DAMAGE ASSESSMENT AND MANAGEMENT OF INSECT AND MITE PESTS ON CHILLI

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JUNE, 2021

DAMAGE ASSESSMENT AND MANAGEMENT OF INSECT AND MITE PESTS ON CHILLI

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REGISTRATION NO. 14-05969

A Thesis

Submitted to the Department of Entomology, Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2021

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CERTIFICATE

This is to certify that thesis entitled ***"DAMAGE ASSESSMENT AND MANAGEMENT OF INSECT AND MITE PESTS ON CHILLI"*** *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* ***ROKAIA JAMILA ROSHNI, Registration no. 14-05969*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2021
Place: Dhaka, Bangladesh

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DEDICATED
TO
MY BELOVED
PARENTS

ACKNOWLEDGEMENT

All the praises due to the Almighty Allah (SWT), the cherisher and sustainer of the world. His blessings have enabled the author to complete her thesis leading to Master of Science in Entomology degree.

The author expresses her heartiest gratitude sincere appreciation, indebtedness and deep sense of respect to her adorable teacher, venerable Supervisor ***Dr. Md. Razzab Ali****, Professor, Department of Entomology, Sher-e-Bangla Agricultural University for his planning, painstaking and scholastic guidance, support, extraordinary kind concern, everlasting encouragement, inestimable cooperation and intellectual encircling the till final preparation of the thesis.*

She express her profuse gratitude, cordial appreciation and gratefulness to her thoughtful, Co-supervisor Professor ***Dr. Tahmina Akter,*** *Department of Entomology, Sher-e-Bangla Agricultural University, for her valuable suggestions, guidance constant encouragement and inestimable during the entire period of study.*

With due regards, she thanks the Chairman, Department of Entomology, Sher-e-Bangla Agricultural University, for the facilities provided, in carrying out this work. She also acknowledges with deep regards the help and cooperation received from her respected teachers and stuff of the Department of Entomology, Sher-e-Bangla Agricultural University while carrying out this work.

She expresses her heartiest gratitude sincere appreciation, indebtedness and deep sense of respect to her parents for their sincere and affectionate support and love, extraordinary kind concern, everlasting encouragement and inestimable cooperation during the entire period of study.

Dated: June, 2021 ***The Author***

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ABSTRACT

The study was conducted in the experimental field of SAU, Dhaka during the period from October, 2019 to February, 2020 to find out the damage and management of insect and mite pests on chilli. The experiment was laid out in Randomized Complete Block Design with three replications. For this study, treatments T_1: Spraying Confidor 2G @ 0.2g/L of water at 7 days intervals; T_2: Spraying Actara 25WG @ 0.05g/L of water at 7 days intervals; T_3: Spraying Ethion 46.5EC @ 3ml/L of water at 7 days intervals; T_4: Spraying Omite 57EC @ 2ml/L of water at 7 days intervals; T_5: Spraying Neem Oil @ 3ml/L of water mixing with 10ml/10gm detergent or trix at 7 days intervals; T_6: Spraying Bioneem Plus 1EC @ 1ml/L of water at 7 days intervals and T_7: Untreated control where only water were sprayed at 7 days intervals. From this study T_3 showed the best performance in terms of number of aphids, thrips, gram pod borer, tobacco caterpillar, and mites (0.53 aphids, 1.04 thrips, 1.19 gram pod borer, 0.60 tobacco caterpillar and 0.81 mites, respectively). T_3 decreases the number of insect pests of chili.Beside this, T_3 also decreases the number of infested leaves, aphid infested leaves, thrips infested leaves, mite infested leaves and percent leaf infestation (102.40 leaves, 97.33 leaves, 87.33 leaves, 78.40 leaves, and 96.42%, respectively) and increases total number of leaves (106.2 leaves). It also decreases total number of infested fruits, thrips infested fruits, bored fruits and percent fruit infestation (9.40 fruits, 8.10 fruits, 2.70 fruits and 7.99%, respectively) whereas it increases total number of fruits (117.60 fruits). Again it decreases total number of infested plants and percent plant infestation (3.00 plants and 30.00%, respectively), whereas it increases the number of branches and plant height (12.47 branches and 67.60 cm, respectively). In case of yield attributing characteristics, T_3 increases fruit length, fruit girth, healthy fruit weight, infested fruit weight, total fruit weight/plot and yield of chilli (6.40 cm, 3.30 cm, 1.41 kg, 0.82 kg, 2.23 kg and 7.43 t/ha, respectively).

ABBREVIATIONS AND ACRONYMS

Abbreviation	Full meaning
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
CV	Coefficient of variation
^{o}C	Degree Celsius
d.f.	Degrees of freedom
DAT	Days after transplanting
et al.	And others
FAO	Food and Agriculture Organization
G	Gram
Ha	Hectare
IPM	Integrated Pest Management
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
Mg	Milligram
MP	Muriate of Potash
%	Percent
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources Development Institute
TSP	Triple Super Phosphate

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CHAPTER I

INTRODUCTION

Chilli (*Capsicum annuum* L.) is an important vegetable cum spice crop grown in almost all parts of tropical and subtropical regions of the world. *C. annuum* is a species of the plant genus Capsicum native to southern North America and northern South America (ARS 2010, Elizabeth 2009). This species is the most common and extensively cultivated of the five domesticated capsicums with wide variety of shapes and sizes of peppers, both mild and hot, such as bell peppers, jalapeños, New Mexico chile, and cayenne peppers. It is cultivated either for pungent fruited genotypes called chilli or non-pungent fruited genotypes called sweet pepper and used for culinary, salad and processing purposes. The plant is not an annual but is frost tender (RHS 2017). In the absence of winter frosts it can survive several seasons and grow into a large, shrubby perennial herb (Gernot 2012). The single flowers are an off-white (sometimes purplish) color while the stem is densely branched and up to 60 cm (24 in) tall. The fruit are berries that may be green, yellow, orange or red when ripe (OECD 2011). While the species can tolerate most frost-free climates, especially productive in warm and dry climates.

Cultivars descended from the wild American bird pepper are still found in warmer regions of the Americas. In the past, some woody forms of this species have been called *C. frutescens*, but the features that were used to distinguish those forms appear in many populations of *C. annuum* and are not consistently recognizable features in *C. frutescens* species.

The species is a source of popular sweet peppers and hot chiles with numerous varieties cultivated all around the world, and is the source of popular spices such as cayenne, chile, and paprika powders. Capsinoid chemicals provide the distinctive tastes in *C. annuum* variants. In particular, capsaicin creates a burning sensation (hotness), which in extreme cases can last for several hours after ingestion (Materska 2015). Hot peppers are used in traditional medicine as well as food in Africa.It is employed in medicine, in combination with Cinchona in intermittent and lethargic affections, and also in atonic gout, dyspepsia accompanied by flatulence, tympanitis, paralysis etc. Its most valuable application appears however to be in cynanche maligna (acute diphtheria) and scarlatina maligna (malignant Scarlet fever, used either as a gargle or administered internally) (Ranjith *et al*. 2015).

It is one of the important cash crops grown in almost all parts of the country and cultivated in both the summer and winter season. There are 39 genus and 51 species of insects and mite attacking chilli in the field and in the storage. Aphids, Thrips and Jassids are the major insect pests of chili (Jadhav *et al*. 2014). During the pre-flowering phase, 5 orders were obtained: Hemiptera, Hymenoptera, Coleoptera, Lepidoptera and Orthoptera. The same orders were found at flowering-fruiting phase, with appearance of one new order, the Thysanoptera. At this stage, exponential growth of Hemiptera and Hymenoptera was also observed. During maturation, Diptera and Lepidoptera were the most abundant pests. *Ceratitis capitata* and *Cryptophlebia leucotreta* were responsible for yield losses (20.46%). Aphids and whiteflies affected plant's fitness, either directly through sap sucking or indirectly through viral transmissions. Ants' transport, disseminate and protect Hemipterans (Djieto-Lordon *et al*. 2014).

Among thrips, *Scirtothrips dorsalis* Hood (Thripidiae: Thysanoptera) is one of the most destructive pest of chilli and under severe infestation 30 to 50 percent crop may be lost (Bhede *et al*. 2008). Thrips alone is reported to be a major pest of chilli in sub-continent (Patel and Khatri 2012).

In Bangladesh, farmers usually used chemical pesticides in the chilli field. They use pesticides indiscriminately in the field. As a result, it has an adverse effect on environment as well as on human health and beneficial insects. Now a days, the practice of natural enemies and botanicals to manage insect pests of chilli increased day by day. There is a need to manage these pests effectively and economically in chili. Therefore, the work aims to investigate the following objectives:

- To assess the infestation level and damage severity of major insect and mite pests on chilli in field condition, and
- To evaluate the chemical insecticides, acaricides and botanicals for controlling major insect and mite pests of chilli.

CHAPTER II

REVIEW OF LITERATURE

Chilli is an important spices in Bangladesh, but the crop cultivation faces various problems including the pest management. Among the insect pests- aphids, thrips, gram pod borer, tobacco caterpillar and mites are the major pests of chilli. An attempt has been taken in this chapter to review the pertinent research work related to the present study. The information is given below under the following sub-headings:

2.1. General review of insect pests of chilli

2.1. Gram pod borer

It is a polyphagous, infesting gram, lablab, safflower, chillies, groundnut, tobacco, cotton etc.

A. Nomenclature

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Noctuidae

Genus: *Helicoverpa*

Species: *Helicoverpa armigera*

Common names: African cotton bollworm; corn earworm; gram pod borer; old world bollworm; tobacco budworm

B. Origin and distribution

Gram pod borer is distributed worldwide. It is well distributed in Algeria, Benin (Tsafack *et al*. 2016, EPPO 2020), Congo (EPPO 2020), Egypt (El-Heneidy *et al*. 2010, Al-shannaf *et al*. 2012,Soliman *et al*. 2014,), Ghana (Badii and Asante 2012), Kenya (Waiganjo *et al*. 2009), Nigeria (Brévault *et al*. 2008,Dialoke *et al*. 2010), Senegal (Niassy *et al*. 2010, Diatte *et al*. 2018), South Africa (Wohlfarter *et* *al*. 2010, Siyoko 2011), Tunisia (Cherif and Grissa-Lebdi 2017), Zimbabwe (Tibugari and Jowah 2014), Bangladesh (Hossain *et al*. 2009), Afghanistan (EPPO 2020), China (Wan *et al*. 2005, Chen Jia *et al*. 2011, Ma *et al*. 2012, Yang *et al*. 2013), Hong Kong (EPPO 2020), India (Sharma and Bisht 2011, Sreekanth and Seshamahalakshmi 2012, Pandey 2012, Byrappa *et al*. 2012, Khajuria *et al*. 2013, Gundannavar *et al*. 2013, Yadav *et al*. 2014, Naik *et al*. 2014, Girish *et al*. 2014, Paul *et al*. 2016, Meena *et al*. 2017, Kukanur *et al*. 2018, Harshita *et al*. 2018, Chakravarty and Srivastava 2020,Husain and Hasan 2020, EPPO 2020), Iran (Mojarab-Mahboubkar *et al*. 2015), Iraq (EPPO 2020), Israel (Kravchenko *et al*. 2005), Laos, Mayanmar, Nepal, Pakistan Philippines (EPPO 2020), Soudi Arabia, Sri Lanka, Syria, Taiwan, Tajikistan, Thailand, Turkey, Yemen (Oztemİz 2008, Bhonwong *et al*. 2009, Demİrumlaut˜er 2012, Mohammad *et al*. 2013), Albania, Hangery, Italy, Malta, Netherlands (IPPC 2007, Keszthelyi *et al*. 2013, Sannino *et al*. 2015), Portugal, Romania, Russia, Slovakia, Spain (Fefelova and Frolov 2008 Avilla and González-Zamora 2010, Roșca 2010, Valverde *et al*. 2015), Puerto Rico (NAPPO 2014), Australia (Baker and Tann 2017), New Zealand (Cameron *et al*. 2006), Argentina (Arnemann *et al*. 2019), Brazil (Pinto *et al*. 2017), Paraguay (Arnemann *et al*. 2016).

C. Life cycle

Egg: The spherical, yellowish eggs are laid singly on tender parts and buds of plants. Yellowish-white and glistening at first, changing to dark-brown before hatching; pomegranate-shaped, 0.4-0.6 mm in diameter; the apical area surrounding the micropyle is smooth, the rest of the surface sculptured in the form of approximately 24 longitudinal ribs, alternate ones being slightly shorter, with numerous finer transverse ridges between them; laid on plants which are flowering, or are about to produce flowers.

Larva: Caterpillars vary in colour, initially brown and later turn greenish with darker broken lines along the side of the body. Body covered with radiating hairs. When full grown, they measure 3.7 to 5 cm in length. The full grown caterpillar pupates in the soil in an earthen cell and emerges in 16-21 days. The first and second larval instars are generally yellowish-white to reddish-brown in colour, without prominent markings; head, prothoracic shield, supra-anal shield and prothoracic legs are very dark-brown to black, as are also the spiracles and tuberculate bases to the setae, which give the larva a spotted appearance; prolegs are present on the third to sixth, and tenth, abdominal segments. A characteristic pattern develops in subsequent instars. Fully grown larvae are ca 30-40 mm long; the head is brown and mottled; the prothoracic and supra-anal plates and legs are pale-brown, only claws and spiracles remaining black; the skin surface consists of close-set, minute tubercles. Crochets on the prolegs are arranged in an arc. The final body segment is elongated. Colour pattern: a narrow, dark, median dorsal band; on each side, first a broad pale band, then a broad dark band; on the lateral line, a broad, very light band on which the row of spiracles shows up clearly. The underside is uniformly rather pale. On the basic dorsal pattern, numerous very narrow, somewhat wavy or wrinkled longitudinal stripes are superimposed. Colour is extremely variable and the pattern described may be formed from shades of green, straw-yellow, and pinkish- to reddish-brown or even black.

Pupa: Pupation takes place inside the soil. Mahogany-brown, 14-18 mm long, with smooth surface, rounded both anteriorly and posteriorly, with two tapering parallel spines at posterior tip. Pupal stage lasts 7-15 days.

Adult: Moth is stout, medium sized with brownish/greyish forewings with a dark cross band near outer margin and dark spots near costal margins, with a wing expanse of 3.7 cm. Stout-bodied moth of typical noctuid appearance, with 3.5-4 cm wing span; broad across the thorax and then tapering, 14-18 mm long; colour variable, but male usually greenish-grey and female orange-brown. Forewings have a line of seven to eight blackish spots on the margin and a broad, irregular, transverse brown band. Hindwings are pale-straw colour with a broad dark-brown border that contains a paler patch; they have yellowish margins and strongly marked veins and a dark, comma-shaped marking in the middle. Antennae are covered with fine hairs.

D. Nature of damage

Young larva feeds on the leaves for some time and then attacks fruits. Internal tissues are eaten severely and completely hollowed out. While feeding the caterpillar thrust its head inside leaving the rest of the body outside. Bored fruits with round holes. Fed leaves, shoots and buds. The activity of Helicoverpa starts on green gram, summer vegetables and maize and continues their generation by August-September months synchronizing with main crop.

2.1.2. Tobacco caterpillar

It is found throughout the tropical and sub tropical parts of the world, wide spread in India. Besides tobacco, it feeds on cotton, castor, groundnut, Chilli, cabbage and various other cruciferous crops.

A. Nomenclature

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Noctuidae

Genus: *Spodoptera*

Species: *Spodoptera litura*

Common names: Armyworm; cluster caterpillar; common cutworm; cotton leafworm; cotton worm; Egyptian cotton leafworm; rice cutworm; tobacco budworm; tobacco caterpillar; tobacco cutworm; tobacco leaf caterpillar

B. Origin and distribution

The tobacco caterpillar, S. litura, is one of the most important insect pests of agricultural crops in the Asian tropics. It is widely distributed throughout tropical and temperate Asia (Tithi *et al*. 2010, Islam *et al*. 2012, Wu ChengXu *et al*. 2015, Sang Song *et al*. 2016, Zhang Li *et al*. 2017, Wang XueGui *et al*. 2018). Records of S. litura having limited distribution in (or being eradicated from) Germany, Russian Federation, Russian Far East, the UK and Réunion may in fact refer to S. littoralis (EPPO 2021).

