name from white wings. Greenhouse whitefly is a small (1 mm long) insect with delicate, white, powdery wax covered wings. They deposit pale yellowish green eggs on the lower side of the leaf. Eggs are elongated and attached to the leaf with a short pedicel. Eggs turn dark as they mature. Greenhouse whiteflies have four nymphal instars which are oval, flat, and often semitransparent. Careful observation through a hand lens is necessary to detect their presence. First instar nymphs that emerge from the eggs are called crawlers which move around in search of an ideal feeding site on the leaf. Later instars are immobile.

Fourth instar nymphs have red eyes and long, waxy filaments and are referred to as pupae. Adults have yellowish body and membranous wings covered with white, waxy substance. (Jones and David, 1995).

Source: (Jones and David, 1995).

2.5.4 Nature of damage

Bemisia can cause economic damage to plants in several ways. Heavy infestations of adults and their progeny can cause seedling death, or reduction in vigor and yield of older plants, due simply to sap removal. When adult and immature whiteflies feed, they excrete honeydew, a sticky excretory waste that is composed largely of plant sugars. The honeydew can stick cotton lint together, making it more difficult to gin and therefore reducing its value. Sooty mold grows on honeydew-covered substrates, obscuring the leaf and reducing photosynthesis, and reducing fruit quality grade (Jones and David, 1995).

2.5.5 Yield loss due to Whitefly

Lal *et al.* (2002) stated the white fly *(Bemisia tabaci*) as a serious pest of young Mator seedling causing severe damage. This is the most devastating pest and is widespread in the Orient. It has been reported to cause 55% seedling loss of Mator *(Pisum sativum)* under favourable climatic conditions. Vicentini and Newaj *et al.* (2005) showed that the Whitefly *(Trialeurodes vaporariorum*), >4 insects per meter of row results in 25% lack of seed and *25%* yield reduction because as the plants were most susceptible at the beginning of fruit formation. pea fly *(tabaci* and other species) is the most important insect pest of mator or pea. It causes significant damage during the seedling stage. The pea fly maggots feed inside the plant stem and their damage cannot be seed from the outside. Bruchids *(Callosobruchus chinensis* and *C. maculatus),* commonly called pulse beetles or cowpea weevils, attack pea *(P. sativum)* in the field. (Prasad *et al.,* 1984) conducted an experiment to quantify the damage to pea *(P. sativum)* by fly and other species) and reported that damage to the flowers and pods increased with percent infestation and reduced the yield to 52.1% in 1985 and 38.1% in 1986.

2.5.6 Control Measures

Mechanical Control: Monitor for whiteflies and manage them on nearby hosts or second year *P. sativum* fields especially those upwind before they move to newly planted or other fields. Second year *P. sativum* can be a good source of infestation for the new fields. Discarding the debris is important in reducing the pest pressure (Prasad *et al*., 1984).

Biological Control: Water roadways to prevent dusty conditions to promote natural enemies. Conserve natural enemies (Prasad *et al*., 1984).

Chemical control: For whiteflies, use lower volume of spray fluid than usual, pass the sprayer more slowly, and ensure thorough coverage of the lower side of the foliage. Rotate chemicals in different modes of action groups (Prasad *et al*., 1984).

Chemicals that affect nervous system: Nicotinic acetylcholine receptor (nACHR) agonists-Neonecotinoids (4A) Imidacloprid (Admire Pro), thiamethoxam (Actara), and acetamiprid (Assail) Sodium channel modulators (3) Fenpropathrin (Danitol) and pyrethroids. Acetylcholinesterase (AChE) inhibitors–Organophosphates (1B) Diazinon and malathion (Prasad *et al*., 1984).

Other modes of action: Prasad *et al*. (1984) reported that, narrow range oil (Omni Oil) and insecticidal soap (M-Pede)

Botanical pesticides: Azadirachtin is a neem-based insect growth regulator and is effective against immature stages. Natural pyrethrins affect the nervous system as sodium channel modulators (Prasad *et al*., 1984).

Microbial pesticides: Insect pathogenic fungi such as *Beauveria bassiana*, *Metarhizium brunneum*, and *Isaria fumosorosea* can be used against whiteflies and aphids (Prasad *et al*., 1984).

2.6 Grasshoppers

Common name: Grasshopper

Scientific name: *Oxya velox*

2.6.1 Systematic position of Grasshopper

Kingdom: Animalia

Phylum: Arthropoda

Subphylum: Hexapoda

Class: Insecta

Order: Orthoptera

Suborder: Caelifera

Family: Acrididae

Genus: *Oxya*

Species: *velox*

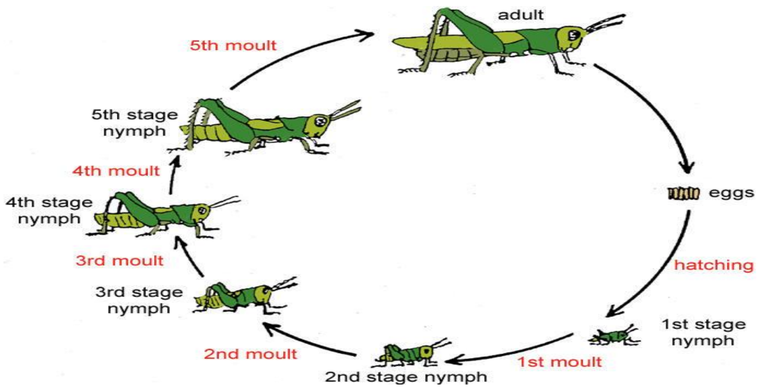
(Dan Johnson, 1998).

2.6.2 Distribution

Dan Johnson (1998) stated that the Caelifera includes some 2,400 valid genera and about 11,000 species. Many undescribed species probably exist, especially in tropical wet forests. The Caelifera have a predominantly tropical distribution with fewer species known from temperate zones, but most of the superfamilies have representatives worldwide. They are almost exclusively herbivorous and are probably the oldest living group of chewing herbivorous insects.

2.6.3 Biology

Some species have fairly elaborate courtship. Mating itself may take up to one hour, and male may ride on back of female for a period of a day or more, a behavior known as mate guarding. Females oviposit in loose soil (typically), among plant roots, in rotting wood, or even in dung. Clutches consist of 10-60 eggs, and females may lay up to 25 clutches over several weeks. Oviposition typically occurs in late summer, and the egg (as a developing embryo) overwinters. Eggs then hatch in spring. Life cycle is typically one year. A few species overwinter as juveniles (nymphs) (Dan Johnson, 1998).



Source: (Dan Johnson, 1998).

2.6.4 Nature of damage

Grasshoppers have chewing mouthparts that remove large sections of leaves and flowers, sometimes devouring entire plants. Garden damage is usually limited to a few weeks in early summer immediately after range weeds dry up. However, during major outbreaks grasshoppers will feed on almost any green plant, and damage may occur over a considerably longer period (Dan Johnson, 1998).

2.6.5 Control Measures

One strategy that can be used in field where migration of grasshoppers frequently occurs is to keep an attractive green border of tall grass or lush green plants around the perimeter of the field to trap insects and divert them from field of *Pisum sativum* (Dan Johnson, 1998).

The best strategy in agricultural and rangeland areas during major migrations is to treat the grasshoppers with an insecticide early in the season when they are still young nymphs living in uncultivated areas (Dan Johnson, 1998).

Field can be applied a bait containing carbaryl around the borders of the field before grasshoppers arrive. If a grasshopper trap crop is being grown around the border of the field, these plants can be baited or sprayed with carbaryl or other products to kill grasshoppers (Dan Johnson, 1998).

2.7 Epilachna beetle

Common name: Epilachna beetle

Scientific name: *Epilachna vigintioctopunctata*

2.7.1 Systematic position of Epilachna beetle

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Coccinellidae

Subfamily: Epilachninae

Genus: *Epilachna*

Species: *Vigintioctopunctata* and *dodecastigma*

(Bernard, 1979).

2.7.2 Distribution

This pest is widely distributed in Southeast Asian countries, Korea, Australia and it is common in South India, also occurs in other parts of India (Bernard, 1979).

2.7.3 Biology

After copulation female start laying eggs in the month of March-April. A female lay about 120-180 eggs. Eggs are laid in the cluster of 45 (average) on the lower surface of the leaves. The eggs are cigar shaped yellowish in color and are arranged side to side on the surface of the leave in erect position.

The larva hatches in 3- 4 days in summer months and in 4-9 days in winter. However, it has been reported that larval period may prolong up to 15 days when it grows on potato leaves or it may extend up to 32 days when grows on certain cucurbits (Bernard, 1979).

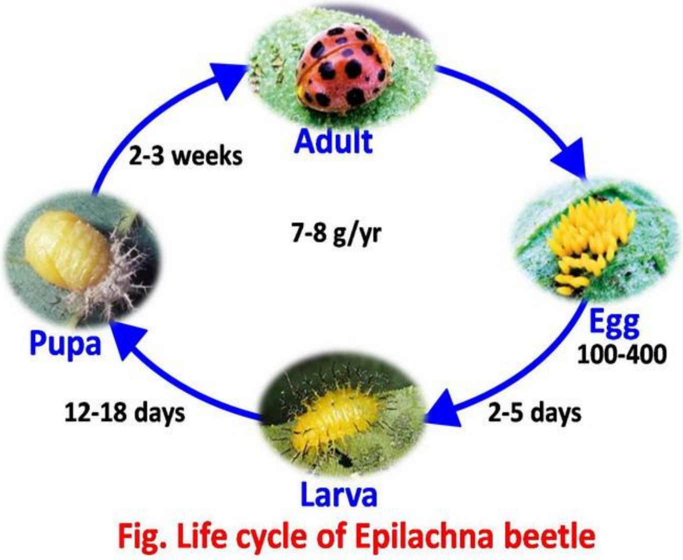


Fig. Life cycle of Epilachna beetle

Source: (Imura and Ninomiya, 1998).

2.7.4 Nature of damage

Due to its infestation, considerable economic loss is occurring during every crop season, adversely affecting both quality and quantity of crop output. The grub and adult feeds on the leaves, retarding the plant growth, which leads to loss of fruit production. Fruit reduction in yield up to 60% has been reported (Alam, 1991).

The damage was greater during April-October and 80% of leaves were injured and the high incidence of the pest has been reported during temperature range of 24-31°C and relative humidity 58-75% RH in the field (Doube, 1983).

2.7.5 Control Measures

Epilachna vigintioctopunctata is an important pest that causes considerable economic losses to many crops including sweet gourd. So, it is necessary to control for successful crop production.

Imura and Ninomiya (1998) studied the activity of four insecticides (fenitrothion, phenthoate, malathion, and cypermethrin) against Mexican bean beetle, Epilachna varivesties in leguminous vegetable fields in Yamanashi and Nagano prefectures, Japan in 1997. The most toxic material against adults was cypermethrin (0.24 ppm), followed by fenitrothion (43.1 ppm) and phenthoate (163.6 ppm). Malathion showed lower activity than other pesticides.

Jaques (1983) evaluated the efficiency of monocrotophos, quinalphos, cypermethrin and fenvalerate against Epilachna vigintioctopunctata infesting aubergine cv. Pusa Purple, sprayed 60, 75, 90 and 105 days after transplanting of aubergine, in Ranchi, Bihar, India during the kharif season of 1995. Treatment with all the insecticides reduced the *E. vigintioctopuntata* populations, with cypermethrin recording the highest reduction in the pest population at all stages of plant growth.

Karim (1994) carried out a field study in Pakistan to test the efficacy ol three insecticides against Epilachna spp. in aubergins. The insecticides were azocard (monocrotophos + cypermethrin), edmitol (fenvalerate + dimethoate) and sumicidin (fenvalerate). Sevin SP (carbary 1) was used as a standard. Results were non significant after 96 hours, but Sevin SP gave better results than the other insecticides.

Alauddin and Alam (2002) found that monocrotophos (0.04%) was better than phosphamidon (0.5%) and both were very promising in reducing the intensity of jassid, aphid and epilachna beetle during vegetative phase of brinjal. In fruiting phase insecticidal emulsion were found to be significantly superior over dust. Between emulsions, endosulfan proved significantly superior over fenvalerate against jassid and was very identical among themselves for controlling aphid and epilachna beetle.

El-Fatah (1991) staled that ditluchenzuron (DF) and penfluron (PF) at 1.125-20 ppm in acetone (25 dip) were equally effective in dose dependent manners against eggs of Henoseplichna treatment vigintioctupunctata but freshly laid eggs were more sensitive than 1 day old eggs.

Kaul (1982) tested malathion and endosulfan against hadda beetle, *E. vigintioctopunctata* and malathion was found more toxic than endosulfan. Larval mortality obtained with 50 and 100 ppm of malathion was 82.0 and 96.2% at 48 hours.

Hung-ChiChung *et al.* (2003) conducted a field trials with five insecticides namely, carbaryl 50 WP, endosulfan 35EC, quinalphos 25EC, fenitrothen 1000EC and monocrotophos 40EC against epilachna beetle on potato. The experimental results showed that endousulfan 35EC followed by carbaryl 50 WP and quinalphos 25EC gave reasonably good control of epilachna beetles within 10 days of treatments.

Jackson (1987) carried out a field experiment in 1992 at Rajendranagar, Andhra Pradesh, India with eight insecticides sprayed at fortnightly intervals between 30 and 105 days after sowing on bitter gourd against *E. vigintioctopunctata*. Fenvalerate was the most effective insecticide against *E. vigintioctopunctata.*

Gannon and Bach (1996) conducted laboratory and field studies in Kerala, India, during 1991, and found that carbofuran granules applied to bitter gourds at 1.5 kg a.i./ha at sowing, vining and flowering gave an effective level of control of *E. vigintioctopunctata.*

Kaul (1982) tested malathion, fanvalerate with dicofol and a fungicide separately and in various combination against pests of brinjal in Tamil Nadu. India, in 1986-87. Mixing malathion with the fungicide and dicofol was found most effective in controlling the larvae of *E. vigintioctopunctata* on brinjal.

Singh and Kavidia (1993) carried out field trials in Rajasthan, India, to determine the effectiveness of various insecticides against pests of brinjal during the fruiting stage. Epilachna beetles were most effectively controlled by application of aldicarb, malathion and fenitrothion.

Kidiavai (2009) observed the efficiency of profenofos, bromophos, ethion. prothiofos. permethirin and butylphenyl methylcarbamate (fenobucarb) against *E. vigintioctopunctata* on brinjal. The insecticides were sprayed 3 times at fortnightly intervals during the fruiting stage and estimations of mortality were based on larval counts. Fenobucarb, ethion, profenofos (all at 0.5 kg a.i./ha) and permethrin (0.1 kg a.i./ha) were most effective in controlling the larvae of *E. vigintioctopunciaia* at 10 days after first spray.

Lwao and Mizuta (1995) carried out a field trials in Swaziland in 1982-84 on the effect of insecticides against Ootheca spp. and *E. dodecastigma* on 3 cowpea cultivars. Insecticides tested were dichlorovos, cypermethrin and monocrotophos. Cypermethrin reduced the number of Ootheca spp. and *E. dodecastigma* by 58% and 39% respectively and monocrotophos reduced the number by 28% and 14%.

Amitava *et al.*, (2002) conducted an experiment where insecticidal sprays of 0.025% quinalphos, 0.05% fenitrothion, 0.05% dichlorvos, 0.05% malathion and 2% carbaryl, and dusts of 10% carbaryl, 5% malathion, 5% mtrichlorfon, 2% fenitrothion, 0.65% lindane and 2% methyl parathion were tested for the control of *E. dodecastigma* on watermelons in Rajasthan, India, in 1983. The carbaryl spray gave the best control, followed by 0.05% malathion and 0.05% dichlorvos. The 10% carbaryl dust also gave good control.

El-Defrawi (1987) conducted an experiment where adult males of *E. dodecastigma* were fed on leaves of Luffa cylindrica that had been soaked for 15 min in water containing 0.05% carbaryl and fenthion. Carbaryl was found more effective to control *E. dodecastigma*.

2.8 Thrips

Common name: Thrips

Scientific name: *Thrips palmi*

2.8.1 Systematic position of Thrips (*Thrips palmi)*

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Thysanoptera

Family: Thripidae

Genus: *Thrips*

Species: *palmi*

(Jones and David, 1995).

2.8.2 Distribution

The Thrips is widely distributed in South, South-East and East Asia in the South Pacific Islands and Australia. Earlier reports listed specific countries of incidence. But recently, the insect is distributed in Bangladesh, India, Pakistan, Sri-Lanka, Nepal, Cambodia, Vietnam, Thailand, China, Taiwan, Malaysia, Singapore, Indonesia, Philippines, Korea, Hong Kong, Japan, Australia and on many Island of South East Asia, Micronesia and Melanesia like Caroline and Mariana Island, Fiji, Papua New Guinea and Solomon Islands. The insect is found mainly on rice throughout the year except in Japan and Korea where it migrates in the summer (Alam *et al*., 2002).

2.8.3 Biology

The rate at which thrips move through their developmental cycles is highly dependent upon environmental conditions, including the temperature and nutrient quality of their food sources. Thrips begin their lives as eggs. These are extremely small (about 0.2 mm long) and kidney-shaped. Hatching may take from as little as a day to several weeks. The females of the suborder Terebrantia are equipped with an ovipositor, which they use to cut slits in plant tissue and then insert their eggs, one per slit. Females of the suborder Tubulifera lack an ovipositor and lay their eggs singly or in small groups on the outside surfaces of plants. Thrips then pass through two wingless instars of nymph (Kidiavai *et al*., 2009).

2.8.4 Nature of damage

If population is high leaves may be distorted; leaves are covered in coarse stippling and may appear silvery; leaves speckled with black feces; insect is small (1.5 mm) and slender and best viewed using a hand lens; adult thrips are pale yellow to light brown and the nymphs are smaller and lighter in color (Cardona *et al*., 2009).

2.8.5 Control Measures

Avoid planting next to onions, garlic or cereals where very large numbers of thrips can build up; use reflective mulches early in growing season to deter thrips; apply appropriate insecticide if thrips become problematic (Jones and David, 1995).

Avoid planting next to onions, garlic or cereals where very large numbers of thrips can build up; use reflective mulches early in growing season to deter thrips; apply appropriate insecticide if thrips become problematic (Drost, 2010).

2.9 Pea pod borer (*Maruca testulalis*)

Common name: Pea pod borer

Scientific name: *Maruca testulalis*

2.9.1 Systematic position of Pod borer:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Pyralidaes

Genus: *Maruca*

Species: *testulalis*

(Das and Islam, 1985).

2.9.2 Distribution

The legume pod borer, *M. vitrata*, is a serious pest ofgrain legumes in the tropics and sub-tropics because ofits extensive host range, and destructiveness. It is widely distributed in Asia, Africa, Australia, and the Americas. Its recorded distribution stretches from the Cape Verde Islands in West Africa to Fiji and Samoa in the Pacific, and also includes the West Indies and the Americas(Sharma, 1998). It is a serious pest ofpea in India and Thailand (Buranapanichpan and Napompeth, 1982), Bangladesh (Das and Islam, 1985), Sri Lanka (Fellows *et al.*, 1977), and Pakistan (Ahmed *et al.*, 1987). It has also been recorded as a pest of-pea in Australia (Sharma, in press), eastern Africa (Nyiira, 1971), and West Africa (Taylor, 1978).

2.9.3 Biology

Egg: The studies on site of egg laying indicated that the most of the eggs were laid on the flower buds and flower surface or inner surface of glass jar. The freshly laid eggs were pale yellowish white, scale like with reticulated markings on the chorion. The eggs were usually laid singly or in overlapping groups. The length and breadth of freshly laid egg ranged from 0.54 to 0.60 mm with an average of 0.58 mm, while the breadth of egg measured from 0.35 to 0.4 mm with an average of 0.38 mm. The results also revealed that the incubation period varied from 2 to 4 days with an average of 3.24 days and hatching percentage was on an average of 81.69. More or less, similar observations were also made by Vishakantaiah and Jagadesh Babu (1980), Ramasubramanian and Babu (1988) and Pachani (2000).

Larva:

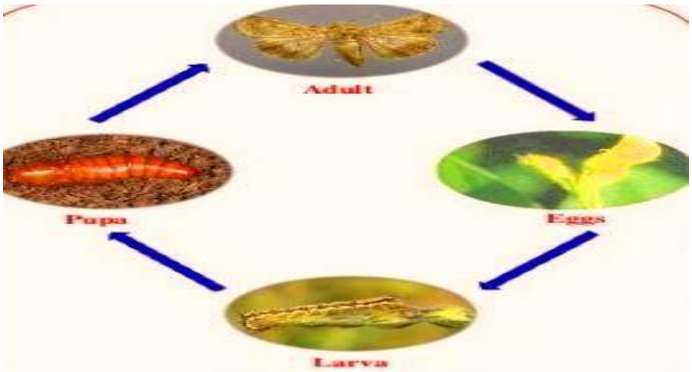
The present study showed that *M. testulalis* passed through the five different larval instars. Similar numbers of larval instars were also reported by Vishakantaiah and Babu (1980), Ramasubramanian and Babu (1988) and Pachani (2000). It is evident from the data that the total larval period of *M. testulalis* varied from 12 to 15 days with an average of 14.04 days. More or less similar observations were also reported by Vishakantaiah and Babu (1980), Ramasubramanian and Babu (1989) and Pachani (2000). Slight variation in the total larval period might be due to host plants on which larva was reared and prevailing laboratory abiotic factors.