C. Life cycle

Eggs: The eggs are spherical, somewhat flattened, and 0.6 mm in diameter. They are usually pale orange-brown or pink in colour, laid in batches and covered with hair scales from the tip of the abdomen of the female moth. Egg masses measure about 4-7 mm in diameter and appear golden brown because they are covered with body scales of females. Female lays about 300 eggs in clusters. The eggs are covered over by brown hairs and they hatch in about 3-5 days.

Larva: The larva is hairless, variable in colour (young larvae are light green, the later instars are dark green to brown on their backs, lighter underneath); sides of body with dark and light longitudinal bands; dorsal side with two dark semilunar spots laterally on each segment, except for the prothorax; spots on the first and eighth abdominal segments larger than others, interrupting the lateral lines on the first segment. Though the markings are variable, a bright-yellow stripe along the length of the dorsal surface is characteristic of S. litura larvae.

Larval instars can be distinguished on the basis of head capsule width, ranging from 2.7 to 25 mm. Body length ranges from 2.3 to 32 mm. Caterpillar measures 35-40 mm in length, when full grown. It is velvety, black with yellowish – green dorsal stripes and lateral white bands with incomplete ring – like dark band on anterior and posterior end of the body. It passes through 6 instars. Larval stage lasts 15-30 days.

Pupa: The pupa is 15-20 mm long, red-brown; tip of abdomen with two small spines. Pupation takes place inside the soil. Pupal stage lasts 7-15 days.

Adult: Moth, with grey-brown body, 15-20 mm long; wingspan 30-38 mm. The forewings are grey to reddish-brown with a strongly variegated pattern and paler lines along the veins (in males, bluish areas occur on the wing base and tip); the hindwings are greyish-white with grey margins, often with dark veins in S. litura (but without in S. littoralis). Moth is medium sized and stout bodied with forewings pale grey to dark brown in colour having wavy white crisscross markings. Hind wings are whitish with brown patches along the margin of wing.

D. Nature of damage

On most crops, damage arises from extensive feeding by larvae, leading to complete stripping of the plants. On Cotton, Leaves are heavily attacked and bolls have large holes in them from which yellowish-green to dark-green larval excrement protrudes. On Tobacco, Leaves develop irregular, brownish-red patches and the stem base may be gnawed off. On Maize, The stems are often mined and young grains in the ear may be injured.

2.1.3. Aphid

Aphids are small sap-sucking insects and members of the superfamily Aphidoidea. Common names include greenfly and blackfly, although individuals within a species can vary widely in color (Ross 2007).

A. Nomenclature

Phylum: Arthropoda

Class: Insecta

Order: Hemiptera

Family: Aphididae

Genus: *Aphis*

Species: *Aphis gossypii*

Common names: Cotton aphid, betelvine aphid; cucurbits aphid; green aphis; melon aphid

B. Origin and distribution

A. gossypii is distributed worldwide. It is a pest in very cold climates on crops grown in greenhouses. Aphid is present in Algeria, Benin, Cameroon, Congo, Egypt, Ethiopia, Ghana, Kenya, Madagascar, Mali, Morocco, Niger, Nigeria, Senegal, Somalia, South Africa, Sudan, Zambia and Zimbabwe countries from Africa continent (Carletto *et al*. 2009, Waiganjo *et al*. 2009, Elégbédé *et al*. 2014, Abang *et al*. 2014, Gaber *et al*. 2015, Djebara *et al*. 2018), Afghanistan, Bangladesh, China, Hong Kong, India, Indonesia, Iran, Iraq, Israel, Japan, Kazakhstan, Lebanon, Malaysia, Myanmar, Nepal, Korea, Oman, Pakistan, Philippines, Qatar, Saudi Arabia, Singapore, Syria, Sri Lanka, Taiwan, Tajikistan, Turky, Thailand, Uzbekistan and Vietnam from Asia continent (Sukhoruchenko and Velikan 2005, Al-Zadjali *et al*. 2006, Basu and Patro 2007, Kubaa *et al*. 2009, Akyürek *et al*. 2010, Shi *et al*. 2011, Ali *et al*. 2012, Iguchi *et al*. 2012, Satar *et al*. 2013, Matsuura and Nakamura 2014, Abang *et al*. 2014, Ferrer-Suay *et al*. 2014, Hosseini-Tabesh *et al*. 2015, Keshavarz *et al*. 2015, , Fazal *et al*. 2018, Kök *et al*. 2016, Maryam *et al*. 2019), Albania, Austria, Belgium, Bulgaria, Cyprus, France, Germany, Greece, Hungary, Italy, Malta, Netherlands, Norway, Poland, Portugal, Russia, Spain, Sweden, Switzerland and United Kingdom from Europe continent

(Borges *et al*. 2006, Balliu and Çota 2007, Lombaert *et al*. 2009, Albanese *et al*. 2010, Riolo *et al*. 2011, Yovkova *et al*. 2013, Basky 2014), Anguilla, Bahamas, Bermuda, Canada, Costa Rica, Cuba, Haiti, Jamaica, Mexico and United States from North America continent (Sánchez-Monge *et al*. 2010, Diaz *et al*. 2015, Avelar *et al*. 2019), Argentina, Brazil, Chile, Colombia, Paraguay, Peru and Venezuela from South America continent (Carletto *et al*. 2009, Fernandes *et al*. 2011, Mallqui and Cobián 2011, Leite *et al*. 2015, Cunha and Sousa e Silva 2016) and Australia, Fiji, Kiribati, New Zealand, Papua New Guinea, Solomon Island and Tonga from Ocenia continent (Carletto *et al*. 2009, Herron and Wilson 2011).

C. Life cycle

The following characteristics can be used to attempt to identify *A. gossypii*.

The cornicles or siphunculi are uniformly sclerotized from tip to base, and darkly pigmented. They are longer than the cauda and gradually taper towards the apex with a small dilation there. The dorsal abdominal segments are uniformly sclerotized and unpigmented. *A. gossypii* reared near the colour transition temperature (see later in this section) often have a blotchy appearance with some parts greenish and other parts more yellow. The cauda usually have 4-7 hairs and are paler than the cornicles. The metafemoral hairs are all shorter than the basal width of the metafemur. Stidulatory apparatus is absent. The antennal tubercles are weakly developed. The terminal process is more than twice the length of the last antennal segment, but less than 3.5 times as long. The rostrum has a blunt apex and the terminal rostral segment shorter than cauda and under 1.5 times the length of the second metatarsal segment.

A. gossypii is a small aphid. Adults range from just under 1-1.5 mm in body length. The minimum diameter is just over 0.34 mm. This is indicated by the fact that a screen with a mesh diameter of under 0.34 mm is able to exclude *A. gossypii*.

Cornicle length distinguishes separate instars of *A. gossypii* reared under fluctuating temperatures. There is considerable overlap between instars, but none between nymphs and adults. Other characteristics combined can provide greater separation between instars especially under constant temperatures .First-instar nymphs are distinguished by having 4 antennal segments, whereas second-instar nymphs have 5 segments. Differences between second- and third-instar nymphs are fairly small, but at constant temperatures they can be distinguished using a combination of characteristics. Third-instar nymphs have no setae on the margin of the genital plate, whereas fourth-instar nymphs have such setae. Second-instar nymphs with developing wings appear to have shoulders, third-instar nymphs have small wing pads, and the developing wings are prominent on fourth-instar nymphs.

The occurrence of the following *A. gossypii* stages have been described in Japan: fundatrix, fundatrigeniae, alienicola, gynoparae, oviparous female, alate and apterous male, hibernating viviparae, virgin androparae, androparae, heteroparae and androgynoparae. There are also individuals with partly developed wings from nearly apterous to nearly functionally winged.

A. gossypii can range in colour from yellow to very dark (almost black) green. The smaller yellow form occurs during warmer summer conditions. The green form is larger and occurs during cooler spring and autumn temperatures, and uncrowded conditions. Colour morphs are able to produce progeny of another colour morph. Host plant can also influence aphid colour reported that green morphs produce more alate offspring than do yellow morphs. However, his observation could be the result of crowding, as the green form also produced more total offspring.

D. Nature of damage

The black bean aphid is a major pest of sugar beet, bean, and celery crops, with large numbers of aphids cause stunting of the plants. Beans suffer damage to flowers and pods which may not develop properly. Early-sown crops may avoid significant damage if they have already flowered before the number of aphids builds up in the spring (RIR 2013). Celery can be heavily infested. The plants are stunted by the removal of sap, the stems are distorted, harmful viruses are transmitted, and aphid residues may contaminate the crop (Godfrey and Trumble 2009). As a result of infestation by this aphid, leaves of sugar beet become swollen, roll, and cease developing. The roots grow poorly and the sugar content is reduced. In some other plants, the leaves do not become distorted, but growth is affected and flowers abort due to the action of the toxic saliva injected by the aphid to improve the flow of sap (HYPP 2013).

To obtain enough protein, aphids need to suck large volumes of sap. The excess sugary fluid, honeydew, is secreted by the aphids. It adheres to plants, where it promotes growth of sooty molds. These are unsightly, reduce the surface area of the plant available for photosynthesis and may reduce the value of the crop. These aphids are also the vectors of about 30 plant viruses, mostly of the non-persistent variety. The aphids may not be the original source of infection, but are instrumental in spreading the virus through the crop (RIR 2013). Various chemical treatments are available to kill the aphids and organic growers can use a solution of soft soap (Godfrey and Trumble 2009).

2.1.4. Thrips

Thrips (order Thysanoptera) are minute (mostly 1 mm long or less), slender insects with fringed wings and unique asymmetrical mouthparts. Different thrips species feed mostly on plants by puncturing and sucking up the contents, although a few are predators (Fedor *et al*. 2010).

A. Nomenclature

Phylum: Arthropoda

Class: Insecta

Order: Thysanoptera

Family: Thripidae

Genus: *Thrips*

Species: *Thrips tabaci*

Common name: Onion thrips, cotton seedling thrips; potato thrips; tobacco thrips

B. Origin and distribution

Thrips is well distributed worldwide. Among them thrips are present in Algeria, Congo, Egypt, Ethiopia, Ghana, Kenya, Libya, Madagascar, Mauritius, Morocco, Nigeria, Senegal, Somalia, South Africa, Sudan, Tanzania, Tunisia, Uganda and Zimbabwe from Africa continent (Lobin *et al*. 2012, Wohlfarter and Venter 2012, Badr 2014, Wahab *et al*. 2015, Karavina and Gubba 2017, Razi *et al*. 2017, Djebara *et al*. 2018), Azerbaijan, China, India, Hong Kong, Indonesia, Iran, Iraq, Israel, Japan, Japan, Philippines, Qatar, Saudi Arabia, Singapore, Thiland, Turkey, Uzbekistan and Vietnum from Asia continent (Shoukat and Shayesteh 2006, Aggarwal *et al*. 2007, Qi *et al*. 2007, Hajiabadi *et al*. 2012, Sartiami and Mound 2013, Mirab-Balou *et al*. 2014, Sanjta and Chauhan 2015), Albania, Austria, Belgium, Bulgaria, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Spain, Sweden, Ukraine and United Kingdom from Europe continent (Chatzivassiliou *et al*. 2009, Pizzol *et al*. 2012, Stanković *et al*. 2012, Virteiu *et al*. 2015), Bahamas, Bermuda, Canada, Costa Rica, Cuba, Jamaica, Haiti, Mexico and United States from North America continent (Rueda *et al*. 2007, Velásquez-Valle *et al*. 2016), Argentina, Brazil, Chile, Colombia, Ecuador, Peru, Uruguay and Venezuela from South America continent (Zawadneak *et al*. 2008 Yamada *et al*. 2016) and Australia, Fiji, New Zealand and Solomon Island from Oceania continent (Steiner and Goodwin 2005).

C. Life cycle

Thrips lay extremely small eggs, about 0.2 mm long. Females of the suborder Terebrantia cut slits in plant tissue with their ovipositor, and insert their eggs, one per slit. Females of the suborder Tubulifera lay their eggs singly or in small groups on the outside surfaces of plants (Gullan and Cranston 2010).

Thrips are hemimetabolous, metamorphosing gradually to the adult form. The first two instars, called larvae or nymphs, are like small wingless adults (often confused with springtails) without genitalia; these feed on plant tissue. In the Terebrantia, the third and fourth instars, and in the Tubulifera also a fifth instar, are non-feeding resting stages similar to pupae: in these stages, the body's organs are reshaped, and wing-buds and genitalia are formed (Gullan and Cranston 2010). The adult stage can be reached in around 8–15 days; adults can live for around 45 days (Smith 2015). Adults have both winged and wingless forms; in the grass thrips Anaphothrips obscurus, for example, the winged form makes up 90% of the population in spring (in temperate zones), while the wingless form makes up 98% of the population late in the summer. Thrips can survive the winter as adults or through egg or pupal diapause.

Thrips are haplodiploid with haploid males (from unfertilised eggs, as in Hymenoptera) and diploid females capable of parthenogenesis (reproducing without fertilisation), many species using arrhenotoky, a few using thelytoky (Kooi and Schwander 2014). In Pezothrips kellyanus females hatch from larger eggs than males, possibly because they are more likely to be fertilized (Katlav *et al* 2020). The sex-determining bacterial endosymbiont Wolbachia is a factor that affects the reproductive mode (Mound 2005, Kumm and Moritz 2008, Kooi and

Schwander 2014). Several normally bisexual species have become established in the United States with only females present (Kooi and Schwander 2014).

D. Nature of damage

The newly hatched nymph feeds on the plant for two of its instars, then falls off the plant to complete its other two instar stages. The insect damages the plant in several ways. The major damage is caused by the adult ovipositing in the plant tissue. The plant is also injured by feeding, which leaves holes and areas of silvery discoloration when the plant reacts to the insect's saliva. Nymphs feed heavily on new fruit just beginning to develop from the flower. The western flower thrips is also the major vector of tomato spotted wilt virus, a serious plant disease.

Thrips attack on the young leaves and flowers. Thrips attacks can cause chilli leaf curling to the upward. The attack of thrips on chilli plants starts from a mild attack to heavy. Mild attack begins from attack symptoms on leaves marked with silvery white color. Furthermore, the silvery color changed to be brown. Paroxysm attack occurs when thrips act as vectors of viruses that cause disease in chilli.

Thrips attack can degrade the quality of agricultural products can reach the half. Thrips attack the buds so that the leaf buds die. Extreme damage can result in yield loss and can be exacerbated by cold weather which further slows plant growth (Williams *et al.* 2011).

2.1.5. Mite :

The broad mite, Polyphagotarsonemus latus (Acari: Tarsonemidae), is a microscopic species of mite found on many species of plants, including important agricultural species such as grapes, apples, and other fruits.

A. Nomenclature of Mite

Phylum: Arthropoda

Class: Arachnida

Order: Trombidiformes

Family: Tarsonemidae

Genus: *Polyphagotarsonemus*

Species: *Polyphagotarsonemus latus*

Common name: Chilli mite; broad mite; citrus silver mite; jute white mite; rubber leaf mite; tropical mite; yellow tea mite

B. Origin and distribution

Mite is present in Benin, Cameroon, Chad, Ethiopia, Kenya, Liberia, Mali, Morocco, Nigeria, Senegal, South Africa, Sudan, Tanzania and Uganda from Africa continent (Adango *et al*. 2006), Bangladesh, China, India, Indonesia, Iran, Japan, Malaysia, Myanmar, Oman, Pakistan, Philippines, Saudi Arabia, Singapore, Sri Lanka, Thailand, Turkey and Vietnam from Asia continent (Prasad *et al*. 2006, Wang *et al*. 2009, Al-Azzazy and Alhewairini 2018), Belgium, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland and United Kingdom from Europe continent (Glavendekić *et al*. 2005, Radonjić and Hrnčić 2011), Bermuda, Canada, Cuba, Costa Rica, Jamaica, Mexico, Panama and United States from North America continent (Vincent *et al*. 2010, Diaz *et al*. 2015, Lugo-Sánchez *et al*. 2019, Aguilar-Piedra and Solano-Guevara 2020), Argentina, Brazil, Colombia, Peru and Venezuela from South America continent (Chiaradia *et al*. 2006, Oliveira *et al*. 2011).