Pupal stage:

Pupation took place on plant, inner side of damaged pods or some times on rearing containers under the laboratory conditions. The pupa was brown in colour and gradually turned darker before the adult emergence. It measured from 12.3 to 12.7 mm with an average of 12.53 mm in length and 2.8 to 3.3 mm with an average of 3.11 mm in breadth . The pupal period varied from 8 to 13 days with an average of 10.84 days. More or less, similar observations were also reported by Ogunwolu, 1990. Some variation in pupal period might be due effects of host plant and prevailing laboratory conditions.

Adult:

The adult moth had medium brown wings and creamy white to brown body with long legs. Forewings were small with semitransparent bands and the hind-wings were silver white with brown spots at the apical margin across the wings. Male and female moths could be clearly distinguished by the abdominal shape. In male, abdomen was tapered towards the end and the tip of female abdomen was long, slightly bulged and provided with two openings. Perusal of the data in Table 1 revealed that the percentage of adult emergence was on an average 72.27 and longevity of male adult varied from 4.0 to 8.0 days with an average of 6.24 days, while that of female adult varied from 7.0 to 10.0 days with an average of 8.06 days. Thus, it can be concluded that male adult survived less than female one. Almost similar conclusion was also drawn by Ramasubramanian and Babu (1988), Pachani (2000) and Sun XingQuan *et al.* (2005).



Source: (Ogunwolu, 1990).

2.9.4 Nature of damage

The importance of *M. vitrata* as a pest on grain legumes results from its early establishment on the crop. The larvae web the leaves and inflo-rescence, and feed inside on flowers, flower buds, and pods. This typical feeding habit protects the larvae from natural enemies and other adverse factors, including insecticides. The flower bud stage is preferred most for oviposition, and it is at this stage that the young larvae cause substantial damage, and reduce the crop potential for flowering and fruit setting. The young larvae bore into the flower buds, and cause flower shedding by destroying the young flower parts enclosed in the sepals. The successful establishment of this pest at the flower bud stage is significant in relation to subsequent damage, reduction in grain yield, and efficiency of control. Young larvae feed on the style, stigma, anther filaments, and ovary; besides a limited feeding on the internal components of the corolla. Little or no feeding has been observed on the anthers (Sharma, 2004). At this stage the damage is largely internal and there is little or no sign of damage externally. Usually more than one larva is present in each flower. These subsequently disperse to other flowers and flower buds on the same or other adjoining peduncles. The larval movement is facilitated by the silken threads, which are used as bridges between flowers. After initial dispersal, larval development is completed on several flowers /pods. The larvae move from one flower to another as they are consumed, and a larva may consume 4-6 flowers before larval development is completed. Third to fifth-instars larvae were capableofboring into the pods and consuming the developing grains (Karel and Schoohoven, 1986). The moths and larvae of *M. vitrata* are nocturnal (Usua and Singh, 1979). The larvae, which are photo-negative, emerge early in the evening and feed on the plant throughout the night. In dual-choice assays, the third-instar larvae preferred pods rather than flowers or young leaves, and flowers rather than leaves (Sharma, in press). First-instar larvae showed a strong preference for flowers over pods and leaves.

2.9.5 Yield loss due to Pod borer

Losses in grain yield of 20 to 60% due to Marc damage in grain legumes have been estimated by Singh and Allen (1980). In Bangladesh, pod borer damage has been estimated to be 54.4% during harvest in Pea, but yield loss was <20% (Ohno and Alam, 1989). In Nigeria, loss in pea grain yield has been estimated to be 72% in 1985 and 48% in 1986, and the economic threshold is nearly 40% larval infestation in flowers (Ogunwolu, 1990).

In Pea, losses due *to M. vitrata* have been estimated to be $US 30 million annually (ICRISAT, 1992).

Patel and Singh (1977) re-ported an average of 1.2 larvae per plant, which caused 10% damage to the fruiting bodies, and the pod damage varied from 25 to 40%.

Nyiira (1971) observed between 9 and 51% infestation at Banga-lore, Karnataka. Patnaik *et al*. (1986) reported 8.2 to 15.9% pod damage, resulting in 3.7 to 8.9% loss in grain yield in Orissa. In Sri Lanka, the pod borer has been reported to cause up to 84% damage in pea (Dharmasena *et al*., 1992, Dharmasena, 1993).

In plants of pea cultivar ICPL 88007, infested with 0, 2, 4, 8, and 16 larvae per plant at the podding stage, there was a progressive increase in pod damage with an increase in insect density (Sharma, in press). Pod damage varied from 12.4 to 71.2%. There was no apparent effect on flower drop with an increase in insect density. With 8 larvae per plant, the loss in grain yield was estimated as 51.75%, and with 16 larvae per plant it was 66.67%.

2.2.7.6 Control Measures

2.9.6.1 Natural enemies

Several parasites and predators have been recorded on *M. vitrata* by Agyen-Sampong (1978), Barrion *et al.* (1987), Usua and Singh (1977), Okeyo-Ow uor *et al*. (1991), ICRISAT (1978, 1981), Subasinghe and Fellow (1978), and Odindo *et al.* (1989); and summarized by Sharma (1998). Parasites recorded on larvae/pupa include tachinids [*Aplomya metallica* (Wiedemann), *Exorista xanthaspis* (Wiedemann), *Palexorista solennis* (Walker), *Peirbaea orbata* (Wiedemann), *Zygobothria atropivora* (Robineau- Desvoidy), *Zygobothria ciliate* (Wulp), *Thelairosom asp, Pseudoperichaetalaevis* (Villeneuve), *Pseudaperichaeta sp,* and *Thecocarcelia incedens* (Rondani)], braconids (*Apanteles teragamae* Vierek, *A pantelessp, Bracong reeni* Ashmead, *Bracon sp, Braunsia sp, Cardiochiles philippinensis* Ashmead, *Chelonussp, Snellenius manila* Ashmead, *Phanerotoma handecasisella* Cameron, and *Phanerotoma sp*), chalcidids (*Antrocephalus sp* nr *subelongatus* Kohl, *Antrocephalus sp,* and *Brachymeria sp*), eulophids (*Nesolynx thymus*), *Tetrastichus sesam*iae Risbec, and *Tetrastichus sp*), ichneumonids (*Caenopimpla arealis)*, *Charops nigrita* Gupta and Maheswary, *Meloborissinicus* (Holmgren), and *Metopius rufus browni* (Ashmead) pteromalids (*Trichomalopsis s),* scelionids (*Telenomus sp*), mites (*Dinothrombius sp*), nematodes, protozoa (*Mettesia sp*, *Nosemamarucae sp* and *Nosema sp*), and bacteria *(Bacil-lus sp* and *Clostridium sp*). Predators include derm apterans (*Diaperastichus erythrocephala* Olivier), mantids (*Polyspilota sp* and *Spodromantis sp*), carabids (*Chlaenius sp)* and *Cicindela lacrymosa* (Fabri- cius), coccinellids (*Coccinella repanda* (Thunberg), M*enochilus sexmaculatus* (Fabricius), and *Synharmonia octomaculata* (Fabricius), anthocorids (*Orius tantillus Motschulsky*), formicids (*Camponotus sericeus Fabricius* and *Camponotus rufoglaucus*). Ohno and Alam (1989) carried out key-factor analysis of *M. vitrata* populations in Kenya. The total mortality from egg to adult stage was nearly 98 to 99%, and highest mortality occurred between the egg stage and the third instar larvae, while the fourth-instar larvae suffered lowest mortality. The causes ofmortality were disappearance, followed by disease. Parasitism contributed minimally to *M. vitrata* mortality. There was no correlation between population density and mortality at the same stage (Okeyo-Owuor *et al.,* 1991). A pupal endoparasitoid, Antrocephalus sp, was the predominant natural enemy, while *Nosema sp* and *Bacillus sp* caused the highest natural mortality. Parasitoids and pathogens contributed 40.7% to the total generation mortality (K) at site 1 and 35.6% at site 2. Parasitism only contributed 3.3% ofthe total generation mortality at site 1 and 3.8% at site 2. Mortality due to disappearance, which also included predation, accounted for 59.4 and 64.8% of K at the respective sites. Life table data and survival curves for the pest revealed high generation mortality (about 98%), most of which occurred in the early life stages of the pest. The results suggested a high potential for utilizing bio-control agents for the management of this pest. Information on the role of various natural enemies in regulating the legume pod borer populations is scanty or unavailable. Published information indicates that parasitoid contribution to the total natural mortality is very low. Pathogens seem to play a major role in the control of pod borer populations under field conditions. This area of research needs to be pursued in future to exploit natural enemies for the management of this pest.

2.9.6.2 Cultural control

Pod borer populations tended to build up over the season, and the pod borer infestation increased on the late sown crops (Alghali, 1993). Grain yield also decreased in late-sown crops. Simultaneous sowings of maize and pea increased pod borer infestation in pea (Ezueh and Taylor, 1984), whereas sowing pea 12 weeks after maize reduced the legume pod borer damage. Pod borer damage in monocrops was greater than the maize-pea-sorghum inter or mixed crops (Amoako-Atta and Omolo, 1982, Omolo *et al.*, 1993). Pod borer incidence was significantly lower in intercropped, and at higher plant populations than in pure stands, and in lower plant populations of common bean, Phaseolus vulgaris (Karel, 1993). Flower and pod damage was significantly lower in an intercrop combination of one third bean two thirds pea. However, Alghali (1993), and Patnaik *et al.* (1989) reported no effect of intercropping on *M. vitrata* damage. Pea weeded 2, 3, or 4 times had less flower infestation by *M. vitrata* than the non weeded plots (Ofuya, 1989). However, effects of weeding frequency on pod damage by *M. vitrata* are not consistent.

2.9.6.3 Chemical control

Effective control of the pod borer on pea has been achieved with endosulfan (applied at 35 DAS twice at weekly intervals) (Jackai, 1983); one spray of cypermethrin, biphenthrin, cyhalothrin, and in combination with dimethoate (Amatobi, 1994); a mixture of cypermethrin + dimethoate using an Electrodyn sprayer (Jackai *et al.* 1987); or two applications of cypermethrin + dimethoate at 10 day intervals (beginning at bud formation) (Amatobi, 1995). Atachi and Sourokou (1989) reported that a sequence of deltamethrin-dimethoate - deltamethrin sprays resulted in the highest grain yield (1.37 t ha-1). Spray regimes which terminated early of fered better protection against the pod borer, but were inadequate for controlling sucking insects. Calendar-based sprays resulted in less borer infestation than when sprays were based on economic thresh-olds (Afun *et al.*, 1991). However, differences in grain yield between the calendar-based sprays and those based on economic thresholds were not significant. Crop monitoring reduced the number of sprays by half compared with those based on calendar schedules. Decamethrin, cypermethrin, and fluvalinate caused the highest mortality of the legume pod borer larvae three days after spraying under laboratory conditions (Bhalani and Prasana, 1987). Plots sprayed with synthetic pyrethroids, except fen valerate at 0.01%, showed least damage to the pods at harvest. Significantly greater grain yield was recorded in plots treated with fluvalinate, followed by those treated with cypermethrin, decamethrin, and fenvalerate at higher dosages. Samolo and Patnaik (1986) reported that of the six insecticides tested, monocrotophos and endosulfan (0.5 kg g a.i. ha-1) were most effective, and three applications ofendosulfan starting at flower initiation (at 20 days interval) were most effective. Foliar application of cypermethrin (0.008%) or dimethoate (0.07%) at flowering or when egg numbers reached 2 per meter row, and then repeated at 10-15 days interval provided effective protection against *M. vitrata* (Rahman, 1991). Cypermethrin (75 g a.i. ha-1) sprayed three times, has been found to be effective against pod borers, followed by decamethrin (12.5 g a.i. ha-1), fenvalerate (150 g g a.i. ha-1), and endosulfan (400 g a.i ha-1) (Okeyo-Owuor *et al.,* 1991).

The latter showed the highest cost-benefit ratio. Sprays of 0.07% traizophos or endosulfan, and 0.04% monocrotophos resulted in maximum reduction in pod borerdamage (Sundara Babu and Rajasekaran, 1984). Dust formulations of phoxim, endosulfan, and phosalone (4%) also gave effective control of the pea pod borer. Venkaria and Vyas (1985) reported that the least number of pods were damaged in plots treated with fenvalerate (0.01%), endosulfan (0.07%)+ miraculan (a plant growth stimulant), followed by those treated with fenvalerate (0.01%), endosulfan (0.07%) + miraculan, and mono-crotophos (0.04%). Thiodicarb (613 ppm) and ethofenprox (125 ppm) were as effective as methamidophos (200 ppm) for the control of legume pod borer on pea in Sri Lanka (Dharmasena, 1993). Insecticide application increased the grain yield by 28%. Thiodicarb sprays resulted in maximum increase (43%) in grain yield over two seasons. Four sprays of cypermethrin 0.008% (1st spray at initiation of flowering, 2nd spray at 50% flowering, 3rd spray at 100% flowering, and 4th spray at 100% pod setting) were effective for protecting the pea crop against Maruca (Rahman and Rahman, 1988). This schedule also offered the highest benefit-cost ratio (6.23). Dimethoate was not as effective as cypermethrin. The number of flowers, pods, and seeds per plant was significantly greater in plots treated with insecticides based on the eco-nomic threshold level of 10 larvae per 100 flowers (3 insecticide applications) than in the untreated plots. The differences in the number of flowers, pods, and seeds per plant were not significant between plots sprayed 3 and 4 times. It has been concluded that 10 larvae per 100 flowers can be considered as a tentative threshold for *M. vitrata* on pea (Dharmasena *et al.,* 1992).

2.9.6.4 Natural/biopesticides

Bacillus thuringiensis (Bt) (Karel and Schoohoven, 1986) and neem seed powder and neem kernel extract (Singh *et al.*, 1985, Jackai *et al.*, 1992) are effective against legume pod borer. Flower infestation was not influenced by 5 and 10% neem leaf extracts in Pea, except in 1994 (Bottenberg and Singh, 1996). Neem leaf extract applied four times on Cv 715 resulted in less pod borer damage than on Cv 941. Neem application reduced pod damage by 12% in Cv 715, and by 16% in Cv 941. In Pea, trials conducted to assess the utility of *Maruca* resistant cultivars for managing this pest revealed that pod borer-resistant lines can reduce the number of insecticide sprays at least by one under certain conditions (Saxena *et al*., 1998).

2.10 Role of ladybird beetle for controlling insect pest

The ladybird beetle belongs to the family Coccinellidae of order Coleoptera. The members of the family are exclusively predator on aphids, mealybugs, scale-insects, whiteflies, thrips, leafhoppers, mites and other small soft bodied insect pests (Stoll, 1992). It is known to prey on about 39 Arthropod species (Hagedorn, 1973). The family Coccinellidae comprises 5,200 described species worldwide (Nair, 1983). Karim (1993) have reported 31 species of Lady beetles.

Common name: Lady bird beetle

Scientific name: *Micraspis discolor*

2.10.1 Systematic position of lady bird beetle

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Superfamily: Cucujoidea

Family: Coccinellidae

Subfamilies: Aleurodicinae, Aleyrodinae, Udamoselinae

Genus: *Micraspis*

Species: *Discolor*

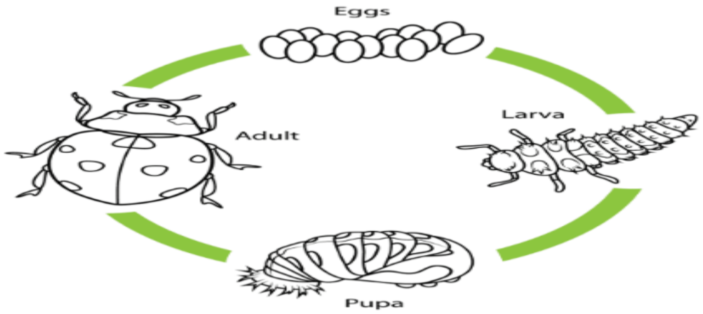
(Solanki, 1998).

2.10.2 Distribution

M. discolor is distributed in different areas of India, Bangladesh, Taiwan, Malaysia, Thailand, Indonesia, Philippines, China, Japan (including Ryukyu Islands) Myanmar, Pakistan and Sri-Lanka (Nair, 1986). *M.* spp. were also recorded in Sydney, Australia (Solanki, 1998).

2.10.3 Biology

Ladybugs live about a year and a few months, and they undergo complete metamorphosis, meaning they look completely different when they are young from when they are adults. The eggs are cone shaped, usually yellowish to orangish, and laid on sticks or leaves near a food source (other bugs). There can be anywhere from 10-50 eggs. When the eggs hatch the young larvae are really weird looking, nothing like the cute little ladybugs we all know and love. In fact, most people would see them in the garden and not know they were baby ladybugs. They are somewhat "alligator shaped" and covered in bristles. As the larvae grow they must shed their exoskeletons (outer cuticle), or molt, much like caterpillars. They molt through four instars, or larval stages before they pupate. Eventually the adult emerges, but its shell is soft, and it's vulnerable to predation until it hardens (Stoll, 1992).



Source: (Stoll, 1992)

2.10.4 Nature of Ladybird beetle as a Natural Enemies

The ladybird beetle belongs to the family Coccinellidae of order Coleoptera. The members of the family are exclusively predator on aphids, mealybugs, scale-insects, whiteflies, thrips, leafhoppers, mites and other small soft bodied insect pests (Aliero, 2003). It is known to prey on about 39 Arthropod species Alam *et al.* (1947). The family Coccinellidae comprises 5,200 described species worldwide (Chi *et al.*, 2003). Fukuda (1996) have reported 31 species of Lady beetles.

Ladybird beetle (*Coccinellidae*) is the most important aphid predator. In addition, parasitic wasps (parasitoids) are often involved in the control of aphid populations. Parasitised aphids can be easily recognised. They turn brown and hard and remain stuck to the plant surface.Natural aphid enemies usually appear with a certain delay because they react to the presence of aphids.

Ahmed (1995) conducted an experiment with seven-spotted ladybird beetle *Coccinella septempunctata* L. a natural enemy of aphids, had been reared on natural and alternative artificial foods. Both larvae and adults of *C. septempunctata* fed on aphid and artificial diet, the predator normally completed its development from egg to adulthood in 20.6 days on aphid prey, in contrast to 29.0 days, when fed on artificial diet. These results indicated that artificial diet containing important ingredients for adults and larvae of *C. septempunctata* can serve as substitute food for the coccinellids, and reproduction nevertheless can occur in the absence of preferred insect prey.

Karim (1993) conducted a laboratory experiment to determine the feeding potential of *C. septempunctata*, *Menochilus sexmaculatus*, *Cheilomenes sexmaculata*, and *Brumoides suturalis* on some insect and they reported that the adult of *C. septempunctata* consumed more larvae.

Kumar and Kairon (1990) reported that among the natural enemies' coccinellids are the best known beneficial predatory insects. Coccinellids are commonly known as ladybird, lady beetles or lady bugs. Lady bird belongs to the family Coccinellidae and order Coleoptera. About 6000 species of ladybird beetles found all over the world.

Nair (1983) reported that ladybird beetles generally considered as useful insects as many species feed on soft bodied insects like aphids, jassids, psyllids, whiteflies, scale insects, mealy bugs, insect eggs, small larvae and phytophagus mites which are injurious to agricultural crops and forest plantations.

The success of capturing prey of ladybird beetle depends on abiotic and biotic factor such as plant structure, species of aphid attacked, the predator, in its particular age, level of hunger and genetic characteristics, intra and inter specific competition (Hagedorn, 1973).

Walker and Hare (1943) reported that the predacious coccinellid beetles, commonly known as lady bird beetles are considered to be of great economic importance in the agro-ecosystem. They have been successfully employed in the bio-control to many injurious insects.

Singh (1980) reported that, in the field pea aphid population is naturally controlled to a large extent by its predator, *Coccinella septempunctata* and plays a vital role in lowering the population of pea aphid in the field.

Singh *et al*. (1985) studied relative abundance of the effective natural enemies of pea aphid *L. erysimi*, in farmers' fields; the *C. septempunctata* was the highest (41.97%) occurring species. All the natural enemies showed increasing trend till harvest of the crop, whereas, the coccinellids occupied a major share with maximum relative abundance of *C. septempunctata*.

Controlling ants feeding on honeydew produced by aphids. They disturb natural enemies giving protection to the aphids. Ploughing and flooding the field destroy ant colonies and expose eggs and larvae to predators and sunlight (Karim, 1987).

2.11 Field ant (*Onthophagus taurus*)

Common name: Field ant

Scientific name: *Onthophagus taurus*

2.11.1 Systematic position of Field ant

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hymenoptera

Family: Formicidae

Genus: *Onthophagus*

Species: *taurus*

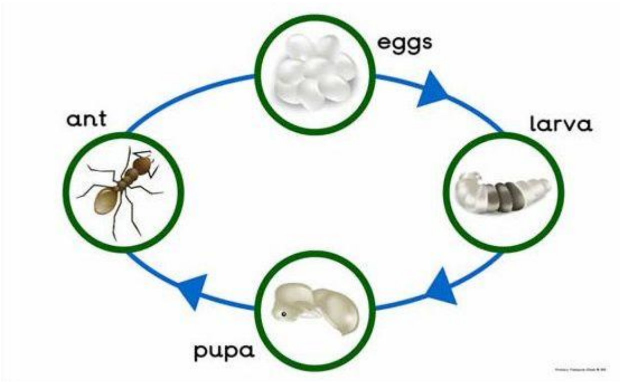
(Perrichot *et al.*, 2007).