C. Life cycle

Egg: Eggs are oval shaped eggs and white in colour. Eggs are glued firmly on the leaf surface.

Nymph: Nymphs white in colour.

Adult: Adults large, oval and broad and yellowish in colour.

D. Nature of damage

Younger leaves at the tip of branch clustering. Both nymphs and adults suck sap and devitalize the plant causing 'Murda' disease of chillies. Infestation results in downward curling of leaves. The affected leaves becoming inverted boat shaped. The leaves rolling down along the margin with elongation of petioles. Affected leaves turning dark green in certain cases.

2.2. Management practices

2.2.1. Host plant resistance

In recent years, genetic engineering techniques have enabled genes carrying the toxic element of *Bacillus thuringiensis* to be introduced into crops such as cotton and tomato. Although the technique is still very much in its early stages, transgenic crop varieties offer considerable promise for use in IPM systems against *H. armigera*. As with the use of all resistant crop varieties, however, care still needs to be taken to avoid excessive selection pressure against the resistance factor, so that in such systems a mixture of both resistant and susceptible varieties is often recommended to lessen this (CABI 2020).

Plant resistance is not yet employed as a component in broad mite (*P. latus*) control, but there is some evidence that the potential exists. In Cuba, a double haploid of sweet pepper (*Capsicum* sp.) that has higher mean fruit weight and yield per plant was tolerant of *P. latus*. Several chilli cultivars in India are resistant to *P. latus*.

2.2.2. Cultural practices

Cultural manipulations of the crop or cropping system and land management have been tried as tactics to manage *H. armigera* populations. Trap cropping and planting diversionary hosts have been widely applied and recommended in the past, although with limited success. In the case of cotton, the diversionary hosts maize and sorghum had too short an attractive period to sustain populations; the tendency of these and earlier-planted crops to augment or create infestations were major disadvantages. The importance of ploughing cotton stubble to reduce overwintering populations of pyrethroid-resistant *H. armigera* and post-harvest cultivation to destroy pupae of bollworms has received considerable attention in the USA. However, all in situ cultural control tactics (including area-wide management of early season populations on wild hosts) and the concept of a close season during which food plants are denied for over one generation, would seem to be largely invalid where the immigration of adults into the protected habitats is the key consideration. One indirect cultural method which could be included under this heading is the regulation of crop agronomy, variety (such as the okra-leaved varieties of cotton), and spacing and fertilizer regimes to render the crop, and thus target larvae, more accessible to insecticides or microbial formulations applied by conventional means.

Remove weeds and plant resi-due to help reduce egg-laying sites and seedling weeds that nourish small cutworms. Tilling land before planting, which helps expose and kill overwintering larvae. Tilling also removes plant residue, which helps to discourage egg laying. Avoid using green manure as this may encourage egg laying, instead use com-post. Tilling land in the fall; this helps destroy or expose overwintering larvae or pupae (Hahn and Burkness, 2015).

2.2.3. Mechanical practices

The importance of dispersive and migratory behaviour in the biology of *H. armigera* suggests that monitoring of these movements could provide an early warning of its invasion of an area or crop. Although work on long-distance movement using radar, backtracking and other techniques indicated that moths were able to (and often did) cover large distances, their occurrence in significant numbers at a particular location could seldom be predicted with any certainty. Changes in catch numbers in light and pheromone traps showed characteristic patterns of abundance for different locations in India but the relationship between trap catch and subsequent egg or larval populations in a susceptible crop was usually variable to poor, with numbers captured differing markedly between traps separated by only a few tens of metres, although it was closest when moth densities were low and at the beginning of the seasonal cycle. Trapping *H. armigera* is thus only useful as a qualitative measure indicating the start of an infestation or a migratory 'wave front', indicating the need to begin scouting for immature stages in the crop.

Reddy *et al*. (2015) who reported that the pest control with LED lights could effectively reduce the dosage of pesticides as well as their pollution on the agricultural products, soil and water. The solar LED light is easy to use and can be applied to various crops. During the day, energy from the solar panels will be stored in the storage batteries at night, the electrical energy from the battery could drive circuit of LED light to control pests. Similarly Sunitha and Rajasekhar (2016) studied the effect of solar light trap in capsicum under net condition and reported that on an average number of insects trapped ranged between 600-700 /night which included whiteflies, thrips, hoppers, termites, cutworms and fruit borers and number of insecticides are reduced from 3 to 1/week and by 70.00%.

2.2.4. Chemical practices

The considerable selection pressure which *H. armigera* has experienced, particularly to the synthetic pyrethroids which were used predominantly in the early 1980s, has resulted in the development of resistance to the major classes of insecticides in many of the areas where these have been used. Field failures resulting from pyrethroid resistance have been reported from Australia, Thailand, Turkey, India, Indonesia and Pakistan. Insecticide resistance management strategies have been aimed either at preventing the development of resistance, or containing it. All rely on a strict temporal restriction in the use of pyrethroids and their alternation with other insecticide groups to minimize selection for resistance. And while the strong propensity of *H. armigera* to disperse confers the advantage of diluting resistant populations through the influx of susceptible insects from unsprayed hosts, the same tendency ensures that the genes for resistance are spread more widely than their area of origin.

Pyrethroid resistance in *H. armigera* may be conferred through three separate mechanisms: detoxification by mixed-function oxidases (metabolic resistance), nerve insensitivity, and delayed penetration. Metabolic resistance may be inhibited by piperonyl butoxide and other synergists, providing a (costly) means whereby the use of pyrethroids might be prolonged in populations where this is the principal mechanism.

P. latus may be difficult to control on certain plants. On the curly leaves of *Psophocarpus tetragonolobus*, dicofol, bromopropylate, azocyclotin and abamectin were not effective, presumably because the mites were protected in curly leaves; chinomethionat was more effective. On the more easily treated leaves of castor, all five pesticides tested virtually eliminated the mite population in 2 weeks, and abamectin remained effective for up to 3 weeks.Dicofol and wettable sulphur were effective against all life stages of *P. latus* on chilli.

In Sao Paulo, Brazil, abamectin was the most efficient acaricide against *P. latus* in 12 applications at a range of rates and one application at a higher rate; the higher rate application maximized the production of beans. Chlorfenapyr is recommended for the control of *P. latus* on cotton in Sao Paulo.

Greenhouse tests in China showed that liuyangmycin (an antibiotic preparation from Streptomyces griseolus) gave the most effective and economical control of *P. latus* on green chilli peppers (Capsicum). Introduction of female adults or nymphs to plants 5 days after treatment with liuyangmycin resulted in 71.1 and 83% mortality, respectively. The effect declined after 7 days, but mite control for the 3 weeks after treatment remained >98%, which was equivalent to a control by dicofol. Three applications liuyangmycin to Capsicum in the greenhouse in September-April gave satisfactory control of the pest, with no side-effects.

In India, leaf extracts of *Lippia nodiflora* and *Aloe* sp. were shown to significantly reduce the population density of *P. latus* on chilli when sprayed as 5% aqueous extracts. In Brazil, Manipueira, a liquid extract from cassava roots, provided 100% control of *P. latus* on papaya plants when it was diluted in water (1:3) and sprayed three times at weekly intervals .

2.2.5. Parasitoid

There have been attempts to enhance mortality due to natural enemies by the introduction of species that might complement existing natural enemies or be superior to them. Attempted introductions have included parasitoids of *Heliothis virescens* and *Helicoverpa zea* from the Americas as well as species from other parts of the range of *H. armigera*. Few of these have been successful. *Trichogramma pretiosum* and *T. perkinsi* from the USA are reported to have become established in Indonesia and South Africa, respectively. Other successful establishments are: India (*Chelonus blackburni*, *Eucelatoria bryani*, both from the USA, and *Bracon kirkpatricki* from Kenya); Fiji (*Cotesia marginiventris*, also from the USA); New Zealand (*Glabrobracon croceipes* from the USA); Western Australia (*Cotesia kazak* and *Hyposoter didymator*, both from Europe).Several species of fungi were tested as possible biocontrol agents against *P. latus*. Mortality of *P. latus* caused by *Beauveria bassiana* occurred fastest at densities fluctuating between 65 and 125 mites per leaf.

2.2.6. Botanicals

There were about 3000 plants and trees with insecticidal and repellant properties in the world, and India was home to about 70 percent of this floral wealth. He stated the use of more than 450 botanical derivatives used in traditional agricultural system and neem was one of the well-documented trees, and almost all the parts of the tree had been found to have insecticidal value. The neem seed kernel extract, neem oil, extracts from the leaves and barks had all been used since ancient times to keep scores of insect pests away. A number of commercial neem based insecticides were now available and they had replaced several toxic chemical insecticides. The extracts were of particular value in controlling the sucking and chewing insect pests. The young caterpillars devouring the tender leaves were well managed by the botanical insecticides. The plant materials should be thoroughly washed before preparing the extract and the right quantity should be used (Sathyaseelan and Bhaskaran 2010).

Shrestha *et al*. (2010), suggested use of neem products and lantana products to protect plants against aphids (Chongtham *et al*. 2009). For small backyard infestations, simply spraying the plants thoroughly with a strong water jet every few days is sufficient protection for roses and other plants.

Azadirachtin had been exempted from residue tolerance requirements by the US environmental protection agency for food crop applications. It exhibited good 20 efficacy against key pests with minimal to no impact on non-target organisms. It was also compatible with other biological control agents and had a good fit into classical integrated pest management programs. Products derived from leaves and kernels of neem (*Azadirachta indica*) are becoming popular in plant protection programs for cotton, mainly because synthetic pesticides have several undesirable effects. Neem products acted both as systemic and as contact poisons and their effects were antifeedant, toxicological, repellent, sterility inducing or insect growth inhibiting. Furthermore, neem products appeared to be environmentally safe and IPM compatible and had the potential to be adopted on a broad scale, together with other measures, to provide a low cost management strategy. Indigenous plant materials were cheaper and hazard free in comparison to chemical insecticide. These were also easily available in everywhere in our country. The biological control agents *Bacillus thuringiensis* (Bt; Delfin 85 WG) at 0.04% and *Trichograma chilonis* at 60000/ha and insecticides Azadirachtin (Econeem) at, 0.0006%, Lufenuron (Match 5EC) at 0.005%, Avermectin (Vertimec [Abamectin] at 0,0004%, Monocrotophos 36SL (Monocil) at 0.05%, Spark 36EC (Detramethrin lEC + Triazophos 35EC) at 0.05%, Bulldock star 262.5EC (Beta-cyfluthrin12.5EC + Chlorpyrifos 250 and Nurelle-D.505. 55EC Cypermethrin 5 + Chlorpyrifos 50) at 0.05% were tested in a field trial in Rahuri, Maharashtra, India, ;ring the kharif season of 2000 against pest complex of brinjal. Azadirachtin was moderately effective against the sucking pest including *Bemisia tabaci*, *Aphis gossypii*, *Amrasca biguttula biguttula*.

The joint action potential of methanoic extract of neem seed kernel (*Azadirachta indica*) in combination with methanolic extracts of two other botanical, viz. sweet flag (*Acorus calamus*) and *Pongamia glabra* (*P. pinnata*) against *Ammrasca devastans* at 1:1:1,2:1:1 and 3:1:1 (v/v) ratio were studied. This combination at

0.42% concentration gave superior control of *A. devastans* (Rao and Rajendran 2002). An experiment was conducted with okra in India to determine the efficacy of neem based pesticide against the cotton jassid, *A. biguttula*. The treatments comprised Endosulfan at 0.07%, A Chook at 3% Neemarin at 0.7%, neem seed kernel extract (NSKE) at 1%, NSKE at 3% with an untreated control. Endosulfan followed by A Chook and NSKE (3%) were most effective in controlling the okra jassid. A Chook treated plots gave the highest yield of 50.06 q/ha and significantly superior to other treatments. However on the basis of cost benefit ratio NSKE (3%) ranked first.The treatments of neem seed kernel extract (NSKE) did not show a significant reduction in parasitization rate of fecundity of larval parasitoid, *Diadegma semiclausum*. The aqueous NSKE had no adverse effects on *D. semiclausum* following dfuect contact. The application of Quinalphos and Triazophos resulted in a resurgence of *A. biguttuta* on okra and abergine (Brinjal), while Endosulfan at 0.07% and Repelin (based on *Azadirachta indica*) l% were highly effective. In India neem oil was least persistant insecticides and caused >50% mortality of jassid only up to 24 hours after application. Different concentrations of soap solution were applied against jassid of cotton. Soap powder (25gm/liter of water) predominantly reduced the pest population during the period and harvested the best yield than other treatments economic return is reasonably satisfied.

2.2.7. IPM packages

Some IPM packages against the insect pests of chilli are given bellow:

Management	**Activity**
Vegetative stage	
Thrips	**Cultural control:** • Inter crop with Sesbania grandiflora, to provide barrier which regulate the thrips population. • Do not follow chilli and onion mixed crop – both the crops attacked by thrips • Sprinkle water over the seedlings to check the multiplication of thrips **Biological control**: • Conserve predators such as predatory mite (*Amblyseius swirskii*), insidious flower bugs (*Orius insidiosus*) etc.