2.11.2 Distribution

on the basis of the fossil record it is highly probable that crown group ants had originated by the late Albian (~100 mya) and they were certainly present before the Turonian (90 mya). There is considerable diversity of body form among putative crown group ants from this period. Stem ants (sphecomyrmines, armanines) are known from contemporaneous deposits. The earliest records of both groups are from the northern hemisphere (France, Myanmar), with the later appearances in eastern North America and southern Africa. This suggests that ants originated and diversified in Laurasia, before dispersing to other regions (Perrichot *et al*., 2007).

2.11.3 Biology

Ants belong to the insect order Hymenoptera, which also includesthe wasps and bees. Ants are distinguished from many of their nearest relatives by two characteristics: a narrow "waist" (the slender free-moving portion of the abdomen called a pedicel) and elbowed antennae. Ants also differ from most other insects in that they are social, similar to termites and certain bees and wasps. This means that ants live in large cooperative groups called colonies. Two or more generations overlap in the colony; adults take care of the young and are divided into castes, specialized groups that take care of certain tasks. Ants have reproductive castes, the queens and males, and non reproductive castes, the workers (Bennet *et al*., 2003).



Source: (Bennet *et al*., 2003)

2.11.4 Activity

They are large (3/8" long) and dark brown to black. They are often confused with the carpenter ant, but can be distinguished by an uneven thorax (see ant identification chart at the end of this module) (Bennet *et al.*, 2003). Field ants feed on other insects as well as insect honeydew. They cause concern because they usually nest near structures and are often mistaken for carpenter ants. Nests are often made in grassy areas and can be difficult to see because they are low to the ground. Field ants will also nest in leaf litter or mulch that is more than two inches thick, and can live under stones, firewood, or other debris that might be found in a lawn area. If pesticide drenches of mounds are used to manage this insect it should be remembered that they will be slow to act because it often takes foraging ants days to return to the nest (Williams and Vail, 1994).

Most outdoor ants increase in population and activity from spring into summer months and then decline from fall into early winter as the temperature drops and the ants' natural food supplies dwindle. Knowing the food habits of the particular ant species is important in ant management because it may enable the location and elimination of the food that is attracting the ants to the site, it can help to locate foraging trails to track the ants back to their nest, and it can help to choose an effective bait (Ebeling, 1975).

Food preferences of ant are often seasonal. When the queen is actively laying eggs, worker ants typically gather protein- based foods for the queen. At other times they may ignore protein foods completely and restrict their foraging to sugars and greases. Many ants obtain sugar by feeding on honeydew, a sweet substance secreted by aphids and other plant-sucking insects. They often defend these insects from predators and tend them as if they were their personal food supply (Hedges, 1991).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh during November, 2014- March, 2015 to evaluate incidence of insect pest complex of BARI Motor-1 *(Pisum sativum* ssp.) and their management. A brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, data collection and analysis of different parameters has been given under the following headings.

3.1 Location

The experiment was carried out in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site was $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude and an elevation of 8.2 m from sea level (FAO, 1988) presented in Appendix I.

3.2 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract (FAO, 1988) under AEZ No. 28 presented in Appendix I and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon . The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka and presented in Appendix III.

3.3 Weather condition of the experimental site

The climatic condition of experimental site was under the subtropical climate, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. Details of the meteorological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from the Bangladesh Meteorological Department, Dhaka and presented in Appendix II.

3.4 Planting materials

BARI Mator-1 was used as planting material in the experiment. The seeds were collected from Bangladesh Agricultural Research Institute, Joydevpur, Gazipur, and Dhaka, Bangladesh.

3.5 Land preparation

The land was first opened on 8^{th} November, 2014 with a power tiller. Final land preparation was done on 10^{th} November, 2014. The land was thorough prepared by four ploughing and cross-ploughing with tractor and rotavator. Weeds, stubbles and crop residues were removed to make the land clean. Final layout was done on 12^{th} November, 2014 according to design adopted. Finally, individual plot was prepared by using spade before sowing of seeds and plot to plot distance was 50cm and plot size was 3m X 3m.

3.6 Application of fertilizers

During land preparation: The plots were fertilized with TSP, MP, B, and ZnSO4 at the rate of 8, 4, 1 and 1 kg/bigah respectively (BARI, 2013).

During vegetative growth: The plots were fertilized with Urea at the rate of 1 kg/bigah.

3.7 Sowing of seeds

Seeds were sown on 15^{th} November, 2014 in line sowing method. The seed rate was 8.0 kg/bigah. There was 30 cm row to row spacing and 10cm plant to plant distance.

3.8 Treatment combination for management practices

Treatment combinations of this experiment were as follows:

T_1= Mechanical and Cultural practices at the 7 days interval

T_2= Mechanical control and spraying Ripcord 10 EC @ 1.0 ml/L of water at the 7 days interval

T_3= Spraying Suntaf 50 SP @ 1.5 g/L of water at the 7 days interval

T_4= Spraying Topgan10 EC @ 1.0 ml/L of water at the 7 days interval

T_5= Untreated control

3.9 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The treatments were randomly allotted in each block. The unit plot size was 3.0m × 3.0m with a distance of 50 cm between the plot to plot, 50 cm between the row to row and 30cm between the line to line.

Plate 01: Experimental Field during the study period

3.10 Intercultural operations

Weeding: Each plot was weeded three times on 15, 30 and 45 days after sowing (DAS). Thinning was also done simultaneously. The final thinning of BARI Mator-1 was done to maintain a plant to plant distance approximately 10 cm.

Irrigation: The experimental field was also irrigated during properly.

3.11 Management Practices:

Chemical control: The plots $T_{2,}$ $T_{3,}$ and $T_{4,}$ were sprayed with Ripcord 10 EC @ 1.0 ml/L of water, Suntaf 50 SP @ 1.5 g/L of water and Topgan10 EC @ 1.0 ml/L of water respectively through knapsack sprayer at 7 days interval.

Collection of data

The parameters were considered during data collection as follows:

1) Number of insects per 10 plants in each plot
2) Number of infested flowers per 10 plants in each plot
3) Number healthy flowers per 10 plants in each plot
4) Number of infested fruits or pods per 10 plants in each plot
5) Number of healthy fruits or pods per 10 plants in each plot
6) Yield per plot
7) Total yield in the experimental plot

Harvesting date: Mature pods were harvested at 02.03.2015.

Statistical analysis of data:

The collected data were analyzed statistically. Analysis of variance (ANOVA) and Least Significant Difference (LSD) test were done to find out the significant difference among the treatment means. The experimental data were analyzed by MSTAT-C software. Mean comparisons for treatment parameters were compared using Duncan's Multiple Range Test at 5% level of significance (Gomez and Gomez, 1984).

A

B

C

Plate 02. Healthy flower **(A),** Healthy Pod **(B)** and Healthy Pod with seeds **(C)**

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted in the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from November, 2014 to March, 2015 to study the incidence of insect pest complex of BARI motor -1 and their management. The results on different parameters have been interpreted, discussed and presented under the following sub headings.

4.1. Occurrence of insect pests in the field of selected BARI motor-1 varieties: During the study period of November, 2014 to March, 2015 the occurrence of difference insects were recorded in the field of BARI motor -1. Significant population of insect pests viz., Whitefly, Aphid, Thrips, Epilachna beetle, Grasshopper and Pod borer etc. were recorded (Table 1).

The occurrence of insect pests in the present study were recorded by observing the incidence of the respective insect pests and their nature of damage on BARI motor -1 during data recording time and identification of insects were made by visual observation with the help of field guidance by BARI (2013).

Table 1. List of insect pests and predators found in the field of BARI motor -1 during the study period

Sl. No.	Name of the insect pests and predators	Order & Family	Stage(g) of insects	Site of infestation	Nature of damage or activity
1	Whitefly (*Bemisia tabaci*)	Homoptera (Aleyrodidae)	Adult & nymph	Foliages	Feed by sucking the sap from the foliage
2	Aphid (*Acyrthosiphon pisum*)	Homoptera (Aphidae)	Adult & nymph	Tender leaves	Sucking cell sap from the tended leaves
3	Thrips (*Thrips palmi*)	Thysanuoptera (Thripidae)	Adult and nymph	Flowers and pods	Feed in growing points and inside flowers
4	Epilachna beetle, (*Epilachna dodecastigma*)	Coleoptera (Coccinellidae)	Adult and Larvae	Tender leaves	Feeds the young leaves
5	Grasshopper (*Oxya velox*)	Orthoptera (Acrididae)	Adult and nymph	Leaves	Feeds the leaves
6	Pod borer *(Maruca vitrata)*	Lepidoptera (Pyralidae)	Larvae	Flowers and developing pods	Feeds inside the flowers before moving to developing pods
7	Lady bird beetle (*Coccinelli septempanuctata*)	Coleoptera (Coccinellidae)	Adult and Larvae		Act as predator
8	Ant (*Onthophagus taurus*)	Hymenoptera (Formicidae)	Adult and Larvae		Act as predator

4.2. Effect of different management practices on abundance of major insect pests of BARI motor -1 during the study period

Insect population

Insect population (Whitefly, Aphid, Thrips, Epilachna beetle, Grasshopper, Pod borer and as a predator lady bird beetle & ant) from 10 selected plant/plot were observed with clean observation and in the experimental plot was counted and recorded (Table 2). For different treatment number of different insect pests varied significantly under the present trial.

4.2.1 Whitefly

In case of Whitefly, the highest number (5.00) of Whitefly per 10 selected plants was recorded from the treatment T_5 (untreated control), whereas the lowest number (1.20) was observed from the treatment T_2 (Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval) which was closely followed (3.27 and 4.47) by T_3 (Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval) and T_4 (Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval), respectively and these were statistically similar. Sepswardi (1976) reported that white fly cause 55% seedling loss of Motor *(Pisum sativum)* under favourable climatic conditions. Martin and Mound (2007) showed that the White fly *(Bemisia tabaci*), >4 insects per meter of row results in 25% lack of seed and *25%* yield reduction because as the plants were most susceptible at the beginning of fruit formation

4.2.2 Aphid

In consideration of aphid, the highest number (8.20) of aphid per 10 selected plants was recorded from the treatment T_5, which was followed by T_1 (3.07) treatment and these were statistically identical, while the lowest number (1.80) was observed from the treatment T_2 which was closely followed by T_3 (2.13). Singh and Taylor (1978) observed that during cultivation of cowpea the farmers faced a serious problem with bean aphid as it is one of the most destructive pests of worldwide. Walker and Snyder(1933) also reported, the bean aphid, *A. craccivora* Koch is the most serious pest of bean plants from seedling to pod bearing stage, causing considerable yield losses. Aphid causes damage directly by sucking cell sap of plant and indirectly by transmitting several vital diseases (Singh and Allen, 1980).

4.2.3 Thrips

For Thrips, the highest number (12.33) was recorded from the treatment T_5, which was statistically different from all other treatments, while the lowest number (1.47) was observed from the treatment T_1 which was closely followed by the treatment T_3 (2.07) and T_4 (2.13).

4.2.4 Epilachna beetle

In consideration of epilachna beetle, the highest number (6.07) of epilachna beetle was recorded from the treatment T_5, which was followed by T_1 (3.93) treatment and these were statistically identical, while the lowest number (2.80) was observed from the treatment T_3 and T_4 which was statistically similar (2.60) to T_2 treatment. the high incidence of the pest has been reported during temperature range of 24-31°C and relative humidity 58-75% RH in the field (Ramzan *et al*., 1981)

4.2.5 Grasshopper

The highest number of grasshopper (8.80) was recorded from the treatment T_5, which was followed (3.40) by T_1 Treatment and they were statistically identical, while the lowest number of grasshopper under the present trial (1.20) was found from the treatment T_2 which was statistically similar (2.07 and 2.20) at T_3 and T treatments.

4.2.6 Pod borer

In consideration of Pod borer, the highest number (9.07) of Pod borer was recorded from the treatment T_5, which was statistically different from all other treatments, whereas the lowest number of Pod borer (1.20) was observed from the treatment T_2 which was statistically similar (1.87 and 1.93) to T_3 and T_4.

4.2.7 Ladybird beetle

In case of Ladybird beetle, the highest number (7.80) of Lady bird beetle was recorded from the treatment T_5, which was statistically different from all other treatments, whereas the lowest number of Ladybird beetle (1.33) was observed from the treatment T_2 which was followed (2.07 and 2.20) to T_3 and T_4 and they were statistically similar.

4.2.8 Ant

Under the present trial, the highest number of ant (5.00) was recorded from the treatment T_5, which was statistically different from all other treatments, while the lowest number of ant (1.00) was found from the treatment T_2 which was statistically similar (1.07 and 1.20) at T_3 and T_4 treatments.

Table 2. Effect of different management practices on abundance of major insect pests and predators of BARI motor-1 during the study period

Treatments	Number of different insect pests/10 selected plants						Number of predators/10 selected plants	
	Whitefly	Aphids	Thrips	Epilachna beetle	Grasshopper	Pod borer	Lady bird beetle	Ant
T_1	5.20 b	3.07 b	4.20 b	3.93 b	3.40 b	2.33 b	4.40 b	2.13 b
T_2	1.20 d	1.80 d	1.47 c	2.60 c	1.20 d	1.20 c	1.33 d	1.00 c
T_3	3.27 c	2.13 cd	2.07 c	2.80 c	2.07 c	1.87 bc	2.07 c	1.07 c
T_4	4.47 b	2.33 c	2.13 c	2.80 c	2.20 c	1.93 bc	2.20 c	1.13 c
T_5	11.40 a	8.20 a	12.33 a	6.07 a	8.80 a	9.07 a	7.80 a	5.00 a
$LSD_{(0.05)}$	1.075	0.399	0.973	0.487	0.465	0.806	0.580	0.399
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	11.18	6.07	11.65	7.09	6.97	13.05	8.64	10.30

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

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

[T_1: Mechanical and Cultural practices at 7 days interval, T_2: Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval, T_3: Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval, T_4: Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval and T_5: Untreated control]

Table 3. Effect of different management practices on damage severity of leaves of BARI motor-1 by whitefly

Treatments	Healthy leaves/10 selected Plants (No.)	Infested leaves/10 selected Plants (No.)	Leaf infestation (%)	Leaf infestation reduction over control
T_1	63.67 bc	6.53 b	9.33 b	45.91
T_2	79.60 a	4.80 c	5.73 c	66.78
T_3	71.53 ab	5.60 bc	7.27 bc	57.86
T_4	68.47 bc	6.20 b	8.30 b	51.88
T_5	59.67 c	12.40 a	17.25 a	--
$LSD_{(0.05)}$	9.143	1.330	2.231	--
Level of significance	0.01	0.01	0.01	--
CV(%)	7.08	9.94	12.38	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

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

[T_1: Mechanical and Cultural practices at 7 days interval, T_2: Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval, T_3: Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval, T_4: Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval and T_5: Untreated control]

The above results indicated that Ripcord 10EC was the highly effective in protecting the BARI motor-1 leaves against White fly, while Suntaf 50SP was moderately effective. From these findings it was revealed that in case of healthy leaves per 5 plants, T_2 was best treatment with the number of healthy leaf (71.53) and lowest number of infested leaf (4.80). So T_2 performed as the best treatment with lowest leaf infestation (5.73%) and leaf infestation reduction over control (66.78) followed by T_3 with leaf infestation (7.27%) and leaf infestation reduction over control (57.86). As a result, the trend of results in terms of reducing the leaf infestation is T_2>T_3>T_4> T_1. Similar findings have also been reported by some researchers supporting the results of the present study. Prasad *et al.* (1984) observed higher percent reduction of reduction of leaf damage over control in White fly treated plants, which was recorded (80.67) and (76.89) percent during 1983 and 1984 respectively. The results obtained by

Rahman (2006) reported that chemical insecticides performed the best ensuring the lowest leaf infestation rendering reduction in leaf by number.

Table 4. Effect of different management practices on damage severity of leaves of BARI motor-1 by aphid

Treatments	Healthy leaves/10 selected Plants (No.)	Infested leaves/10 selected Plants (No.)	Leaf infestation (%)	Leaf infestation reduction over control
T_1	67.73 bc	5.27 b	7.24 b	40.61
T_2	78.87 a	3.93 c	4.76 c	60.95
T_3	72.67 ab	4.27 c	5.57 c	54.31
T_4	71.40 ab	4.47 c	5.91 c	51.52
T_5	61.40 c	8.53 a	12.19 a	--
$LSD_{(0.05)}$	9.156	0.753	1.273	--
Level of significance	0.05	0.01	0.01	--
CV(%)	6.91	7.56	9.47	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment and means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of probability

[T_1: Mechanical and Cultural practices at 7 days interval, T_2: Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval, T_3: Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval, T_4: Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval and T_5: Untreated control]

From the above findings it was revealed that the highest number of healthy leaves and lowest number of infested leaves were observed in T_2 in number of 78.87 and 3.93 respectively during the management of aphids followed by T_3 (72.67 and 4.27), T_4 (71.40 and 4.47) respectively. So T_2 performed as the best treatment with lowest leaf infestation (4.76 %) and leaf infestation reduction over control (60.95%) followed by T_3 and T_4 with lowest leaf infestation (5.57 % and 5.91%) and leaf infestation reduction over control (54.31and 51.52) respectively. As a result, the trend of results in terms of reducing the leaf infestation is T_2>T_3>T_4> T_1>T_5.

Table 5. Effect of different management practices on damage severity of leaves of BARI motor-1 by Epilachna beetle

Treatments	Healthy leaves/10 selected Plants (No.)	Infested leaves/10 selected Plants (No.)	Leaf infestation (%)	Leaf infestation reduction over control
T_1	78.60 a	7.07 b	8.28 b	44.62
T_2	84.40 a	4.80 c	5.39 c	63.95
T_3	75.00 ab	5.80 bc	7.23 b	51.64
T_4	75.27 ab	6.20 b	7.62 b	49.03
T_5	65.53 b	11.53 a	14.95 a	--
$LSD_{(0.05)}$	9.942	1.233	1.485	--
Level of significance	0.05	0.01	0.01	--
CV(%)	6.97	9.25	9.08	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment and means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of probability

[T_1: Mechanical and Cultural practices at 7 days interval, T_2: Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval, T_3: Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval, T_4: Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval and T_5: Untreated control]

From the above findings it was revealed that the highest number of healthy leaves and lowest number of infested leaves were observed in T_2 in number of 84.40 and 4.80 respectively during the management of epilachna beetle followed by T_1 (78.60 and 7.07), T_3 (75.00 and 5.80) and T_4 (75.27 and 6.20) respectively. So T_2 performed as the best treatment with lowest leaf infestation (5.39%) and leaf infestation reduction over control (63.95%) followed by T_1, T_4 and T_3 with lowest leaf infestation (7.23 %, 7.62% and 8.28%) and leaf infestation reduction over control (44.62, 49.03 and 51.64%) respectively. As a result, the trend of results in terms of reducing the leaf infestation is T_2>T_1>T_4> T_3>T_5.

Table 6. Effect of different management practices on damage severity of pods of BARI motor-1 at early pod development stage by pod borer

Treatments	Healthy pods/10 selected Plants (No.)	Infested pods /10 selected Plants (No.)	Pod infestation (%)	Pod infestation reduction over control
T_1	20.67 b	1.40 b	6.33 b	47.12
T_2	27.40 a	0.87 c	3.06 c	74.44
T_3	23.53 ab	1.40 b	5.60 b	53.22
T_4	22.40 b	1.33 bc	5.67 b	52.63
T_5	20.53 b	2.80 a	11.97 a	--
$LSD_{(0.05)}$	4.033	0.480	0.955	
Level of significance	0.05	0.01	0.01	
CV(%)	9.35	16.30	7.76	

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment and means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of probability

[T_1: Mechanical and Cultural practices at 7 days interval, T_2: Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval, T_3: Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval, T_4: Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval and T_5: Untreated control]

At early pod development stage, it was revealed from the above findings that the highest number of healthy pods and T_2 with the number of 27.40 which was statistically different from all other treatment, whereas lowest number of healthy pods were observed in T_5 (20.53) untreated control treatment which was statistically similar with T_1 treatment. Incase infestation, the lowest percent of pod infestation recorded from T_2 (0.87%) treatment which was closely followed by T_4 (1.33) treatment, while the highest percent of pod infestation recorded from T_5 (2.80%) and treatment. So T_2 treatment performed as the best treatment with pod infestation reduction over control (74.44), followed by T_3 and T_4 with pod infestation reduction over control (53.22 and 52.63) respectively. As a result, the trend of results in terms of lowest pod infestation is T_2>T_3>T_4> T_1>T_5.