	• Apply neem cake to the beds @ 100 kg/acre in two split doses at the time of planting and 30 days after transplanting **Chemical control**: • Seed treatment with imidacloprid 70% WS @ 400-600 g/100 kg seed. • Apply fipronil 5% SC @ 320-400 ml in 200 l of water/acre or lambda-cyhalothrin 4.9% CS @ 200 ml in 200 l of water/acre or lambda-cyhalothrin 5% EC @ 120 ml in 160-240 l of water/acre or spinosad 45% SC @ 64 ml in 200 l of water/acre or thiacloprid 21.7% SC @ 90-120 ml in 200 l of water/acre or acetamiprid 20% SP @ 20- 40 g in 200-240 l of water/acre or emamectin benzoate 5% SG @ 80 g in 200 l of water/acre or carbaryl 50% WP @ 800 g in 200-400 l of water/acre or carbofuran 3% CG @ 13320 g/acre or ethion 50% EC @ 600-800 ml in 200-400 l of water/acre or fenpropathrin 30% EC @ 100-136 ml in 300-400 l of water/acre or methomyl 40% SP @ 300-450 ml in 200-400 l of water/acre or oxydemeton-methy 25% EC @ 400 ml in 200-400 l of water/acre or phorate 10% CG @ 4000 g/acre or phosalone 35% EC @ 800 ml in 200-400 l of water/acre or indoxacarb 14.5% + acetamiprid 7.7% W/W SC @ 160-200 ml in 200 l of water/acre
Aphids	**Biological control**: • Conserve parasitoids such as *Aphidius colemani, Diaeretiella spp*. *Aphelinus spp*. etc. • Conserve predators such as anthocorid bugs/pirate bugs (*Orius* spp.), mirid bugs, syrphid/hover flies, green lacewings (*Mallada basalis* and *Chrysoperla carnea*), predatory coccinellids (*Stethorus punctillum*), staphylinid beetle (*Oligota* spp.), predatory cecidomyiid fly (*Aphidoletis aphidimyza*) and predatory gall midge, (*Feltiella minuta*), earwigs, ground beetles, rove beetles, spiders, wasps etc. **Chemical control:** • Seed treatment with imidacloprid 70% WS @ 400-600 g/100 kg seed. • Apply fipronil 5% SC @ 320-400 ml in 200 l of water/acre or oxydemeton methyl 25% EC @ 640 ml in 200-400 l of water/acre or carbofuran 3% CG @ 13320 g/acre or carbosulfan 25% EC @ 320-400 ml in 200- 400 l of water/acre or phorate 10% CG @ 4000 g/acre or phosalone 35% EC @ 800 ml in 200-400 l of water/acre or quinalphos 25% GEL @ 400 g in 200-400 l of water/acre or quinalphos 25% EC @ 400 ml in 200-400 l of water/acre or quinalphos 1.5% DP @ 8000 g/acre • Alternate chemicals at 10 days interval till the end of aphid population

Yellow mite/other mites	**Cultural control**: • Chilli crop bordered by two rows of maize at every 0.5 acre area (31.2 x 60 sqm). **Biological control**: • Conserve the predators such as predatory mite (*Amblyseius ovalis*), predatory bug (*Orius* spp.), spiders etc. • If the incidence of mites is low, spray neem seed powder extract 4% at 10 days interval **Chemical control**: • Spray dimethoate 30% EC @ 396 ml in 200-400 l of water/acre or emamectin benzoate 5% SG @ 80 g in 200 l of water/acre or fenazaquin 10% EC @ 500 ml in 160-240 l of water/acre or fenpropathrin 30% EC @ 100-136 ml in 300-400 l of water/acre or fenpyroximate 5% EC @ 120-240 ml in 120-200 l of water/acre or milbemectin 1% EC @ 130 ml in 200 l of water/acre or propargite 57% EC @ 600 ml in 200-250 l of water/acre or spiromesifen 22.9% SC@ 160 ml in 200- 300 l of water/acre or chlorfenapyr 10% SC @ 300-400 ml in 200 l of water/acre or diafenthiuron 50% WP @ 240 g in 200-300 l of water/acre or ethion 50% EC @ 600-800 ml in 200-400 l of water/acre or hexythiazox 5.45% W/W EC @ 120-200 ml in 250 l of water/acre or lambda-cyhalothrin 5% EC @ 120 ml in 160-240 l of water/acre or or oxydemeton-methy 25% EC @ 800 ml in 200-400 l of water/acre or phorate 10% CG @ 4000 g/acre or phosalone 35% EC @ 514 ml in 200-400 l of water/acre or quinalphos 25% EC @ 600 ml in 200-400 l of water/acre
Tobacco caterpillar	**Cultural control:** • Field sanitation and roguing • Castor can be grown as a trap crop along the field border to attract the egg laying female adult moths (collect and destroy the laid egg masses and gregarious neonates) • Pest repellant plants: Ocimum/Basil • Setting up light traps for collecting adults @ 1/acre • Erecting of bird perches for encouraging predatory birds such as king crow, mynah etc. • Install pheromone traps @ 4-5/acre for monitoring adult moth activity. Replace the lures with fresh lures after every 2-3 weeks **Biological control**: • Spray NSKE 5 % against eggs and first instar larva. • Spray B. t. var gallariae @ 600-800 g in 400 l of water/acre • Conserve parasitoids such as *Trichogramma chilonis* (egg), *Tetrastichus* spp. (egg), *Telenomus* spp. (egg), *Chelonus blackburni* (egg-larval), *Carcelia* spp. (larval-pupal), *Campoletis chlorideae* (larval), *Eriborus argentiopilosus* (larval), *Microplitis* sp etc.

	• Conserve predators such as *Chrysoperla carnea*, coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthecona furcellata*), earwigs, ground beetles, rove beetles etc. **Chemical control** • Apply emamectin benzoate 5% SG @ 80 g in 200 l of water/acre or fipronil 5% SC @ 320-400 ml in 200 l of water/acre or flubendiamide 39.35% M/M SC @ 40-50 ml in 200 l of water/acre or indoxacarb 14.5% SC @ 133-160 ml in 120-240 l of water/acre or lufenuron 5.4% EC @ 240 ml in 200 l of water/acre or spinosad 45% SC @ 64 ml in 200 l of water/acre or novaluron 10 % EC @ 150 ml in 200 l of water/acre or chlorantraniliprole 18.5% SC @ 60 ml in 200 l of water/acre or deltamethrin 2.8% EC @ 160-200 ml in 160-240 l of water/acre or lambda-cyhalothrin 4.9% CS @ 200 ml in 200 l of water/acre or lambda-cyhalothrin 5% EC @ 120 ml in 160-240 l of water/acre or methomyl 40% SP @ 300-450 ml in 200- 400 l of water/acre or thiodicarb 75% WP @ 250.4-400 g in 200 l of water/acre or indoxacarb 14.5% + acetamiprid 7.7% W/W SC @ 160-200 ml in 200 l of water/acre or pyriproxyfen 5% + fenpropathrin 15% EC @ 200-300 ml in 200-300 l of water/acre
Gram pod borer	**Cultural control:** • Field sanitation and roguing • Erecting suitable physical barriers such as nylon nets • Growing intercrops such as cowpea, onion, maize, coriander, urdbean in 5 or 4:1 ratio • Guard crop sorghum or maize in 4 rows all around cotton crop as guard crop. • Rotate the chilli crop with a non-host cereal crop, cucurbit, or cruciferous vegetable. • Repellant plants: Ocimum/Basil • Erecting of bird perches for encouraging predatory birds such as king crow, mynah, and drongo etc. • Install pheromone traps @ 4-5/acre for monitoring adult moths activity. Replace the lures with fresh lures after every 2-3 weeks • Use of ovipositional trap crops such as marigold @ 100 plants/acre 1 row of marigold for every 18 rows of chilli and collection of larvae from flowers (marigold seedling of 45 days should be planted along with chilli transplanting) **Biological control:** • Release of egg parasitoid Trichogramma pretiosum @ 50,000 adults (in the form of parasitized card)/acre/week commenced right from the start of flower initiation to till end of the crop, tie the egg cards on the stick placed through out the field at 4-5 m apart, in the evening, a day prior to the

	emergence of adult. • Conserve parasitoids such as *Tetrastichus* spp. (egg), *Telenomus* spp. (egg), *Campoletis chlorideae* (larval) etc. • Conserve predators such as *Chrysoperla carnea*, coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs (*Geocoris* sp), pentatomid bug (*Eocanthecona furcellata*), earwigs, ground beetles, rove beetles etc. **Chemical control:** • Seed treatment with thiamethoxam 30% FS @ 7 g/kg seed • Apply emamectin benzoate 5% SG @ 80 g in 200 l of water/acre or fipronil 5% SC @ 320-400 ml in 200 l of water/acre or flubendiamide 39.35% M/M SC @ 40-50 ml in 200 l of water/acre or indoxacarb 14.5% SC @ 133-160 ml in 120-240 l of water/acre or lufenuron 5.4% EC @ 240 ml in 200 l of water/acre or spinosad 45% SC @ 64 ml in 200 l of water/acre or novaluron 10 % EC @ 150 ml in 200 l of water/acre or chlorantraniliprole 18.5% SC @ 60 ml in 200 l of water/acre or deltamethrin 2.8% EC @ 160-200 ml in 160-240 l of water/acre or lambda-cyhalothrin 4.9% CS @ 200 ml in 200 l of water/acre or lambda-cyhalothrin 5% EC @ 120 ml in 160-240 l of water/acre or methomyl 40% SP @ 300-450 ml in 200- 400 l of water/acre or thiodicarb 75% WP @ 250.4-400 g in 200 l of water/acre or indoxacarb 14.5% + acetamiprid 7.7% W/W SC @ 160-200 ml in 200 l of water/acre or pyriproxyfen 5% + fenpropathrin 15% EC @ 200-300 ml in 200-300 l of water/acre
Reproductive stage	
Nutrients	• Micronutrient deficiency should be corrected by foliar spray of particular micronutrient.
Weeds	• Left over weeds should be removed from the field to avoid further spread of weed seeds.
Gram pod borer and Tobacco caterpillar	• Same as in vegetative stage
Thrips	• Same as in vegetative stage
Mites	• Same as in vegetative stage

Source: AESA 2014

CHAPTER III

MATERIALS AND METHODS

The present study regarding damage assessment and management of insect and mite pests on chilli particularly gram pod borer, tobacco caterpillar, aphid, thrips and broad mite has been conducted during October 2019 to February 2020 in the experimental field of SAU, Dhaka. Laboratory studies were also done in the laboratory under the Department of Entomology, SAU. Required materials and methodology are described below under the following sub-headings:

3.1. Location

The experiments were conducted in the experimental farm of SAU, Dhaka-1207 situated at latitude 23.46N and longitude 90.23E with an elevation of 8.45 meter the sea level. Laboratory studies were done in the laboratory of Entomology department, SAU.

3.2. Climate

The experimental area is characterized by subtropical rainfall during the month of May to September and scattered rainfall during the rest of the year.

3.3. Soil

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with pH 5.8-6.5, CEC-25.28 .

3.4. Land preparation

The soil was well prepared and good tilth was ensured for commercial crop production. The target land was divided into 21 equal plots (2m×3m) with plot to plot distance of 0.50 m and block to block distance is 0.75 m. The land of the experimental field was ploughed with a power tiller. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was ready. The field layout and design of the experiment were followed immediately after land preparation.

3.5. Manure and fertilizer

Recommended fertilizers were applied at the rate of 60 kg urea, 70 kg triple super phosphate (TSP), 60 kg muriate of potash (MP), 25 kg Gypsum and 1.25 kg Zinc oxide per hectare were used as source of nitrogen, phosphorus, potassium, sulpher and zinc, respectively. Moreover, well-decomposed cow dung (CD) was also applied at the rate of 20 ton/ha to the field at the time of land preparation (Miah *et al.* 2005).

3.6. Design of experiment and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with 3 replications. The whole area of experimental field was divided into 3 blocks and each block was again divided into 7 unit plots. The size of the unit plot was 2m×3m. The block to block and plot-to-plot distance was 0.75m and 0.50m, respectively.

3.7. Collection of seed, seedling raising

The seeds of selected chilli variety BARI Morich-1 was collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Before sowing, the germination test of seeds was done and on an average, 90% germination was found for this variety. Seeds were then sown on the 10th October, 2019 in seedbed containing a mixture of equal proportion well decomposed cow dung and loam soil. After sowing seeds, the seedbeds were irrigated regularly. After germination, the seedlings were sprayed with water by a hand sprayer. Soil was spaded 3 or 4 days for a week.

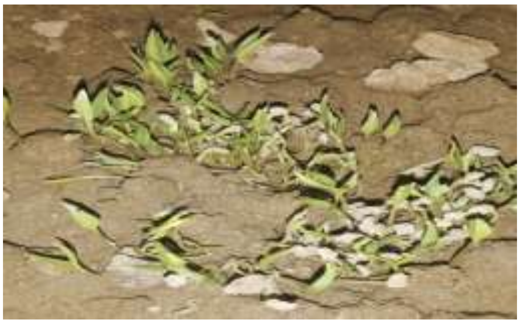

Plate 1: Sprouted seed in seedbed

Plate 2: Seedling raising in seedbed

3.8. Seedling transplanting

The 20 days old healthy and uniform sized seedlings of chilli variety was transferred in polybag on November 1st, 2019. Then 25 days old healthy transferred seedlings were transplanted in the main field on November 26th, 2019. Each plot contains 6 seedlings of chilli with 50cm (plant to plant distance).

Plate 3: Seedling transplanting in main field

3.9. Cultural practices

After transplanting, a light irrigation was given. Subsequent irrigation was applied in all the plots as and when needed. Various intercultural operations like gap filling, weeding, earthen up, drainage, sticking, netting, fencing, binding etc. was done as and when necessary to cultivate chilli.

3.10. Treatments

The experiment was evaluated to determine the damage assessment and management of insect and other arthropod pests of chilli particularly gram pod borer, tobacco catarpiller, aphid, thrips, and broad mite. The treatments were used in this study are given follow:-

Treatments	Doses
T_1	Spraying Confidor 2G @ 0.2g/L of water at 7 days intervals
T_2	Spraying Actara 25WG @ 0.05g/L of water at 7 days intervals
T_3	Spraying Ethion 46.5EC @ 3ml/L of water at 7 days intervals
T_4	Spraying Omite 57EC @ 2ml/L of water at 7 days intervals
T_5	Spraying Neem Oil @ 3ml/L of water mixing with 10ml/10gm detergent or trix at 7 days intervals
T_6	Spraying Bioneem Plus 1EC @ 1ml/L of water at 7 days intervals
T_7	Untreated control where only water will be sprayed at 7 days intervals

3.11. Neem oil preparation

The fresh neem oil was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the local market of Agargoan bazaar, Dhaka. A quantity of 3ml fresh neem oil and 10ml liquid trex was mixed in 1000ml 0f water to make 0.3% neem oil mixture. For neem oil application, 15 ml neem oil (@ 3.0 ml/L of water i.e. 0.3% per 5 liter of water was used. The mixture was sprayed on the upper and lower surface of the plants of the treatment until the drop run off from the plant.

3.12. Treatment application

T_1: Confidor 2G @ 0.2 g/L of water was sprayed at 7 days interval. For this treatment 1.0 gm of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 15 DAT.

T_2: Actara 25WG @ 0.05g/L of water was sprayed at 7 days interval. For this treatment 0.25g of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 15 DAT.

T_3: Ethion 46.5EC @ 3ml/L of water was sprayed at 7 days interval. For this treatment 15ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 15 DAT.

T_4: Omite 57EC @ 2ml/L of water was sprayed at 7 days interval. For this treatment 10.0ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 15 DAT.

T_5: Neem oil @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, neem oil was applied @ 15 ml /5L of water mixed with trix liquid detergent @ 10 ml (1%) to make the oil easy soluble in water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 15 DAT.

T_6: Bioneem Plus 1EC @ 1ml/L of water was sprayed at 7 days interval. For this treatment 5ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 15 DAT.

T_7: Untreated control treatment. There was no any control measure was applied in capsicum field.

3.13. Data collection

For data collection, five plants per plot were randomly selected and tagged. Data collection was started at vegetative stage of chilli plant. The data were recorded on number of gram pod borer, tobacco caterpillar, aphid, thrips and broad mite, number of infested leaves by the insects and number of infested fruit by the insects. The following parameters were considered during data collection.

3.13.1. Number of insect pests of chilli and number of infested leaves caused by different insect pests and mite

Data were collected on the number of gram pod borer, tobacco caterpillar, aphid, thrips, broad mite and number of infested leaves and fruits caused by gram pod borer, tobacco caterpillar, aphid, thrips, and broad mite randomly selected 5 tagged plants per plot and counted separately for each treatment. Data were collected through visual observation in the morning.

3.13.2. Number of infested plants by different insect pests and mite of chilli

Data were collected on the number of infested plants by different insect pests and mite of chilli per plot and counted separately for each treatment.

3.13.3. Number and weight of the healthy and infested chilli fruits

Data were collected on the number of healthy and infested chilli fruits per plot which was harvested at fully mature stage of fruit and weighted separately for each treatment.

3.14. Calculation

3.14.1. Percent of infested leaves by insect pests and mite of chilli

Number of infested leaves was counted from total leaves per five plants and percent leaf infestation by insect pests and mite of chilli were calculated as follows:

$$\% \text{ of infested leaves} = \frac{\text{Number of infested chilli leaves}}{\text{Total number of chilli leaves}} \times 100$$

3.14.2. Percent of infested plants by insect pests and mite of chilli

Number of infested plants was counted from total plants per plot and percent plant infestation by insect pests and mite of chilli were calculated as follows:

$$\% \text{ of infested plants} = \frac{\text{Number of infested chilli plants}}{\text{Total number of chilli plants}} \times 100$$

3.14.3. Percent fruit infestation by number

Infested fruits were counted from total harvested and the percent chilli fruit infestation was calculated using the following formula:

$$\% \text{ fruit infestation (number)} = \frac{\text{Number of the infested fruit}}{\text{Total number of fruit}} \times 100$$

3.14.4. Percent fruit infestation by weight

Weight of the infested chilli fruits were recorded from total weight of the harvested chilli fruit and the percent chilli fruit infestation by weight was calculated using the following formula:

$$\% \text{ fruit infestation (weight)} = \frac{\text{Weight of the infested fruit}}{\text{Total weight of fruit}} \times 100$$

3.14.5. Percent reduction of chilli fruit infestation over control

The number and weight of infested chilli fruit and total chilli fruit for each treated plot and untreated control plot were recorded and the percent reduction of chilli fruit infestation in number and weight was calculated using the following formula:

$$\% \text{ fruit infestation reduction over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where, X_1 = the mean value of the treated plot

X_2 = the mean value of the untreated plot

3.14.6. Percent yield loss

The weight of infested chilli fruit was recorded from the total weight of the harvested chilli fruit for each plot and the percent yield loss was calculated considering the following formula:

$$\%\ \text{yield loss} = \frac{\text{Avg. wt. of healthy fruit} - \text{Avg. wt. of whole plot}}{\text{Average weight of healthy fruit per plot}} \times 100$$

3.14.7. Statistical analysis

Data statistically analyzed by Randomized Complete Block Design (RCBD) through MSTAT-C software and LSD range tests was used to determine the damage assessment and management of insect and mite pests of chilli with regards to study gram pod borer, tobacco caterpillar, aphid, thrips and broad mite infestation.

Plate 4: Aphid Infested Leaves of chilli plant

Plate 5: Healthy and infested fruites in different treatment

Plate 6: Healthy Chilli plant with Lady bird beetle (Predator) in Experimental field

Plate 7: Flower of chilli plant in Experimental field.

Plate 8: Healthy Chilli plant with healthy fruites in Experimental field

Plate 9: Healthy Chilli (fruites) during the study period after harvest.

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to evaluate damage assessment and management of insect and mite pests on chilli in the field under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2019 to February, 2020. The results have been presented and discussed, and possible interpretations have been given under the following sub-headings:

4.1. Number of insect pests of chilli

4.1.1. Aphid

The significant variation was observed among different treatments used in this study in terms of number of aphid per ten tagged plants in the chilli field at different days after transplanting by visual observation. In case of 30 DAT, T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (0.70 aphids), which was followed by T_4 (1.93), T_5 (2.99) and T_6 (3.80 aphids). On the other hand, the lowest performance was showed in T_7 (5.51 aphids) comprises with untreated control, which was significantly similar with T_2 (5.39) followed by T_1 (4.76 aphids) (Table 1). More or less same trend of result was observed in case of 40 DAT and 50 DAT.

In case of average, T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (0.53 aphids), which was followed by T_4 (1.66), T_5 (2.81) and T_6 (3.57 aphids). On the other hand, the lowest performance was showed in T_7 (5.32 aphids) comprises with untreated control, which was followed by T_2 (4.99) and T_1 (4.32 aphids) (Table 1).

Table 1: Effect of different treatments on the number of aphid per ten tagged plants of chilli

Treatments	Number of aphid per ten tagged plants			
	30 DAT	**40 DAT**	**50 DAT**	**Average**
T_1	4.76 b	4.39 b	3.18 c	4.32 c
T_2	5.39 a	5.04 a	4.52 b	4.99 b
T_3	0.70 f	0.52 f	0.36 g	0.53 g
T_4	1.93 e	1.52 e	1.52 f	1.66 f
T_5	2.99 d	2.67 d	2.76 e	2.81 e
T_6	3.80 c	3.62 c	3.28 d	3.57 d
T_7	5.51 a	5.28 a	5.18 a	5.32 a
CV (%)	7.48	6.21	6.29	3.53
LSD $_{(0.05)}$	0.46	0.35	0.33	0.20

[T_1: Spraying Confidor 2G @ 0.2g/L of water at 7 days intervals; T_2: Spraying Actara 25WG @ 0.05g/L of water at 7 days intervals; T_3: Spraying Ethion 46.5EC @ 3ml/L of water at 7 days intervals; T_4: Spraying Omite 57EC @ 2ml/L of water at 7 days intervals; T_5: Spraying Bioneem Plus 1EC @ 1ml/L of water at 7 days intervals; T_6: Spraying Neem Oil @ 3ml/L of water mixing with 10ml/10gm detergent or trix at 7 days intervals; T_7: Untreated control where only water will be sprayed at 7 days intervals]

From this above findings it was revealed that, T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment (0.53 aphids). Whereas the lowest performance showed in T_7 (5.32 aphids) (untreated control). As a result, the order of efficacy of different treatments in terms of number of aphids per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

4.1.2. Thrips

The significant variation was observed among different treatments used in this study in terms of number of thrips per ten tagged plants in the chilli field at different days after transplanting by visual observation. In case of 30 DAT, T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (1.37 thrips), which was followed by T_4 (2.65), T_5 (3.27) and T_6 (3.92 thrips). On the other hand, the lowest performance was showed in T_7 (5.27 thrips) comprises with untreated control, which was followed by T_2 (4.59) and T_1 (4.36 thrips) (Table 2). More or less same trend of result was observed in case of 40 DAT and 50 DAT.

In case of average, T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (1.04 thrips), which was followed by T_4 (1.88), T_5 (2.57) and T_6 (3.18 thrips). On the other hand, the lowest performance was showed in T_7 (4.60 thrips) comprises with untreated control, which was followed by T_2 (4.06) and T_1 (3.68 thrips) (Table 2).

Table 2: Effect of different treatments on the number of thrips per ten tagged plants of chilli

Treatments	**Number of thrips per ten tagged plants**			
	30 DAT	**40 DAT**	**50 DAT**	**Average**
$\mathbf{T_1}$	4.36 bc	3.59 bc	3.11 b	3.68 c
$\mathbf{T_2}$	4.59 b	4.11 b	3.48 ab	4.06 b
$\mathbf{T_3}$	1.37 f	1.05 e	0.70 e	1.04 g
$\mathbf{T_4}$	2.65 e	1.55 e	1.44 d	1.88 f
$\mathbf{T_5}$	3.27 d	2.56 d	1.89 d	2.57 e
$\mathbf{T_6}$	3.92 c	3.14 c	2.49 c	3.18 d
$\mathbf{T_7}$	5.27 a	4.66 a	3.86 a	4.60 a
CV (%)	7.64	10.76	12.99	7.22
LSD $_{(0.05)}$	0.47	0.54	0.54	0.37

[T_1: Spraying Confidor 2G @ 0.2g/L of water at 7 days intervals; T_2: Spraying Actara 25WG @ 0.05g/L of water at 7 days intervals; T_3: Spraying Ethion 46.5EC @ 3ml/L of water at 7 days intervals; T_4: Spraying Omite 57EC @ 2ml/L of water at 7 days intervals; T_5: Spraying Bioneem Plus 1EC @ 1ml/L of water at 7 days intervals; T_6: Spraying Neem Oil @ 3ml/L of water mixing with 10ml/10gm detergent or trix at 7 days intervals; T_7: Untreated control where only water will be sprayed at 7 days intervals]

From this above findings it was revealed that, T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment (1.04 thrips). Whereas the lowest performance showed in T_7 (4.60 thrips) (untreated control). As a result, the order of efficacy of different treatments in terms of number of thrips per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

4.1.3. Gram pod borer

The significant variation was observed among different treatments used in this study in terms of number of gram pod borer per ten tagged plants in the chilli field at different days after transplanting by visual observation. In case of 30 DAT, T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (1.80 gram pod borer), which was significantly similler with T_4 (2.06) and followed by T_5 (2.55) and T_6 (2.67 gram pod borer). On the other hand, the lowest performance was showed in T_7 (5.30 gram pod borer) comprises with untreated control, which was followed by T_2 (4.23) and T_1 (3.36 gram pod borer) (Table 3). More or less same trend of result was observed in case of 40 DAT and 50 DAT.

In case of average, T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (1.19 gram pod borer), which was followed by T_4 (1.67), T_5 (2.09) and T_6 (2.30 gram pod borer). On the other hand, the lowest performance was showed in T_7 (4.68 gram pod borer) comprises with untreated control, which was followed by T_2 (3.90) and T_1 (3.28 gram pod borer) (Table 3).

Table 3: Effect of different treatments on the number of gram pod borer per ten tagged plants of chilli

Treatments	Number of gram pod borer per ten tagged plants			
	30 DAT	40 DAT	50 DAT	Average
T_1	3.36 c	3.29 c	3.19 b	3.28 c
T_2	4.23 b	3.82 b	3.65 b	3.90 b
T_3	1.80 e	1.08 f	0.68 d	1.19 f
T_4	2.06 e	1.82 e	1.12 cd	1.67 e
T_5	2.55 d	2.40 d	1.33 c	2.09 d
T_6	2.67 d	2.60 d	1.64 c	2.30 c
T_7	5.30 a	4.44 a	4.28 a	4.68 a
CV (%)	5.36	9.54	13.29	6.33
LSD $_{(0.05)}$	0.29	0.45	0.51	0.30

[T_1: Spraying Confidor 2G @ 0.2g/L of water at 7 days intervals; T_2: Spraying Actara 25WG @ 0.05g/L of water at 7 days intervals; T_3: Spraying Ethion 46.5EC @ 3ml/L of water at 7 days intervals; T_4: Spraying Omite 57EC @ 2ml/L of water at 7 days intervals; T_5: Spraying Bioneem Plus 1EC @ 1ml/L of water at 7 days intervals; T_6: Spraying Neem Oil @ 3ml/L of water mixing with 10ml/10gm detergent or trix at 7 days intervals; T_7: Untreated control where only water will be sprayed at 7 days intervals]

From this above findings it was revealed that, T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment (1.19 gram pod borer). Whereas the lowest performance showed in T_7 (4.68 gram pod borer) (untreated control). As a result, the order of efficacy of different treatments in terms of number of gram pod borer per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

4.1.4. Tobacco caterpillar

The significant variation was observed among different treatments used in this study in terms of number of tobacco caterpillar per ten tagged plants in the chilli field at different days after transplanting by visual observation. In case of 30 DAT, T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (0.84 tobacco caterpillar), which was followed by T_4 (1.26), T_5 (1.71) and T_6 (2.09 tobacco caterpillar). On the other hand, the lowest performance was showed in T_7 (3.85 tobacco caterpillar) comprises with untreated control, which was followed by T_2 (3.44) and T_1 (2.38 tobacco caterpillar) (Table 4). More or less same trend of result was observed in case of 40 DAT and 50 DAT.

In case of average, T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (0.60 tobacco caterpillar), which was followed by T_4 (1.03), T_5 (1.42) and T_6 (1.88 tobacco caterpillar). On the other hand, the lowest performance was showed in T_7 (3.47 tobacco caterpillar) comprises with untreated control, which was followed by T_2 (3.07) and T_1 (2.27 tobacco caterpillar) (Table 4).

From this above findings it was revealed that, T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment (0.60 tobacco caterpillar). Whereas the lowest performance showed in T_7 (3.47 tobacco caterpillar) (untreated control). As a result, the order of efficacy of different treatments in terms of number of tobacco caterpillar per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

Table 4: Effect of different treatments on the number of tobacco caterpiller per ten tagged plants of chilli

Treatments	Number of tobacco caterpiller per ten tagged plants			
	30 DAT	40 DAT	50 DAT	Average
T_1	2.38 c	2.32 c	2.11 b	2.27 c
T_2	3.44 b	3.01 b	2.76 a	3.07 b
T_3	0.84 g	0.53 e	0.42 e	0.60 g
T_4	1.26 f	1.03 d	0.80 de	1.03 f
T_5	1.71 e	1.42 d	1.12 d	1.42 e
T_6	2.09 d	1.89 c	1.66 c	1.88 d
T_7	3.85 a	3.47 a	3.07 a	3.47 a
CV (%)	5.74	12.80	13.07	8.39
$LSD_{(0.05)}$	0.22	0.43	0.38	0.28

[T_1: Spraying Confidor 2G @ 0.2g/L of water at 7 days intervals; T_2: Spraying Actara 25WG @ 0.05g/L of water at 7 days intervals; T_3: Spraying Ethion 46.5EC @ 3ml/L of water at 7 days intervals; T_4: Spraying Omite 57EC @ 2ml/L of water at 7 days intervals; T_5: Spraying Bioneem Plus 1EC @ 1ml/L of water at 7 days intervals; T_6: Spraying Neem Oil @ 3ml/L of water mixing with 10ml/10gm detergent or trix at 7 days intervals; T_7: Untreated control where only water will be sprayed at 7 days intervals]

4.1.5. Mite

The significant variation was observed among different treatments used in this study in terms of number of mites per ten tagged plants in the chilli field at different days after transplanting by visual observation. In case of 30 DAT, T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (1.63 mites), which was followed by T_4 (2.50), T_5 (4.59) and T_6 (7.40 mites). On the other hand, the lowest performance was showed in T_7 (10.73 mites) comprises with untreated control, which was followed by T_2 (9.55) and T_1 (8.47 mites) (Table 5). More or less same trend of result was observed in case of 40 DAT and 50 DAT. In case of average, T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (0.81 mites), which was followed by T_4 (1.37), T_5 (2.70) and T_6 (4.80 mites). On the other hand, the lowest performance was showed in T_7 (7.96 mites) comprises with untreated control, which was followed by T_2 (6.37) and T_1 (5.47 mites) (Table 5).

Table 5: Effect of different treatments on the number of mite per ten tagged plants of chilli

Treatments	Number of mite per ten tagged plants			
	30 DAT	40 DAT	50 DAT	Average
T_1	8.47 c	4.65 c	3.29 c	5.47 c
T_2	9.55 b	5.52 b	4.04 b	6.37 b
T_3	1.63 g	0.45 f	0.34 f	0.81 g
T_4	2.50 f	1.00 e	0.62 f	1.37 f
T_5	4.59 e	2.13 d	1.37 e	2.70 e
T_6	7.40 d	4.45 c	2.55 d	4.80 d
T_7	10.73 a	7.62 a	5.52 a	7.96 a
CV (%)	3.70	4.97	7.19	3.46
LSD $_{(0.05)}$	0.40	0.31	0.31	0.25

[T_1: Spraying Confidor 2G @ 0.2g/L of water at 7 days intervals; T_2: Spraying Actara 25WG @ 0.05g/L of water at 7 days intervals; T_3: Spraying Ethion 46.5EC @ 3ml/L of water at 7 days intervals; T_4: Spraying Omite 57EC @ 2ml/L of water at 7 days intervals; T_5: Spraying Bioneem Plus 1EC @ 1ml/L of water at 7 days intervals; T_6: Spraying Neem Oil @ 3ml/L of water mixing with 10ml/10gm detergent or trix at 7 days intervals; T_7: Untreated control where only water will be sprayed at 7 days intervals]

From this above findings it was revealed that, T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment (0.81 mites). Whereas the lowest performance showed in T_7 (7.96 mites) (untreated control). As a result, the order of efficacy of different treatments in terms of number of mites per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

4.2. Leaves of chilli

4.2.1. Number of leaves

The significant variation was observed among different treatments used in this study in terms of number of leaves per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (152.3 leaves), which was followed by T_4 (140.8), T_5 (129.7) and T_6 (128.5 leaves). On the other hand, the lowest performance was showed in T_7 (106.2

leaves) comprises with untreated control, which was statistically similar with T_2 (108.5) and followed by T_1 (125.8 leaves) (Table 6).

4.2.2. Aphid infested leaves

The significant variation was observed among different treatments used in this study in terms of number of infested leaves caused by aphid per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (64.67 leaves), which was followed by T_4 (76.13), T_5 (84.40) and T_6 (85.27 leaves). On the other hand, the lowest performance was showed in T_7 (97.33 leaves) comprises with untreated control, which was statistically similar with T_2 (95.80) and T_1 (93.60 leaves) (Table 6).

4.2.3. Thrips infested leaves

The significant variation was observed among different treatments used in this study in terms of number of infested leaves caused by thrips per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (66.67 leaves), which was significantly similar with T_4 (67.40) and followed by T_5 (74.60) and T_6 (76.20 leaves). On the other hand, the lowest performance was showed in T_7 (87.33 leaves) comprises with untreated control, which was statistically similar with T_2 (84.40) and followed by T_1 (76.53 leaves) (Table 6).

4.2.4. Mite infested leaves

The significant variation was observed among different treatments used in this study in terms of number of infested leaves caused by mite per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (47.20 leaves), which was significantly similar with T_4 (53.40) and followed by T_5 (59.40) and T_6 (65.20 leaves). On the other hand, the lowest performance was showed in T_7 (78.40 leaves) comprises with untreated control, which was statistically similar with T_2 (72.20) and followed by T_1 (67.60 leaves) (Table 6).

4.2.5. Total infested leaves

The significant variation was observed among different treatments used in this study in terms of number of total infested leaves per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (89.40 leaves), which was followed by T_4 (92.60), T_5 (95.60) and T_6 (97.20 leaves). On the other hand, the lowest performance was showed in T_7 (102.40 leaves) comprises with untreated control, which was statistically similar with T_2 (98.40) and followed by T_1 (97.20 leaves) (Table 6).

4.2.6. Percent infested leaves

The significant variation was observed among different treatments used in this study in terms of percent infested leaves per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (58.70%), which was followed by T_4 (65.77), T_5 (73.71) and T_6 (75.64%). On the other hand, the lowest performance was showed in T_7 (96.42%) comprises with untreated control, which was followed by T_2 (90.69) and T_1 (77.27%) (Table 6).

4.2.7. Percent reduction over control

T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (39.12%) on the reduction over control, which was followed by T_4 (31.79), T_5 (23.55) and T_6 (21.55%). On the other hand, the lowest performance was showed in T_2 (5.94%) comprises with untreated control on the reduction over control, which was followed by T_1 (19.86%) (Table 6).

Table 6: Effect of different treatments on the total number of leaves and number of infested leaves ten tagged plants of chilli

Treatments	Number of leaves per ten tagged plants						
	Total leaves	Aphid infested leaves	Thrips infested leaves	Mite infested leaves	Total infested leaves	% Infested leaves	% Reduction over control
T_1	125.8 c	93.60 a	76.53 b	67.60 bc	97.20 bc	77.27 c	19.86
T_2	108.5 d	95.80 a	84.40 a	72.20 ab	98.40 ab	90.69 b	5.94
T_3	152.3 a	64.67 d	66.67 c	47.20 e	89.40 c	58.70 e	39.12
T_4	140.8 b	76.13 c	67.40 c	53.40 de	92.60 c	65.77 d	31.79
T_5	129.7 c	84.40 b	74.60 b	59.40 cd	95.60 bc	73.71 c	23.55
T_6	128.5 c	85.27 b	76.20 b	65.20 bc	97.20 bc	75.64 c	21.55
T_7	106.2 d	97.33 a	87.33 a	78.40 a	102.40 a	96.42 a	0
CV (%)	2.70	3.19	3.39	8.16	7.15	7.34	-
LSD $_{(0.05)}$	5.85	4.64	4.40	8.80	12.09	9.82	-

[T_1: Spraying Confidor 2G @ 0.2g/L of water at 7 days intervals; T_2: Spraying Actara 25WG @ 0.05g/L of water at 7 days intervals; T_3: Spraying Ethion 46.5EC @ 3ml/L of water at 7 days intervals; T_4: Spraying Omite 57EC @ 2ml/L of water at 7 days intervals; T_5: Spraying Bioneem Plus 1EC @ 1ml/L of water at 7 days intervals; T_6: Spraying Neem Oil @ 3ml/L of water mixing with 10ml/10gm detergent or trix at 7 days intervals; T_7: Untreated control where only water will be sprayed at 7 days intervals]

From this above findings it was revealed that, T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment in case of total number of leaves, aphid infested leaves, thrips infested leaves, mite infested leaves, total infested leaves and percent leaf infestation. Whereas the lowest performance showed in T_7 (untreated control) in case of total number of leaves, aphid infested leaves, thrips infested leaves, mite infested leaves, total infested leaves and percent leaf infestation. As a result, the order of efficacy of different treatments in terms of total number of leaves, aphid infested leaves, thrips infested leaves, mite infested leaves, total infested leaves and percent leaf infestation per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

4.3. Fruits of chilli

4.3.1. Number of fruits

The significant variation was observed among different treatments used in this study in terms of number of fruits per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (117.60 fruits), which was statistically similar with T_4 (108.20) and followed by T_5 (103.00) and T_6 (84.20 fruits). On the other hand, the lowest performance was showed in T_7 (21.00 fruits) comprises with untreated control, which was followed by T_2 (80.40) and T_1 (84.20 fruits) (Table 7).

4.3.2. Thrips infested fruits

The significant variation was observed among different treatments used in this study in terms of number of infested fruits caused by thrips per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (8.10 fruits), which was statistically similar with T_4 (8.50), T_5 (8.80) and T_6 (9.20 fruits). On the other hand, the lowest performance was showed in T_7 (12.70 fruits) comprises with untreated control, which was followed by T_2 (11.30) and T_1 (9.60 fruits) (Table 7).

4.3.3. Bored fruits

The significant variation was observed among different treatments used in this study in terms of number of bored fruit caused by gram pod borer per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (2.70 fruits), which was significantly similar with T_4 (3.30) and followed by T_5 (5.60) and T_6 (7.60 fruits). On the other hand, the lowest performance was showed in T_7 (14.70 fruits) comprises with untreated control, which was statistically similar with T_2 (12.30) and followed by T_1 (8.60 fruits) (Table 7).

4.3.4. Total infested fruits

The significant variation was observed among different treatments used in this study in terms of number of infested fruits per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (9.40 fruits), which was significantly similar with T_4 (9.70) and followed by T_5 (11.40) and T_6 (12.30 fruits). On the other hand, the lowest performance was showed in T_7 (15.00 fruits) comprises with untreated control, which was statistically similar with T_2 (14.60) and followed by T_1 (13.70 fruits) (Table 7).

4.3.5. Percent infested fruits

The significant variation was observed among different treatments used in this study in terms of percent infested fruits per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (7.99%), which was statistically similar with T_4 (8.97) and followed by T_5 (11.07) and T_6 (14.61%). On the other hand, the lowest performance was showed in T_7 (71.43%) comprises with untreated control, which was followed by T_2 (18.16) and T_1 (16.27%) (Table 7).

4.3.6. Percent reduction over control

T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (88.81%) on the reduction over control, which was followed by T_4 (87.44), T_5 (84.50) and T_6 (79.55%). On the other hand, the lowest performance was showed in T_2 (74.58%) comprises with untreated control on the reduction over control, which was followed by T_1 (77.22%) (Table 7).

Table 7: Effect of different treatments on the number of fruits and infested fruits per ten tagged plants of chilli

Treatments	**Number of fruits per ten tagged plants**					
	Total fruit	**Thrips infested fruit**	**Bored fruit**	**Infested fruit**	**% Infested fruit**	**% Reduction over control**
T_1	84.20 c	9.60 c	8.60 b	13.70 bc	16.27 bc	77.22
T_2	80.40 c	11.30 b	12.30 a	14.60 ab	18.16 b	74.58
T_3	117.60 a	8.10 c	2.70 d	9.40 d	7.99 e	88.81
T_4	108.20 ab	8.50 c	3.30 d	9.70 d	8.97 e	87.44
T_5	103.00 b	8.80 c	5.60 cd	11.40 c	11.07 d	84.50
T_6	84.20 c	9.20 c	7.60 c	12.30 bc	14.61 c	79.55
T_7	21.00 d	12.70 a	14.70 a	15.00 a	71.43 a	0
CV (%)	8.60	8.37	10.85	8.16	4.18	-
LSD $_{(0.05)}$	12.53	1.39	2.98	8.99	2.47	-

[T_1: Spraying Confidor 2G @ 0.2g/L of water at 7 days intervals; T_2: Spraying Actara 25WG @ 0.05g/L of water at 7 days intervals; T_3: Spraying Ethion 46.5EC @ 3ml/L of water at 7 days intervals; T_4: Spraying Omite 57EC @ 2ml/L of water at 7 days intervals; T_5: Spraying Bioneem Plus 1EC @ 1ml/L of water at 7 days intervals; T_6: Spraying Neem Oil @ 3ml/L of water mixing with 10ml/10gm detergent or trix at 7 days intervals; T_7: Untreated control where only water will be sprayed at 7 days intervals]

From this above findings it was revealed that, T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment in case of total number of fruits, thrips infested fruits, bored fruits, total infested fruits and percent fruit infestation. Whereas the lowest performance showed in T_7 (untreated control) in case of total number of fruits, thrips infested fruits, bored fruits, total infested fruits and percent fruit infestation. As a result, the order of efficacy of different treatments in terms of total number of fruits, thrips infested fruits, bored fruits, total infested fruits and percent fruit infestation per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

4.4. Plants of chilli

4.4.1. Number of branches

The significant variation was observed among different treatments used in this study in terms of number of branchess per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (12.47 branches), which was statistically similar with T_4 (12.33) and T_5 (11.87) and followed by T_6 (11.00 branches). On the other hand, the lowest performance was showed in T_7 (9.13 branches) comprises with untreated control, which was followed by T_2 (9.87) and T_1 (10.13 branches) (Table 8).

4.4.2. Plant height (cm)

The significant variation was observed among different treatments used in this study in terms of plant height per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (67.60 cm), which was statistically similar with T_4 (63.30) and followed by T_5 (58.30) and T_6 (55.70 cm). On the other hand, the lowest performance was showed in T_7 (43.30 cm) comprises with untreated control, which was statistically similar with T_2 (48.90) and followed by T_1 (51.70 cm) (Table 8).

4.4.3. Number of infested plants

The significant variation was observed among different treatments used in this study in terms of number of infested plants per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (3.00 plants), which was followed by T_4 (5.00), T_5 (5.00) and T_6 (6.00 plants). On the other hand, the lowest performance was showed in T_7 (8.00 plants) comprises with untreated control, which was followed by T_2 (7.00) and T_1 (7.00 plants) (Table 8).

4.4.4. Percent infested plants

The significant variation was observed among different treatments used in this study in terms of percent infested plants per ten tagged plants in the chilli field by visual observation. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (30.00%), which was followed by T_4 (50.00), T_5 (50.00) and T_6 (60.00%). On the other hand, the lowest performance was showed in T_7 (80.00%) comprises with untreated control, which was followed by T_2 (70.00) and T_1 (70.00%) (Table 8).

4.4.5. Percent reduction over control

T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (62.50%) on the reduction over control, which was followed by T_4 (37.50), T_5 (37.50) and T_6 (25.00%). On the other hand, the lowest performance was showed in T_2 (12.50%) comprises with untreated control on the reduction over control, which was followed by T_1 (12.50%) (Table 8).

Table 8: Effect of different treatments on the number of plants per ten tagged plants of chilli

Treatments	**Number of plants per ten tagged plants**					
	Number of branches	**Plant height (cm)**	**Total plant**	**Infested plant**	**% Infested plant**	**% Reduction over control**
T_1	10.13 c	51.70 cd	10.00	7.00 b	70.00 b	12.50
T_2	9.87 c	48.90 de	10.00	7.00 b	70.00 b	12.50
T_3	12.47 a	67.60 a	10.00	3.00 e	30.00 e	62.50
T_4	12.33 a	63.30 ab	10.00	5.00 d	50.00 d	37.50
T_5	11.87 a	58.30 bc	10.00	5.00 d	50.00 d	37.50
T_6	11.00 b	55.70 bcd	10.00	6.00 c	60.00 c	25.00
T_7	9.13 d	43.30 e	10.00	8.00 a	80.00 a	0
CV (%)	3.11	7.98	-	9.26	9.26	-
LSD $_{(0.05)}$	0.58	7.55	-	0.92	7.70	-

[T_1: Spraying Confidor 2G @ 0.2g/L of water at 7 days intervals; T_2: Spraying Actara 25WG @ 0.05g/L of water at 7 days intervals; T_3: Spraying Ethion 46.5EC @ 3ml/L of water at 7 days intervals; T_4: Spraying Omite 57EC @ 2ml/L of water at 7 days intervals; T_5: Spraying Bioneem Plus 1EC @ 1ml/L of water at 7 days intervals; T_6: Spraying Neem Oil @ 3ml/L of water mixing with 10ml/10gm detergent or trix at 7 days intervals; T_7: Untreated control where only water will be sprayed at 7 days intervals]

From this above findings it was revealed that, T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment in case of number of branches, plant height, total number of plant, infested plant and percent plant infestation. Whereas the lowest performance showed in T_7 (untreated control) in case of total number of branches, plant height, total number of plant, infested plant and percent plant infestation. As a result, the order of efficacy of different treatments in terms of total number of branches, plant height, total number of plant, infested plant and percent plant infestation per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

4.5. Yield attributing characteristics

4.5.1. Fruit length (cm)

The significant variation was observed among different treatments used in this study in terms of fruit length per ten tagged plants in the chilli field after harvesting. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (6.40 cm), which was statistically similar with T_4 (6.30) and T_5 (5.80) and followed by T_6 (5.50 cm). On the other hand, the lowest performance was showed in T_7 (3.10 cm) comprises with untreated control, which was followed by T_2 (3.60) and T_1 (4.30 cm) (Table 9).

4.5.2. Fruit grith (cm)

The significant variation was observed among different treatments used in this study in terms of fruit girth per ten tagged plants in the chilli field at after harvesting. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (3.30 cm), which was followed by T_4 (2.90), T_5 (2.60) and T_6 (2.40 cm). On the other hand, the lowest performance was showed in T_7 (1.60 cm) comprises with untreated control, which was statistically similar with T_2 (1.80) and followed by T_1 (2.20 cm) (Table 9).

4.5.3. Weight of healthy fruit (kg)

The significant variation was observed among different treatments used in this study in terms of weight of healthy fruit per plot in the chilli field after harvesting. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (1.41 kg), which was statistically similar with T_4 (1.27) and T_5 (1.17) and followed by T_6 (1.01 kg). On the other hand, the lowest performance was showed in T_7 (0.52 kg) comprises with untreated control, which was statistically similar with T_2 (0.55) and followed by T_1 (0.90 kg) (Table 9).

4.5.4. Weight of infested fruit (kg)

The significant variation was observed among different treatments used in this study in terms of weight of infested fruit per plot in the chilli field after harvesting. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (0.82 kg), which was statistically similar with T_4 (0.76) and followed by T_5 (0.72) and T_6 (0.66 kg). On the other hand, the lowest performance was showed in T_7 (0.23 kg) comprises with untreated control, which was followed by T_2 (0.43) and T_1 (0.56 kg) (Table 9).

4.5.5. Weight of total fruit (kg)

The significant variation was observed among different treatments used in this study in terms of weight of total fruit per plot in the chilli field after harvesting. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (2.23 kg), which was statistically similar with T_4 (2.03) and followed by T_5 (1.89) and T_6 (1.67 kg). On the other hand, the lowest performance was showed in T_7 (0.75 kg) comprises with untreated control, which was statistically similar with T_2 (0.98) and followed by T_1 (1.46 kg) (Table 9).

4.5.6. Yield (t/ha)

The significant variation was observed among different treatments used in this study in terms of yield of chilli. T_3 comprises with spraying Ethion 46.5EC @ 3ml/L of water showed the best performance (7.43 t/ha), which was statistically similar with T_4 (6.77) and followed by T_5 (6.30) and T_6 (5.57 t/ha). On the other hand, the lowest performance was showed in T_7 (2.50 t/ha) comprises with untreated control, which was statistically similar with T_2 (3.27) and followed by T_1 (4.87 t/ha) (Table 9).

Table 9: Effect of different treatments on the yield and yield attributing characteristics of chilli

Treatments	Fruit length (cm)	Fruit girth (cm)	Weight of healthy fruit (kg)	Weight of infested fruit (kg)	Total fruit weight (kg)	Yield (t/ha)
T_1	4.30 c	2.20 d	0.90 c	0.56 d	1.46 d	4.87 d
T_2	3.60 cd	1.80 e	0.55 d	0.43 e	0.98 e	3.27 e
T_3	6.40 a	3.30 a	1.41 a	0.82 a	2.23 a	7.43 a
T_4	6.30 ab	2.90 b	1.27 a	0.76 ab	2.03 ab	6.77 ab
T_5	5.80 ab	2.60 bc	1.17 ab	0.72 bc	1.89 bc	6.30 bc
T_6	5.50 b	2.40 cd	1.01 bc	0.66 c	1.67 cd	5.57 cd
T_7	3.10 d	1.60 e	0.52 d	0.23 f	0.75 e	2.50 e
CV (%)	9.13	9.18	14.14	9.78	10.09	10.04
LSD $_{(0.05)}$	0.78	0.38	0.24	0.09	0.27	0.90

[T_1: Spraying Confidor 2G @ 0.2g/L of water at 7 days intervals; T_2: Spraying Actara 25WG @ 0.05g/L of water at 7 days intervals; T_3: Spraying Ethion 46.5EC @ 3ml/L of water at 7 days intervals; T_4: Spraying Omite 57EC @ 2ml/L of water at 7 days intervals; T_5: Spraying Bioneem Plus 1EC @ 1ml/L of water at 7 days intervals; T_6: Spraying Neem Oil @ 3ml/L of water mixing with 10ml/10gm detergent or trix at 7 days intervals; T_7: Untreated control where only water will be sprayed at 7 days intervals]

From this above findings it was revealed that, T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment in case of yield attributing characteristics such as fruit length, fruit girth, fruit weight and yield of chilli. Whereas the lowest performance showed in T_7 (untreated control) in case of yield attributing characteristics such as fruit length, fruit girth, fruit weight and yield of chilli. As a result, the order of efficacy of different treatments in terms of fruit length, fruit girth, fruit weight and yield of chilli is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

4.6. Different interactions with the yield of chilli

4.6.1. Number of Aphid and Yield

Correlation study was done to establish the relationship between number of aphids and yield (t/ha) of chilli in case of different treatments. From the study it was revealed that significant correlation was observed between the number of aphids and yield of chilli (Figure 1). It was evident from the Figure 1 that the egression equation y = -0.9172x + 8.1244 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8974) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of aphids and yield of chilli.

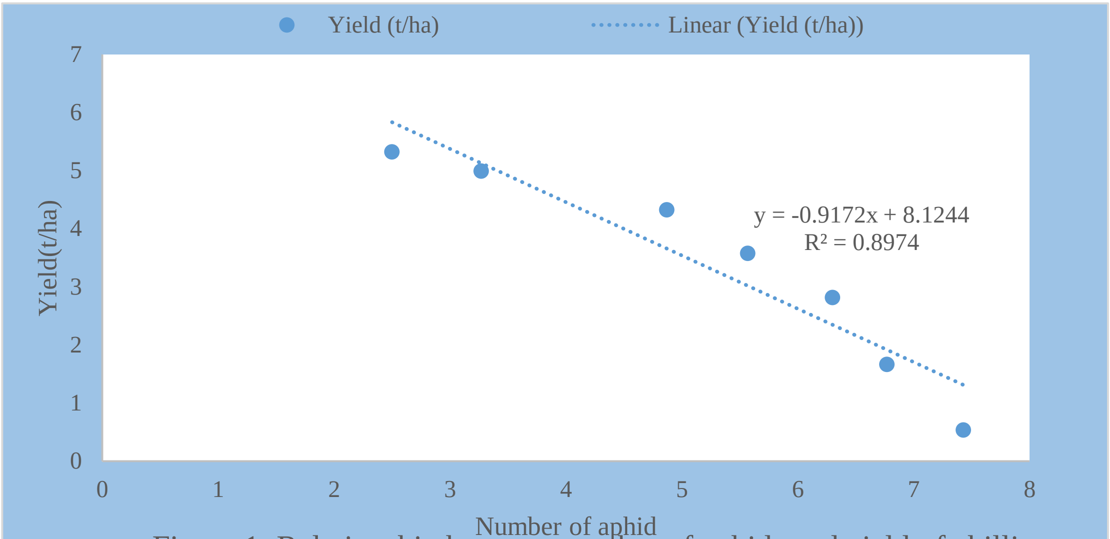

Figure 1: Relationship between number of aphids and yield of chilli

4.6.2. Number of thrips and Yield

Correlation study was done to establish the relationship between number of thrips and yield (t/ha) of chilli in case of different treatments. From the study it was revealed that significant correlation was observed between the number of thrips and yield of chilli (Figure 2). It was evident from the Figure 2 that the egression equation y = -0.6598x + 6.4615 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9156) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of thrips and yield of chilli.

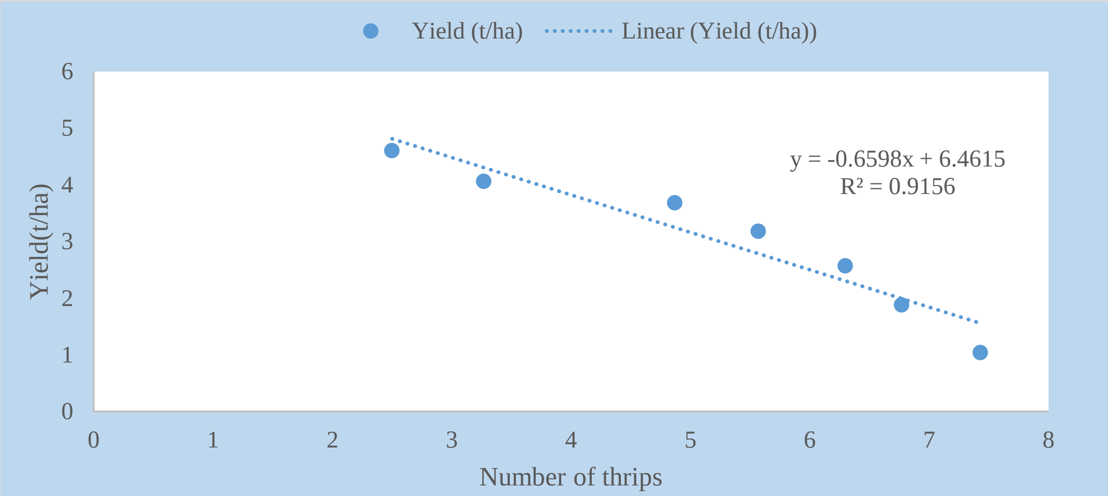

Figure 2: Relationship between number of thrips and yield of chilli

4.6.3. Number of gram pod borer and Yield

Correlation study was done to establish the relationship between number of gram pod borer and yield (t/ha) of chilli in case of different treatments.

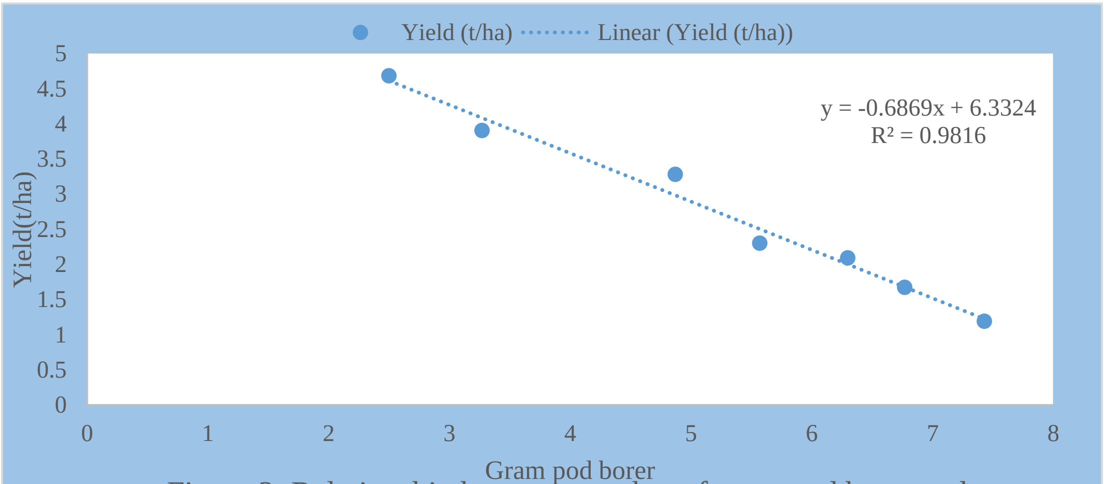

Figure 3: Relationship between number of gram pod borer and yield of chilli

From the study it was revealed that significant correlation was observed between the number of gram pod borer and yield of chilli (Figure 3). It was evident from the Figure 3 that the egression equation y = -0.6869x + 6.3324 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9816) showed that, fitted regression line had a significant regression co-efficient.From this regression analysis, it was evident that there was a negative relationship between the number of gram pod borer and yield of chilli.

4.6.4. Number of tobacco caterpillar and Yield

Correlation study was done to establish the relationship between number of tobacco caterpillar and yield (t/ha) of chilli in case of different treatments. From the study it was revealed that significant correlation was observed between the number of tobacco caterpillar and yield of chilli (Figure 4).It was evident from the Figure 4 that the egression equation y = -0.575x + 4.9782 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9934) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of tobacco caterpillar and yield of chilli.

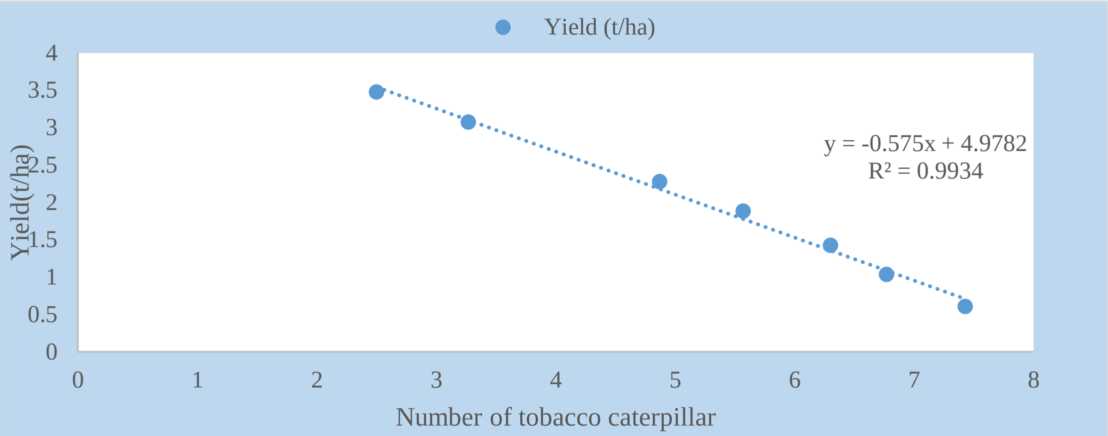

Figure 4: Relationship between number of tobacco caterpillar and yield of chilli

4.6.5. Number of mites and Yield

Correlation study was done to establish the relationship between number of mites and yield (t/ha) of chilli in case of different treatments. From the study it was revealed that significant correlation was observed between the number of mites and yield of chilli

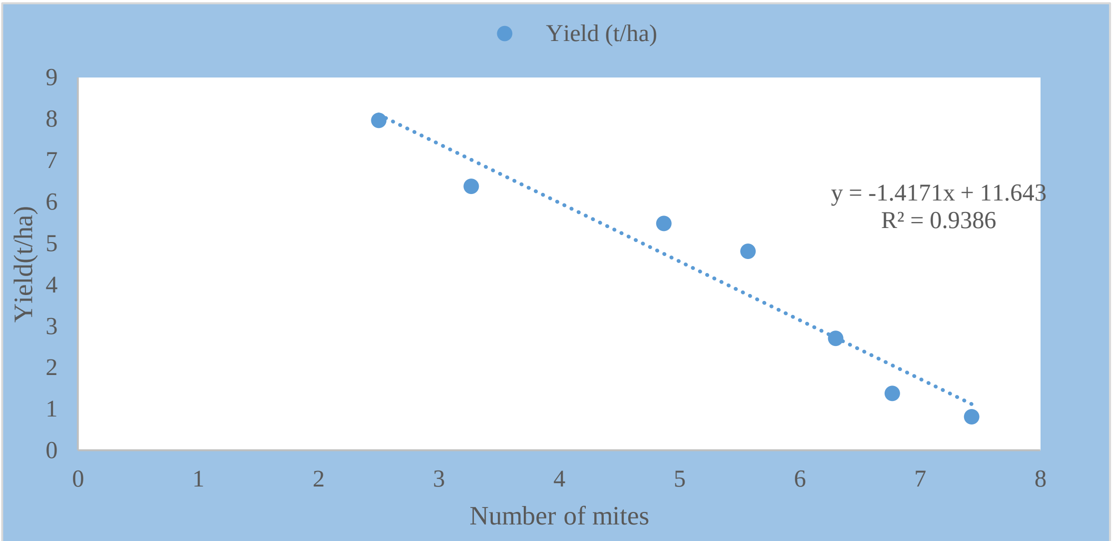

Figure 5: Relationship between number of mites and yield of chilli

(Figure 5). It was evident from the Figure 5 that the egression equation y = -1.4171x + 11.643 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9386) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of mites and yield of chilli.

4.6.6. Percent infested leaves and Yield

Correlation study was done to establish the relationship between percent infested leaves (%) and yield (t/ha) of chilli in case of different treatments. From the study it was revealed that significant correlation was observed between percent infested leaves and yield of chilli (Figure 6). It was evident from the Figure 6 that the egression equation y = -7.111x + 114.18 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.969) showed that, fitted regression line had a significant

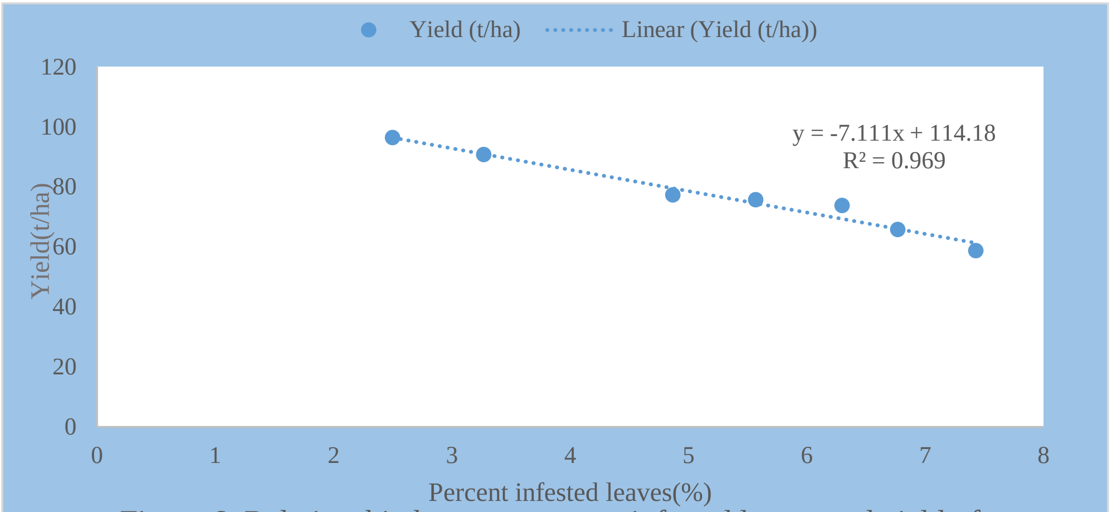

Figure 6: Relationship between percent infested leaves and yield of chilli

regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between percent infested leaves and yield of chilli.

4.6.7. Percent infested fruit and Yield

Correlation study was done to establish the relationship between percent infested fruit (%) and yield (t/ha) of chilli in case of different treatments.

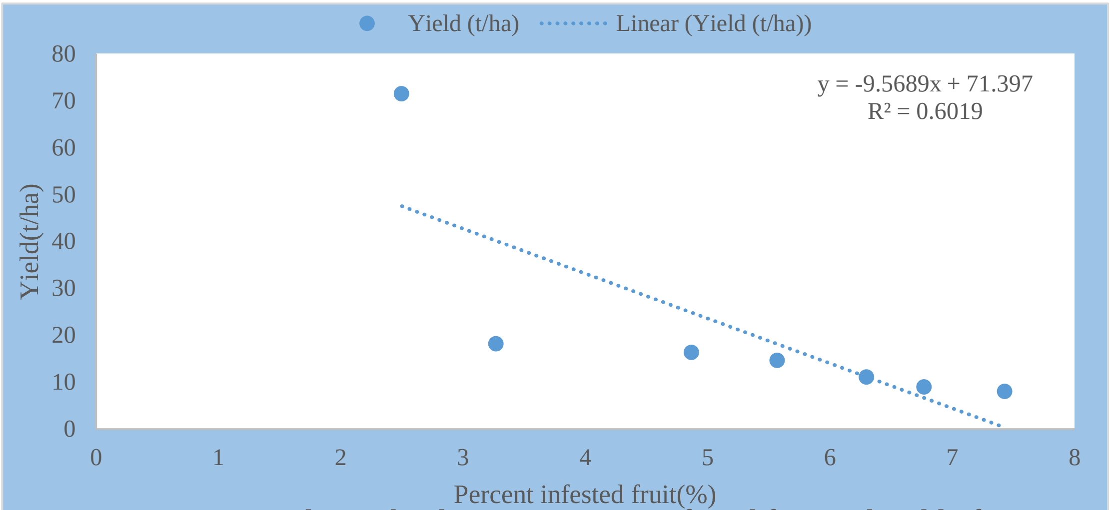

Figure 7: Relationship between percent infested fruit and yield of chilli

From the study it was revealed that significant correlation was observed between percent infested fruit and yield of chilli (Figure 7). It was evident from the Figure 7 that the egression equation y = -9.5689x + 71.397 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.6019) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between percent infested fruit and yield of chilli.

4.6.8. Percent infested plant and Yield

Correlation study was done to establish the relationship between percent infested plant (%) and yield (t/ha) of chilli in case of different treatments. From the study it was revealed that significant correlation was observed between percent infested plant and yield of chilli (Figure 8).

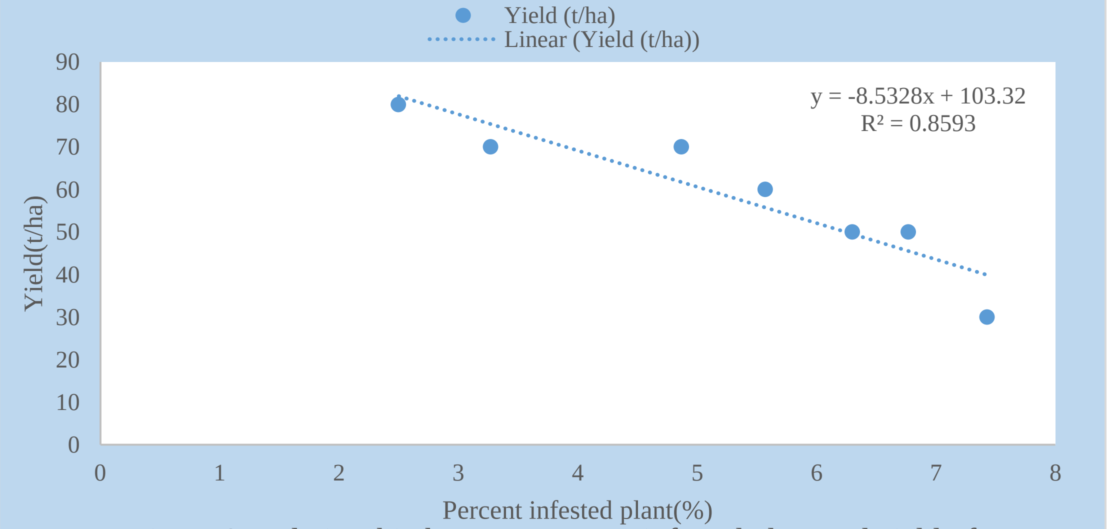

Figure 8: Relationship between percent infested plant and yield of chilli

It was evident from the Figure 8 that the egression equation y = -8.5328x + 103.32 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8593) showed that, fitted regression line had a significant regression co-efficient.

From this regression analysis, it was evident that there was a negative relationship between percent infested plant and yield of chilli.

4.6.9. Number of branches and Yield

Correlation study was done to establish the relationship between number of branches and yield (t/ha) of chilli in case of different treatments.

From the study it was revealed that significant correlation was observed between the number of branches and yield of chilli (Figure 9).

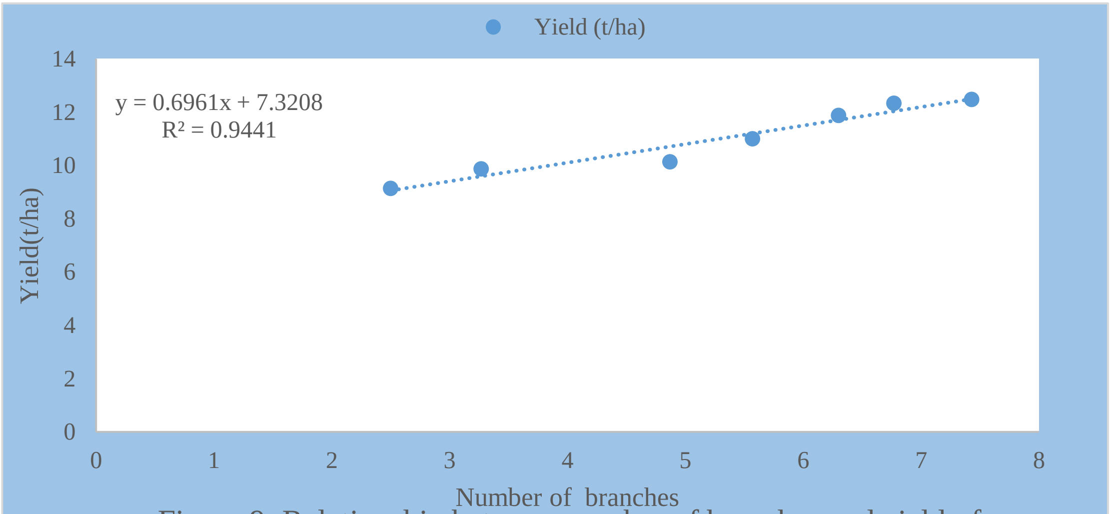

Figure 9: Relationship between number of branches and yield of chilli

It was evident from the Figure 9 that the egression equation y = 0.6961x + 7.3208 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9441) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between the number of branches and yield of chilli.

CHAPTER V

SUMMARY AND CONCLUSION

The experiments were conducted in the experimental field of SAU, Dhaka, Bangladesh, during October 2019 to February 2020 to evaluate damage assessment and management of insect and mite pests on chilli. Based on the findings of the study, the summary and conclusion are made bellow:

SUMMARY

T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment (0.53 aphids). Whereas the lowest performance showed in T_7 (5.32 aphids) (untreated control). The order of efficacy of different treatments in terms of number of aphids per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment (1.04 thrips). Whereas the lowest performance showed in T_7 (4.60 thrips) (untreated control). The order of efficacy of different treatments in terms of number of thrips per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment (1.19 gram pod borer). Whereas the lowest performance showed in T_7 (4.68 gram pod borer) (untreated control). The order of efficacy of different treatments in terms of number of gram pod borer per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment (0.60 tobacco caterpillar). Whereas the lowest performance showed in T_7 (3.47 tobacco caterpillar) (untreated control). The order of efficacy of different treatments in terms of number of tobacco caterpillar per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment (0.81 mites). Whereas the lowest performance showed in T_7 (7.96 mites) (untreated control). The order of efficacy of different treatments in terms of number of mites per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment in case of total number of leaves, aphid infested leaves, thrips infested leaves, mite infested leaves, total infested leaves and percent leaf infestation (152.3 leaves, 64.67 leaves, 66.67 leaves, 47.20 leaves, 89.40 leaves and 58.70%, respectively). Whereas the lowest performance showed in T_7 (untreated control) in case of total number of leaves, aphid infested leaves, thrips infested leaves, mite infested leaves, total infested leaves and percent leaf infestation (106.2 leaves, 97.33 leaves, 87.33 leaves, 78.40 leaves, 102.40 leaves and 96.42%, respectively). The order of efficacy of different treatments in terms of total number of leaves, aphid infested leaves, thrips infested leaves, mite infested leaves, total infested leaves and percent leaf infestation per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment in case of total number of fruits, thrips infested fruits, bored fruits, total infested fruits and percent fruit infestation (117.60 fruits, 8.10 fruits, 2.70 fruits, 9.40 fruits and 7.99%, respectively). Whereas the lowest performance showed in T_7 (untreated control) in case of total number of fruits, thrips infested fruits, bored fruits, total infested fruits and percent fruit infestation (21.00 fruits, 12.70 fruits, 14.70 fruits, 15.00 fruits and 71.43%, respectively). The order of efficacy of different treatments in terms of total number of fruits, thrips infested fruits, bored fruits, total infested fruits and percent fruit infestation per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment in case of number of branches, plant height, total number of plant, infested plant and percent plant infestation (12.47 branches, 67.60 cm, 10.00 plants, 3.00 plants and 30.00%, respectively). Whereas the lowest performance showed in T_7 (untreated control) in case of total number of branches, plant height, total number of plant, infested plant and percent plant infestation (9.13 branches, 43.30 cm, 10.00 plants, 8.00 plants and 80.00%, respectively). The order of efficacy of different treatments in terms of total number of branches, plant height, total number of plant, infested plant and percent plant infestation per ten tagged plants in chilli field is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

T_3 (spraying Ethion 46.5EC @ 3ml/L of water) performed as the best treatment in case of yield attributing characteristics such as fruit length, fruit girth, healthy fruit weight, infested fruit weight, total fruit weight/plot and yield of chilli (6.40 cm, 3.30 cm, 1.41 kg, 0.82 kg, 2.23 kg and 7.43 t/ha, respectively). Whereas the lowest performance showed in T_7 (untreated control) in case of yield attributing characteristics such as fruit length, fruit girth, healthy fruit weight, infested fruit weight, total fruit weight/plot and yield of chilli (3.10 cm, 1.60 cm, 0.52 kg, 0.23 kg, 0.75 kg and 2.50 t/ha, respectively). The order of efficacy of different treatments in terms of fruit length, fruit girth, healthy fruit weight, infested fruit weight, total fruit weight/plot and yield of chilli is $T_3 < T_4 < T_5 < T_6 < T_1 < T_2 < T_7$.

CONCLUSION

From the present study, it may be concluded that spraying Ethion 46.5EC @ 3ml/L 0f water at 7 days interval was the best treatment comprising the other treatments. It decreases the number of insects and other arthropod pests (like aphid, thrips, gram pod borer, tobacco caterpiller and mite), infestation (fruits, leaves and plants), but increases the other yield attributing characteristics and yield.

Considering the findings of the study the following recommendations can be drawn:

1. Ethion 46.5EC was the most effective treatment against insect and other arthropod pests of chilli.
2. To minimize the use of chemical insecticides in chilli, neem oil performed best against insect and other arthropod pests of chilli.
3. Further study is needed in different varieties of chilli.
4. Further study is also needed in different locations of Bangladesh and different seasons for accuracy of the results obtained from the present experiment.
5. More experiments are needed including different combinations of eco-friendly management practices to manage insect pests of chilli.

CHAPTER VI

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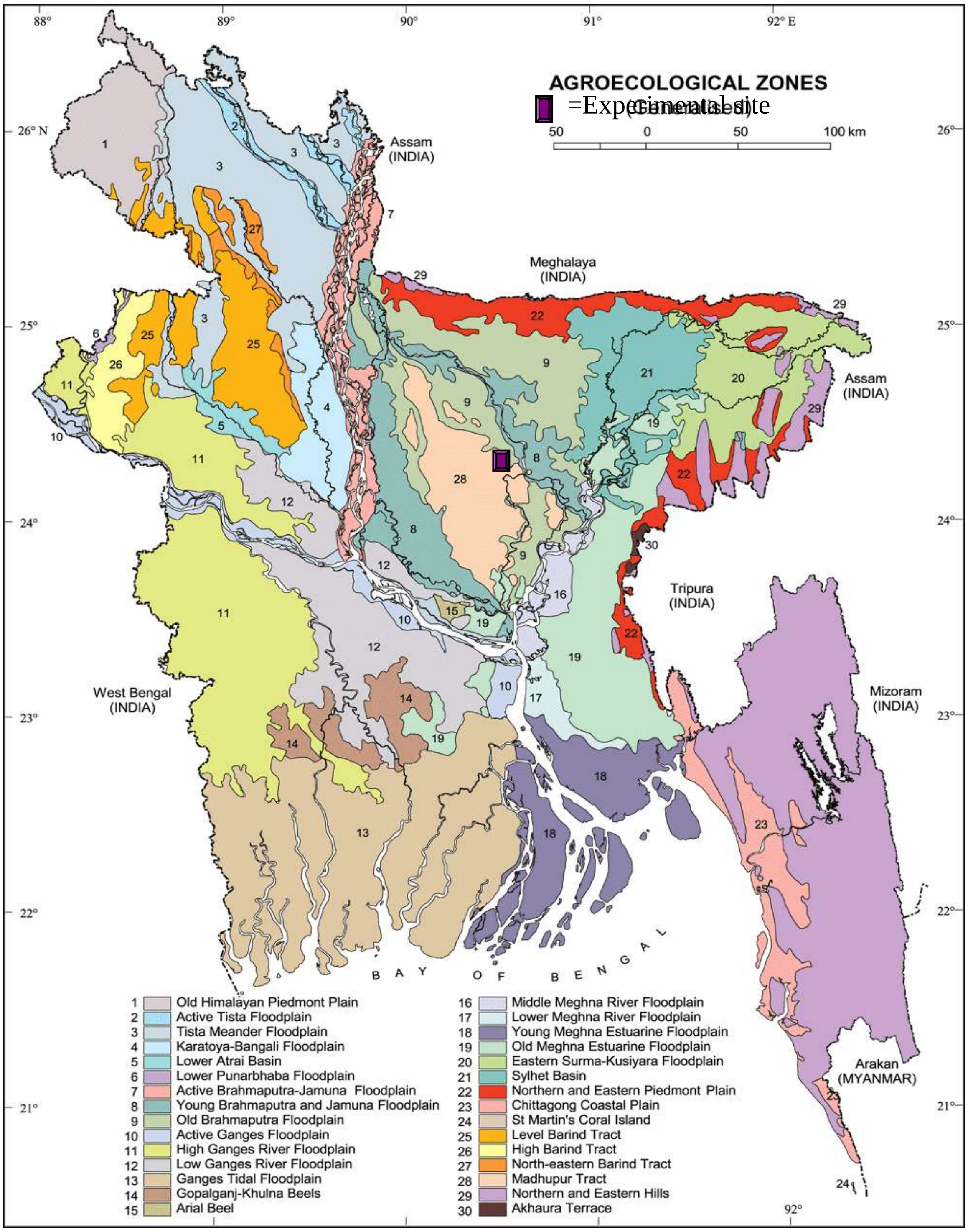
CHAPTER VII

APPENDICES

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



Appendix II. 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 (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

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