Table 7. Effect of different management practices on damage severity of pods of BARI motor-1 at mid pod development stage by pod borer

Treatments	Healthy pods/10 selected Plants (No.)	Infested pods /10 selected Plants (No.)	Pod infestation (%)	Pod infestation reduction over control
T_1	28.53 b	2.60 b	8.39 b	38.98
T_2	39.67 a	1.73 c	4.23 d	69.24
T_3	37.13 a	2.53 b	6.39 c	53.53
T_4	29.07 b	2.33 b	7.44 bc	45.89
T_5	26.47 b	4.20 a	13.75 a	--
$LSD_{(0.05)}$	6.313	0.315	1.255	--
Level of significance	0.01	0.01	0.01	--
CV(%)	10.42	6.24	8.29	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment and means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of probability

[T_1: Mechanical and Cultural practices at 7 days interval, T_2: Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval, T_3: Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval, T_4: Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval and T_5: Untreated control]

The comparative effectiveness of various treatments on pod infestation by the pod borer has been evaluated in terms of percent (%) pod infestation as well as in percent (%) reduction in infestation over control is presented in Table 7 at mid pod development stage. Among the different treatments treated plots the percent pod infestation was the lowest (4.23%) in the plots treated with Mechanical control + Ripcord 10EC @ 1.0 ml//L of water at 7 days interval followed by Suntaf 50SP (6.39%) having statistically different. The highest percent pod infestation (13.75%) was recorded in the untreated control plots.

In terms of percent pod infestation reduction over control all insecticides reduced considerable amount of pod damage over control as shown in the table-7.The highest percent reduction of pod infestation (69.24%) was recorded in Mechanical control +

Ripcord 10EC treated plots followed by Suntaf 50SP (53.53%) treated plots during cropping season.

Table 8. Effect of different management practices on damage severity of pods of BARI motor-1 at late pod development stage by pod borer

Treatments	Healthy pods / 10 selected Plants (No.)	Infested pods/10 selected Plants (No.)	Pod infestation (%)	Pod infestation reduction over control
T_1	38.80 b	3.86 b	9.10 b	38.56
T_2	49.40 a	2.60 c	5.00 c	66.24
T_3	44.60 ab	3.47 b	7.23 bc	51.18
T_4	41.80 b	3.67 b	8.10 b	45.31
T_5	37.20 b	6.40 a	14.81 a	--
$LSD_{(0.05)}$	6.976	0.767	2.555	--
Level of significance	0.05	0.01	0.01	--
CV(%)	8.75	10.19	15.33	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment and means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of probability

[T_1: Mechanical and Cultural practices at 7 days interval, T_2: Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval, T_3: Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval, T_4: Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval and T_5: Untreated control]

At late pod development stage, the comparative effectiveness of various treatments on pod infestation by the pod borer has been evaluated in terms of percent (%) pod infestation as well as in percent (%) reduction in infestation over control is presented in Table 8. Among the different treatments treated plots the percent pod infestation was the lowest (5.00%) in the plots treated with Mechanical control + Ripcord 10EC @ 1.0 ml//L of water at 7 days interval followed by Suntaf 50SP (7.23%), Topgan 10EC (8.10%) and Mechanical and Cultural practices at 7 days interval (9.10%), having statistically different between them. The highest percent pod infestation (14.81%) was recorded in the untreated control plots.

In terms of percent pod infestation reduction over control all insecticides reduced considerable amount of pod damage over control as shown in the table-7.The highest percent reduction of pod infestation (66.24%) was recorded in Mechanical control + Ripcord 10EC treated plots followed by Suntaf 50SP (51.18%) treated plots during cropping season.

Table 9. Occurrence of ladybird beetle population during the management practices of insect pest complex on BARI motor-1

Treatments	Incidence of adult ladybird beetle(No./ 10 selected Plants)	% Reduction over control	Incidence of ant (No./ 10 selected Plants)	% Reduction over control
T_1	4.40 b	44.09	2.13 b	57.40
T_2	1.33 d	83.10	1.00 c	80.00
T_3	2.07 c	73.70	1.07 c	78.60
T_4	2.20 c	72.05	1.13 c	77.40
T_5	7.87 a	--	5.00 a	--
$LSD_{(0.05)}$	0.450	--	0.298	--
Level of significance	0.01	--	0.01	--
CV(%)	6.70	--	7.70	--

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment and means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of probability

[T_1: Mechanical and Cultural practices at 7 days interval, T_2: Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval, T_3: Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval, T_4: Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval and T_5: Untreated control]

From above table it was revealed that, significant variation were observed among different management practices in terms of adult ladybird beetle population during the management practices of insect pest complex on BARI motor -1 in the field (Table 10).The highest number of adult ladybird beetle and ant per plant were observed (7.87and 5.00 respectively) in the untreated plots followed by Mechanical and Cultural practices at 7 days interval (4.40 and 2.13) being statistically different. On the other hand, the lowest number of adult ladybird beetle and ant were observed in (1.33) was recorded in Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval treated plots (T_2) which are significantly different from all other treatments. In case of percent (%) reduction of adult lady bird beetle and ant over control due to application of different management practices against insect pest complex on BARI motor -1, the highest reduction of lady bird beetle and ant (83.10% and 80.00% respectively) were observed in Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval treated plots (T_2) followed by T_3 (73.70 and 78.60 %), T_4 (72.05 and 77.40 %) treated plots. As a result, the trend of reduction of adult lady bird beetle and ant population among different management practices was $T_2 > T_3 > T_4 > T_1 > T_5$.

Table 10. Effect of different management practices on yield contributing characters and yield of BARI motor-1

Treatments	Plant height (cm)	Number of pods/10 selected Plants	Number of seeds/pod	Weight of 100-seeds (g)	Yield (t/ha)
T_1	48.76 a	45.33 bc	4.93 b	15.65 bc	2.00 a
T_2	50.94 a	50.47 a	5.27 a	17.15 a	2.09 a
T_3	49.04 a	47.53 ab	5.07 ab	16.63 ab	2.02 a
T_4	49.67 a	48.47 ab	5.13 ab	16.22 abc	1.98 a
T_5	45.01 b	42.33 c	4.33 c	15.17 c	1.68 b
$LSD_{(0.05)}$	3.347	4.669	0.223	1.271	0.260
Level of significance	0.05	0.05	0.01	0.05	0.05
CV(%)	3.65	5.30	2.39	4.18	7.08

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment and means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of probability

[T_1: Mechanical and Cultural practices at 7 days interval, T_2: Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval, T_3: Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval, T_4: Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval and T_5: Untreated control]

In case plant highest, from the above findings (Table 10) it was revealed that the highest plant height was observed in T_2 with the value of 50.94 cm which was statistically similar with T_4 (49.67 cm), T_3(49.04 cm) and T_1 (48.76cm) respectively, whereas the lowest plant height was observed in untreated control treatment (45.01cm). In case of highest number of pods, T_2 performed as the best treatment with the highest number of pods (50.47) followed by T_4 (48.47) and T_3 (47.53) respectively. In case of number of seeds per pod was highest in T_2 (5.27) followed by T_4 (5.13) and T_3 (5.07). So T_2 performed as the best treatment with the highest yield (2.09 ton/ha) followed by T_3 (2.02 ton/ha) and T_1 (2.00 ton/ha). As a result, the trend of results in terms of highest yield (ton/ha) is $T_2>T_3>T_1>T_4>T_5$.

Table 11. Cost of BARI motor-1 production for different management practices in controlling insect pests

Treatments	Cost of pest Management (Tk.)	Yield (t/ha)	Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	Benefit cost ratio
T_1	23500	2.00	500000	476500	56500	2.40
T_2	26300	2.09	522500	496200	76200	2.90
T_3	24500	2.02	505000	480500	60500	2.47
T_4	24000	1.98	495000	471000	51000	2.13
T_5	0	1.68	420000	420000	0	

Price of motor shuti @ 25 Tk./kg

[T_1: Mechanical and Cultural practices at 7 days interval, T_2: Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval, T_3: Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval, T_4: Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval and T_5: Untreated control]

4.4 Cost analysis

Economic analysis of different management practices with or without insecticide for controlling insect pests of BARI motor-1 is presented in Table 11. In this study, the untreated control (T_5) did not require any pest management cost. But the cost was involved in mechanical control and Cultural practices at 7 days interval (T_1) for the removal of the infested leaf, flowers and fruits, weed etc. as well as for clean cultivation. The cost for the treatment involved insecticide and its application were incurred the cost for labor, insecticide and its application cost. Considering the controlling of insect pests of BARI motor-1 the highest benefit cost ratio (2.90) was recorded in the treatment T_2 (Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November, 2014 to March, 2015 to evaluate the efficacy of some management practices against insect pest complex of BARI motor-1. BARI motor-1 was used as the test crop in this experiment. The experiment comprised of the following control measure as treatment- T_1: Mechanical and Cultural practices at 7 days interval, T_2: Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval, T_3: Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval, T_4: Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval and T_5: Untreated control. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Data were recorded on pest incidence, number of healthy, infested plants & leaf for different pests and infestation level and also yield contributing characters and yield of BARI motor-1 and significant variations was observed for different treatments.

Under the present experiment the occurrence of difference insects were recorded during the study period in the field of BARI motor -1. Significant population of insect pests viz., Whitefly, Aphid, Thrips, Epilachna beetle, Grasshopper and Pod borer etc. and predatory insect ladybird beetle & and ant were recorded. Insect population for 10 selected plants/plot were observed with clean observation and in the experimental plot, the highest number of insect pests and predatory insects were recorded from T_5, whereas the lowest number of these insect pests was observed from T_2 treatment.

In consideration of whitefly, aphid, thrips, grasshopper, Pod borer, Ladybird beetle and ant, the highest number (5.00, 8.20, 12.33, 8.80, 9.07, 7.80 and 5.00 respectively) of these insects were recorded from T_5 (untreated control), whereas the lowest number (1.20, 1.80, 1.47, 1.20, 1.20, 1.33 and 1.00 respectively) was observed from T_2 (Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval).

In leaf infestation of BARI motor-1 caused by whitefly the lowest leaf infestation (5.73 %) was recorded from T_2, whereas the highest leaf infestation (17.25%) was observed from T_5. In case of leaf infestation of BARI motor-1 caused by aphid the lowest leaf infestation (4.76 %) was recorded from T_2, whereas the highest leaf infestation (12.19%) was observed from T_5. In consideration of leaf infestation by Epilachna beetle the lowest leaf infestation (5.39 %) was recorded from T_2, whereas the highest leaf infestation (14.95%) was observed from T_5.

In pods infestation of BARI motor-1 at early, mid and and late pod development stage caused by pod borer the lowest infestation (3.06, 4.23 and 5.00 % respectively) was recorded from T_2, whereas the highest infestation (11.97, 13.75 and 14.81% respectively) was observed from T_5.

Impact of management practices on predatory ladybird beetle and ant

Considering the impact of the management practices on the population of ladybird beetle, T_2 comprising applying of mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval adversely affected and reduced the highest population (83.10%) of adult lady bird beetle over control followed by T_3(73.70%) comprising spraying of Spraying Suntaf 50SP @ 1.5 g/L of water at 7 days interval. As a result, order of the level of adverse impact among different management practices in reducing the population of adult ladybird beetle in the BARI motor field was T_2> T_3>T_4>T_1>T_5.

Similarly, T_2 also adversely affected the population of field ant during the management of BARI motor-1 and reduced the highest population (80.00%) over control followed by Spraying Suntaf 50SP @ 1.5 g/L of water (78.60%), Spraying Topgan 10EC @ 1.0 ml/L of water (77.40%), whereas Mechanical and Cultural practices at 7 days interval (57.40%) showed the least level of adverse effect in reducing field ant. As a result, order of the level of adverse impact among different management practices in reducing the population of field ant was T_2> T_3>T_4>T_1>T_5.

Considering the effectiveness of different management practices in terms of reducing the level of infestation caused by different insect pest complexes of BARI motor-1 as well as their impacts on the predatory ladybird beetle and ant, it was revealed that higher population of predatory ladybird beetle adult as well as predatory field and ant were found in the treatments where the pod infestation of BARI motor-1 were found also higher. Simultaneously, these highly effective and toxic treatments for insect pest complexes of BARI motor-1 also adversely affected the population of predatory ladybird beetle adults as well as predatory field ant in the pea field. Thus, the best treatment (T_2) reduced the maximum population of ladybird beetle adults as well as field ant by maintaining the leaves and pod infestation at minimum level. Hence, it is revealed that the mechanical + chemical treatments T_2 comprising spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval and T_3 comprising spraying of Suntaf 50SP @ 1.5 g/L of water at 7 days interval both reduced the maximum pea infestation caused by insect pests, consequently they reduced the maximum population of natural enemies than other treatments. The experimental results broadly suggest that introduction of the new prospective insecticides offer environmentally friendly management practices of insect pest complex of BARI motor-1. They are also more healthy options in the time of pesticide hazards leading to serious health problems to human and domestic animal.

Among the control measure applying mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval was the better for the controlling of insect pest complex of BARI motor-1 and considering the controlling of insect pests of BARI motor-1 the highest benefit cost ratio (2.90) was recorded in the treatment T_2 (Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval).

CONCLUSION

From the above finding it was revealed that mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval was more effective among the management practices for controlling insect pest complex of BARI motor-1 which was followed by Spraying Suntaf 50SP @ 1.5 g/L of water and Spraying Topgan 10EC @ 1.0 ml/L of water at 7 days interval. Considering the controlling of insect pests of BARI motor-1 the highest benefit cost ratio (2.90) was recorded in the treatment T_2 (Mechanical control and spraying Ripcord 10EC @ 1.0 ml//L of water at 7 days interval).

RECOMMENDATIONS

Considering the situation of the present experiment, further studies in the following areas may be suggested:

- Such study needs to be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability

- Using chemical with different combinations may be used for further study

- Integrated pest management practices may be introduced for effective control insect pest complex of BARI motor-1.

CHAPTER VI

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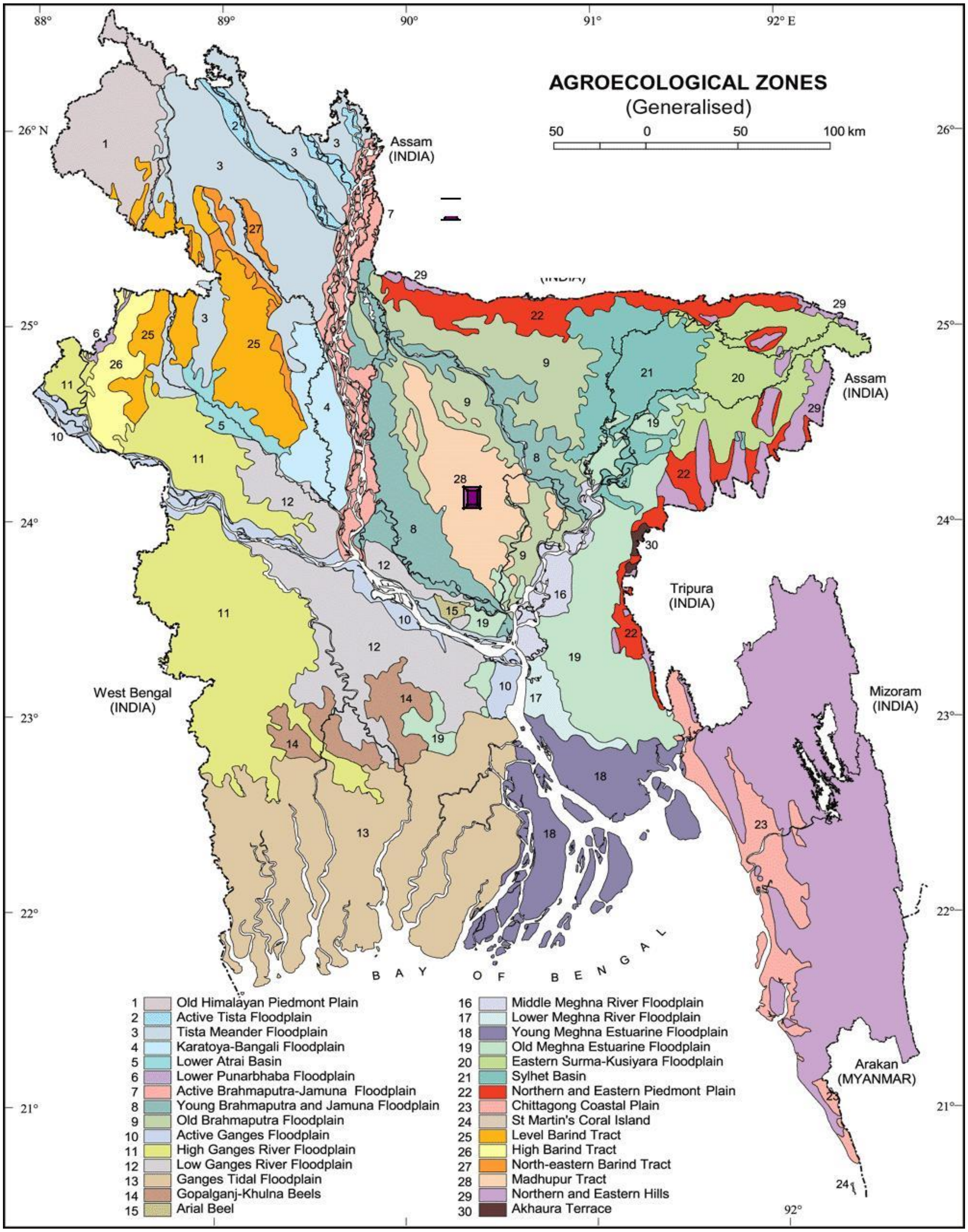
APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from November, 2014- March, 2015

Month	Air temperature (^0C)			RH (%)	Total rainfall (mm)
	Maximum	Minimum	Mean		
November	33.25	25.07	29.18	79.58	310
December	33.00	26.72	29.86	77.00	167
January	34.00	27.05	30.53	78.55	350
February	32.85	26.15	29.50	79.05	165
March	33.20	25.50	29.35	75.5	170

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix III. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0- 15 cm depth)

Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.07
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Magnesium	1.00 meq/100 g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Zinc	3.32 µg/g soil
Potassium	0.30 µg/g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka

Appendix IV. Analysis of variance of the data on abundance of major insect pests of BARI motor-1 during the study period as influenced by different management practices

Source of variation	Degrees of freedom	Mean square							
		Number of different insect pests/plant							
		Aphids	Thrips	Whitefly	Epilachna beetle	Grasshopper	Lady bird beetle	Ant	Pod borer
Replication	2	0.019	0.104	0.243	0.0001	0.051	0.008	0.019	0.0001
Treatment	4	21.297**	61.617**	44.004**	6.351**	27.847**	20.791**	8.713**	31.889**
Error	8	0.045	0.267	0.326	0.067	0.061	0.095	0.045	0.183

**: Significant at 0.01 level of probability;

Appendix V. Analysis of variance of the data on damage severity of leaves of BARI motor-1 by whitefly, epilachna beetle and grass hopper as influenced by different management practices

Source of variation	Degrees of freedom	Mean square								
		Whitefly			Epilachna beetle			Grass hopper		
		Healthy leaves/ plant (No.)	Infested leaves/ plant (No.)	Leaf infestation (%)	Healthy leaves/ plant (No.)	Infested leaves/ plant (No.)	Leaf infestation (%)	Healthy leaves/ plant (No.)	Infested leaves/ plant (No.)	Leaf infestation (%)
Replication	2	4.419	0.099	0.808	13.352	0.072	0.008	4.499	0.099	0.0001
Treatment	4	175.323**	27.571**	60.470**	141.091*	20.583**	40.170**	134.163**	14.916**	28.956**
Error	8	23.579	0.499	1.404	27.879	0.429	0.622	11.999	0.112	0.413

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on damage severity of BARI motor-1 by aphid, thrips, lady bird beetle and ant as influenced by different management practices

Source of variation	Degrees of freedom	Mean square							
		Aphid			Thrips			Incidence of adult lady bird beetle (No./plant)	Incidence of ant (No./plant)
		Healthy leaves/ plant (No.)	Infested leaves/ plant (No.)	Leaf infestation (%)	Healthy flower/ plant (No.)	Infested flower/ plant (No.)	Flower infestation (%)		
Replication	2	2.219	0.067	0.060	4.835	0.019	0.036	0.011	0.019
Treatment	4	124.449*	10.564**	26.387**	89.649*	13.647**	28.450**	21.217**	8.713**
Error	8	23.645	0.160	0.457	19.811	0.149	0.241	0.057	0.025

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on damage severity at early, mid and late pod development stage of BARI motor-1 by pod borer as influenced by different management practices

Source of variation	Degrees of freedom	Mean square								
		Early pod development stage			Mid pod development stage			Late pod development stage		
		Healthy pods (No.)	Infested pods (No.)	Pod infestation (%)	Healthy pods (No.)	Infested pods (No.)	Pod infestation (%)	Healthy pods (No.)	Infested pods (No.)	Pod infestation (%)
Replication	2	0.003	0.008	0.605	2.819	0.008	0.518	1.928	0.056	1.385
Treatment	4	23.617*	1.591**	32.491**	102.164**	2.516**	37.734**	70.644*	6.100**	40.163**
Error	8	4.589	0.065	0.257	11.242	0.028	0.444	13.728	0.166	1.841

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on yield contributing characters and yield of BARI motor-1 as influenced by different management practices

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm)	Number of pods/plant	Number of seeds/pod	Weight of 100-seeds (g)	Yield (t/ha)
Replication	2	1.256	1.075	0.011	0.310	0.002
Treatment	4	14.754*	29.144*	0.396**	1.829*	0.075*
Error	8	3.160	6.148	0.014	0.456	0.019

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability