ECO-FRIENDLY MANAGEMENT OF SUCKING AND OTHER FOLIAR INSECT PESTS OF BRINJAL

SANJUKTA BISWAS

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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ECO-FRIENDLY MANAGEMENT OF SUCKING AND OTHER FOLIAR INSECT PESTS OF BRINJAL

BY

SANJUKTA BISWAS

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Approved by:

....
Prof. Dr. Md. Razzab Ali
Supervisor
Department of Entomology
SAU, Dhaka

....
Dr. Kabir Uddin Ahmed
Co-supervisor
Chief Scientific Officer
Planning and Evaluation Division
BARC, Farmgate, Dhaka

……...
Prof. Dr. S. M. Mizanur Rahman
Chairman
Examination Committee

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University (SAU)
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that thesis entitled ***"ECO-FRIENDLY MANAGEMENT OF SUCKING AND OTHER FOLIAR INSECT PESTS OF BRINJAL"*** *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* ***SANJUKTA BISWAS, Registration no. 12-05146*** *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, 2018
Place: Dhaka, Bangladesh

____

Prof. Dr. Md. Razzab Ali
Supervisor
Department of Entomology
SAU, Dhaka

DEDICATED
TO
MY BELOVED
PARENTS

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ABSTRACT

A field experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University to find out the effective environment friendly management practice(s) of brinjal, cultivated during Rabi season (November, 2017 to March, 2018). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental treatments were T_1 (spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with 1 liter of water @ 7 days interval); T_2 (spraying of neem seed kernel extract @ 5.0 ml/L of water at 7 days interval); T_3 (spraying of bioneem plus @ 3.0 ml/L of water at 7 days interval); T_4 (spraying of Marshal 25 EC@ 3.0 ml/L of water at 7 days interval); T_5 (spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval); T_6 (spraying of Imitaf 20 SL @ 0.1 ml/L of water at 7 days interval); T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) and T_8 (untreated control). Treatment T_7 contributed to reduce the highest number of leaf hopper, aphid, epilachna beetle, leaf roller, percent leaf infestation and plant infestation by leaf hopper, aphid, epilachna beetle, leaf roller were 5.72 leaf hopper/plant, 2.79 aphid/plant, 1.14 epilachna beetle/plant, 2.12 leaf roller/plant, 13.45%leaf/ five plant, 12.03 %leaf/ five plants, 9.20% leaf/five plants, 5.66% leaf/five plants, 13.89% plant/plot, 13.89% plant/plot, 8.33% plant/plot, 8.33% plant/plot respectively. Similarly, T_1 also contribute to reduce the number of leaf hopper (6.91), aphid (3.89), epilachna beetle (2.03), leaf roller (3.03), percent infestation of leaf and plant respectively by them. According to eco-friendly management T_1 showed the highly incidence of beneficial arthropods like lady bird beetle (5.21 lady bird beetle/plant), field spider (3.53 field spider/plant), ants (4.05 ants/plant) etc. in the brinjal field throughout the growing season. T_7 showed best performance for high single fruit weight (39.00 gm) and yield (25.57 ton/ha) of brinjal. T_1 also showed more or less similar performance in case of single fruit weight (34.66 gm) and yield (24.59 ton/ha). Considering the environmental hazard and effect of incidence of beneficial arthropods T_1 was the best treatment against sucking and other foliage insect pests of brinjal.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full meaning
BADC	Bangladesh Agricultural Development Corporation
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCPC	British Crop Production Council
CV	Coefficient of variation
^{o}C	Degree Celsius
d.f.	Degrees of freedom
et al.	And others
EC	Emulsifiable Concentrate
FAO	Food and Agriculture Organization
gm	Gram
ha	Hectare
IPM	Integrated Pest Management
CRSP	Collaborative Research Support Program
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
mg	Milligram
ml	Milliliter
MP	Muriate of Potash
%	Per cent
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate
WP	Wetable Powder

CHAPTER I

INTRODUCTION

Brinjal or eggplant (*Solanum melongena* L.) is the most common, popular and principal vegetables in Bangladesh and other parts of the world (Nonnecke, 1989). Brinjal is the second most important vegetables crops after potato in relation to its total production (Anon., 1996). This useful crop is grown year round in Bangladesh and covers 48679 ha with a production of 507000 tons (BBS, 2017) with about 25.4% of the total vegetable area of the country. Brinjal is grown all over areas and seasons of Bangladesh. But the brinjal is intensively grown in winter season in Jashore, Mymensingh, Narsingdi, Cumilla, Savar, Bogura, Jamalpur, Dinajpur and Rajshahi districts of Bangladesh.

Brinjal is well known for its nutritive value as a source of carbohydrate, proteins, minerals and vitamin (FAO, 1995). It is also a good source of dietary fiber and folic acid, and is very low in saturated fat, cholesterol and sodium. It is a native to India and is extensively grown in all the Southeast Asian countries. Brinjal is one of the most important vegetables in South Asia (India, Nepal and Srilanka). This region of South Asian accounts for almost 50% of the world area under brinjal cultivation (Alam *et al.*, 2003). Brinjal is grown in Bangladesh throughout the year including the summer season, when the supply of vegetables in the market is scarce. Thus, the farmers find it as a cash crop, which serves as a source of continuous flow of income (FAO, 2003). Sales of eggplant throughout the prolonged harvest season provide farmers with valuable cash income (Alam *et al.*, 2003).

Brinjal is a high income generating crop and its price reaches up to Tk.80 per kilogram during the month of Ramadan in Bangladesh. Due to various uses of brinjal, it is liked by rich and poor, urban and rural class people. The importance of brinjal to the farmers stems from its reasonably consistent and high yields of about 19 tons/ha per growing season. The crop is relatively hard and can withstand adverse conditions better than other crops. It can also be chopped and re-grown as a perennial crop. Brinjal is extensively grown in kitchen and commercial gardens in both rabi and kharif season in Bangladesh, especially in the hot humid monsoon season when other vegetables are in short supply. Brinjal is practically the only vegetable that is available at an affordable price for rural and urban consumers. It is cultivated largely on small family owned farms, where weekly sales of it brings in a readily cash income. The crop is infested by various arthropods pest species in the field. El-Shafie (2001) recorded 28 species of insect pests under 7 different insect orders from the brinjal ecosystem in Sudan. Latif (2007) observed 20 species of pest under 6 different orders, jassid was the second most common in the field after brinjal shoot and fruit borer. Srinivasan (2009) reported that, eggplant production is severely constrained by several insect and mite pests. The major pests include eggplant shoot and fruit borer, leaf hopper, whitefly, thrips, aphid, spotted beetles, leaf roller, stem borer, blister beetle, red spider mite, and little leaf disease.

The leafhopper sucks the nutrient sap from the xylem and severe infestation results in crinkling of leaves, hopper burn and cupping up symptoms (Anand *et al*, 2013). Leafhopper nymphs and adults sucks the sap or juice of the plant; however, damage to the crop is brought about not so much by its direct feeding but rather by the plant reaction to the toxin in its saliva (Barroga and Bernardo, 1993). Damage symptom due to the toxic saliva, which is slight yellowing of leaf margins become noticeable even at low population density of 1-2 leafhopper (Navasero, 2003). Aphid causes cupping, distortion of leaves and stunted growth of plants. It suck cell sap from the leaves and secrete honey dew, which causes fungal diseases (Cueva, *et al.*, 2015). Adult and larva of epilachna beetle feed on leaves by scraping the surface cells between veins leaving marks, which are initially C-shaped that later on result in irregularly-shaped holes or strips. High level of infestation severely damages the leaves, giving them a skeletonized or lace-like coupled with slight yellowish to brownish appearance due to drying of affected tissues. Leaf roller suck the cell sap from the underside of the leaves and curl leaves upward and role that and stay in that. Farmers spray synthetic insecticides four to six times for managing these sucking pests, resulting in the reduction of natural enemies and beneficial organisms. Even though, neonicotinoids are widely used for managing the homopteran insect pest, very little work on their side effects on natural enemy has been carried out (Cloyd and Bethke, 2011).

The management of these sucking and foliar pests through various non-chemical method namely, cultural, mechanical, biological and host plant resistant etc. was limited throughout the world. Management practices in Bangladesh and other countries are still limited to frequent spray of toxic chemical pesticides (Alam, 2005; Anon., 2005; Misra and senapati, 2003; Singh and choudhary, 2001; Bhargava *et al*., 2001; Ali and Karim, l994; Yadgirwar *et al.*, 1994; Singh *et al*., l99I). Farmers spray synthetic insecticides four to six times for managing these sucking pests, resulting in the reduction of natural enemies and beneficial organisms. Even though, neonicotinoids are widely used for managing the homopteran insect pest, very little work on their side effects on natural enemy has been carried out (Cloyd and Bethke, 2011). The insecticides used mostly belong to organophosphates, carbamates, and synthetic pyrithroides. Bangladeshi farmers usually apply six to eight schedule based insecticide sprays against this pest throughout the season. But this kind of insect pest control strategy relying solely on chemical protection had got many limitations and undesirable side effects (Husain 1993, 1984) and this in the long run led to many insecticides related complications (Frisbie, 1984) such as direct toxicity to beneficial insect, fishes and other non-target organism (Munakata, 1997; Goodland *et al.*, 1985; Pimentel, 1981), human health hazards (Bhaduri *et al.,* 1989) resurgence of pests (Husain, 1993; Luckmann and Metcalt, 1975) out-break of secondary pest (Hagen and Franz, 1973) and environmental pollution (Fiswick, 1988; Kavadia *et al.,* 1984).

To overcome the hazards of chemical pesticides, botanicals such as neem seed kernel extract, neem oil, soap water are now used in many developed and developing countries for combating this pest infestation with the aim of increasing crop yield (Hossain *et al.,* 2003; Mote and Bhavikatti, 2003; Singh and Kumar, 2003; Rao and Rajendran, 2002; Gahukar, 2000; Lawrence *et al*., 1996). Shrestha *et al.,* (2010) suggested use of neem products and lantana products to protect plants against aphids. Neem extract, neem oil, neem seed carnel etc. are also effective to control epilachna beetle, leaf hopper and other sucking insects in brinjal field. To use these botanicals human health hazard become low and incidence of beneficiary insects remain hazard free, so that, they can control the insect pest of brinjal keeping the environment sound.

Keeping this perspective in view of the experiment was undertaken against sucking and foliage insects like leafhopper, aphid, epilachna beetle, leaf roller etc. to fulfill the following objectives:

- To find out the level of infestation caused by leafhopper and other sucking pest of brinjal in filed condition
- To reduce the infestation of leafhopper and other sucking pest of brinjal using botanicals and other insecticides in field condition and
- To find out the impact of botanicals and other chemical insecticides of beneficial arthropods in the field of brinjal during managements of leafhopper and other sucking pest of brinjal

CHAPTER II

REVIEW OF LITERATURE

Sucking insect pests are very much dangerous for most of the vegetable crops. Aphid, leafhopper, epilachna beetle and leaf roller are considered as major sucking insect pests of brinjal, which cause significant damage to crop every year. The incidence of those insects occurs sporadically or in epidemic form throughout Bangladesh and affecting adversely the quality and yield of the crop. In the favorable weather severe infestation may occur and total crop may be damaged. Literatures regarding their population dynamics and management in brinjal are scanty. However, review of the available literatures relevant to the present study is presented below under the following sub-headings.

2.1. Sucking and foliage insect pests of brinjal

2.1.1. Leafhopper

2.1.1.1. Scientific classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hemiptera

Family: Cicadellidae

Genus: *Amrasca*

Specis: *A. biguttula biguttula*

2.1.1.2. Origin and distribution

Although found throughout much of the United States east of the Rocky Mountains, the potato leafhopper only overwinters along the Gulf Coast. The insect undergoes mass movements northward in the spring and early summer and becomes established in many areas of the country. The potato leafhopper is generally distributed northward by wind. Although the potato leafhopper does not overwinter in northern areas, it may complete several generations in these areas.

It occurs in several countries including India, Bangladesh, China, Myanmar, North Africa, Pakistan, Philippines, Sri Lanka, and Taiwan. Relatively dry and humid weather favors population build-up (Padwal *et al*, 2016).

2.1.1.3. Host range

The potato leafhopper feeds on a variety of plant species and has been reported to feed on nearly 200 kinds of plants. Flowers attacked by the potato leafhopper include dahlia, rose, and sunflower. Ornamental trees that are hosts for this leafhopper are Chinese chestnut, elm, English walnut, flowering Japanese cherry, hickory, locust, oak, and redbud. Flowering fruit trees, e.g., crabapple, also have been reported as hosts of potato leafhopper. A few of the economic plants that are infested with this insect are alfalfa, apple, eggplant, peanut, potato, soybean, and sweet potato. Leafhopper is widely distributed in India and most destructive to American cotton in the north-western region. Besides cotton it also feeds, potato, brinjal and some wild plant like hollyhock, kangi buti, etc. (Atwal, 1986). The insect also invades cotton, lady's finger, tomato and many other malvaceous and solanaceous plants (Alam, 1969). Jacob *et al*. (2000) identified *A. devastans* on castor bean, which attained at pest status. A survey report in Madhya Pradesh, India revealed that *A. devastans* infested potatoes in that area (Dharpure, 2003). Mamun (2006) reported that leafhopper prefers tomato, sweet gourd, country bean, brinjal, okra and cotton as host.

2.1.1.4. Seasonal abundance

Population of jassid varies in different time of the year. Alam *et al*. (2005) stated that jassid population was higher during the dry period especially mid February to mid April and number of jassid per leaf reached to its maximum (15.41) peak during the month of April. During long dry period especially in the month of February-March jassid became a serious problem for brinjal cultivation (Alam *et al*., 2006). Mall *et al*. (1992) described that seasonal incidence of jassid was more prevalent during vegetative phase of the crop up to the 3rd week of September when the average temperature and humidity were more than 28ºC and 80 percent respectively.

Early plantings are more injured by the cicadellidae than the late planting. The pest breed practically throughout the year but during the winter month only adult was found on plants such as potato, brinjal, tomato etc. In spring they migrate to okra and started breeding. Particularly the American cotton was very susceptible to this pest (Nair, 1986). The cotton jassid was formally considered to be on early season pest attacking plant in Bangladesh (Bohlen, 1984). Ali (1987) reported that jassid had been found to attack plants throughout the season. The incidence of jassid on brinjal planted at various dates from 20 July to 20 December was higher an early planted crop than on late planted crops (Borah, 1995). Seasonal abundance of cotton jassid on okra was dependent on meteorological parameters. Jassid population was maximum during middle of April (30.00 nymph/leaf) to last week of May (37.5 nymph/leaf). High temperature (30.36ºC) evening relative humidity (below 80%) and low rainfall period coupled with bright sunshine hours were favourable for the development of cotton jassid population (Inee *et al*., 2000). Muthukumar and Kalyanasundaram (2003b) observed that jassid had a negative association with minimum temperature and rainfall when investigation on the seasonal incidence of jassid (*Amrasca biguttula biguttula*) population on okra and their correlation with abiotic factors were carried out kharif 1990 in the semiarid region in India. The infestation of jassid started in the fourth week of July and reached peak in the second and fourth weeks of September respectively (Kumawat *et al*., 2000). Studies on the seasonal incidence of jassid on cotton under rainfed conditions were conducted at Bharuch, and Gujarat in India, during 1979-80 and 1981-82. Results showed that population of *Amrasca biguttula biguttula* ranged from 0.59 to 2.78 per plant recorded in the second fortnight of November (Patel and Patel, 1998).

The spatial distribution of *A. biguttula biguttula* was studied in upland cotton in India. Environmental heterogeneity at low population in July and innate behaviour at high population were responsible for aggregated dispersion in the species of hemiptera (Singh *et al*., 1990). Ali and Karim (1991) investigated the influence of cotton plant age on the seasonal abundance of *A. biguttula*. They found that the insect remained below the economic threshold level of 1 insect/leaf for up to 35 days of plant age in kharif cotton and 65 days of plant age in rabi cotton. Most of the cicadellids were found in 35 to 75 days old cotton plants in kharif and 65 to 130 days old cotton plants in the rabi season. Cotton grown in the kharif season was more vulnerable to insect attack than cotton grown in the rabi season. The population of leaf hopper on brinjal was positively correlated with average maximum-minimum temperature, relative humidity and total rainfall (Shukla, 1989). Observation on the jassid population was made from the second week of July up to the third week of September. The insect population increased from July to August. The maximum activity of the insect occurred from the 1stweek to the middle of August. After this period, the jassid population gradually declined, probably due to the slight increase in atmospheric temperature and RH, maximum crop damage coincidence with the maximum activity of the pest (Poonia, 2005). Investigations on the seasonal incidence of jassid population on okra with abiotic factors were carried out during kharif 1996 in the semiarid region of

Rajasthan, India. The infestation of jassid started in the 4th week of July and reached peaks in the 2nd and 4th weeks of September, respectively (Kumawat *et al*., 2000).

2.1.1.5. Biology of leafhopper

The adults mated two days after emergence and the eggs were laid two to seven days after copulation (Nair, 1986). Eggs were laid on the leaves of food plants and are hatched in about a week (Alam, 1969). Eggs were laid singly within leaf veins in the paranchymatous layer between the vascular bundles and the epidermis on the upper leaf surface. An average of 15 eggs (with a maximum of 29) was laid per female. Mature leaves (35-45 days old) were prefened for egg deposition; curved, greenish-yellow, eggs (0.7-0.9 x 0.15-0.2 mm) were laid, the egg period last for 4- 11 days (Nair 1986). The females deposited slender white eggs within the stems and larger veins of the leaves and hatching period was 6-9 days (Davidson, 1987). A female laid 25-30 eggs of 1:4 eggs per day, which were hatched in 4 to 11 days (Nair, 1986).

Nymphs were pale green, wedge shaped, 0.5-2.0 mm long, have a characteristics crab like, sideways movement when disturbed. They were confined to the under surface of leaves during the day time but found anywhere on the leaves at night. The nymphal period varied from 7 to 2l days depending on food supplies and temperature they passed through six stages of growth during nymphal period (Atwal, 1986). Another study revealed that they became full grown in seven days in autumn and 25 days in winters. Nair (1986) reported the five nymphal instars completed in 19-21days. Bohlen (1984) stated five nymphal instars and the nymphs resembled the adult but had no wings. The nymphs were smaller than the adult but wingless. Nymphs were found on the underside of leaves (FAO, 2003). The adult were small, elongate, wedge shaped, about 2.5 mm long, body pale green semi-transparent wings very active having aside way walk like the nymph, but quick to hop and fly when disturbed. The adult of the summer brood were greenish yellow in color and those of the winter broad radish. Unmated adults lived for 3 month or more, when mated, they lived five weeks in summer and seven weeks in winter. Life cycle was completed in 15-46 days in the different seasons and up to eleven generation was completed in a year (Nair, 1986). They were also attracted to light at night (Atwal, 1986). Adults were usually less than 13 mm long with slender, tapered bodies of various colors from bright grey to yellow green with shiny wings and had two distinct black spot at distal found on the foliage in large numbers and moved around by jumping but flew very rapidly when disturbed. The adults were found on the under sides of the leaves (FAO, 2003).

2.1.1.6. Nature of damage

Jassid, *Amrasca devastans* infestation was manifested by some characteristic symptoms. The primary symptom was characterized by leaf edge curling and the secondary symptom was characterized by leaf edge curling along with leaf edge and vein colouring and drying of the leaves. From the initial infestation, the symptoms developed in sequence leading to hopper burn and shedding of leaves in severe cases of infestations, which ultimately caused the retraction of plant growth and reduction of yield (Afzal and Ghani, 1953). Nair (1986) reported that the nymphs and adults of *A. biguttula biguttula* attacked host leaves at all stages of development. The adults and nymphs feed on the sap and injected saliva into the tissues, which caused toxemia and injury of the leaves. The edges of the infested leave turned pale-green, then yellow and finally brick red brown in colour. The colour changes were accompanied by severe crinkling and curling of the leaf. The whole leaf gradually dried up and dropped. The plant became stunted and quality of fruit was also affected. El-Tom (1987) reported that cotton jassid; *A. biguttula biguttula* was one of the key pests of cotton and in the major factor limiting cotton yield in

Bangladesh. This pest caused more than 50% reduction of seed cotton yield in some cotton genotypes (Bhat *et al*., 1984).

The jassid while sucking the plant sap injected some toxic substances with saliva into the cotton plants. Time required to development characteristic jassid damage symptoms in cotton plants were found positively corelated with age of the plant. The younger plants were found susceptible to jassid attack than the older plants (Nayer *et al*., 1984). As the plants grew older they became less susceptible to jassid infestation (Ali, 1990). Rote *et al*. (1985) reported a significant positive correlation between jassid damage symptoms and jassid population levels on the plant. Yield losses of cotton due to sucking pests (*Amrasca biguttula biguttula*) were evaluated during the rainy season of 1985 and 1986 in Karnataka, India. The average yield loss was 46.41% (Panchabhavi *et al*., 1990).

2.1.2. Epilachna beetle

2.1.2.1. Scientific classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Coccinellidae

Genus: *Epilachna*

Specis: *E. vigintioctopunctata*

2.1.2.2. Origin and distribution

South Canada, USA, Mexico, Guatemala, Africa and South East Asia. It occurs in Russia, China, Japan, and Korea. This species is native to southeastern Asia, primarily India, but has been accidentally introduced to other parts of the world, including Australia and New Zealand. It has also been recorded from Brazil and Argentina, beginning in 1996 (CSIRO, 2005).

2.1.2.3. Host range

Brinjal, potato, tomato, cucurbitaceous plants, wild solanaceous plants.

2.1.2.4. Natural abundance

This species causes damage to agricultural crops primarily in the family Solanaceae, especially potatoes; other crops include pumpkin, turnips, radishes, beans and spinach.

2.1.2.5. Life cycle

Egg period: 2-4 days. Cigar shaped, laid in clusters on lower leaf surface, yellow; 120-460 eggs/female. Grub: 10-35 days. Yellowish bearing six rows of longitudinal spines. Pupa: 5-6 days. Yellowish with spines on posterior part; anterior portion being devoid of spines. Pupates on the stem or leaves. Adult *E. dodecastigma*: Copper-coloured, 6 spots / elytra *E. demurille*: Dull appearance, light copper coloured and six black spots surrounded by yellowish area on each elytra. *E. vigintioctopunctata*: 14 spots on each elytra, deep red. Total life period: 20-50 days. 7 generations / year.

The orange and black spotted adults are about 7-10 millimetres long. The head, prothorax (first part of the middle body) and elytra (wing covers) are covered with short fine hairs. The elytra are covered with 28 spots. The size and shape of the spots is variable, but only the pairs of spots by the mid line of the second and fourth transverse rows may join each other. The underside of the ladybird orange-brown and black. There are three pairs of orange-brown legs. Under the elytra is a pair of wings used for flying. The small head is mainly pale orange and has a pair of compound eyes and two short antennae. The antennae are orange-brown.

Female ladybirds lay clusters of yellow eggs near infestations of prey. A larva hatches from each egg. There are four larval instars (stages). As the larva grows, it moults (changes skin). The newly hatched larva is pale yellow and covered with tubercles with long seta. The body remains yellow and the tergites, tubercles, setae and legs become dark grey. There are three pairs of legs. Larvae also use the tip of the abdomen for holding onto the substrate on which they are walking.

The tip of the abdomen also holds the larva to the surface during moulting both to another larval instar and to a pupa. When the fourth larval instar is fully grown, it attaches itself to a sheltered place on a plant. The spiny skin of the larva remains attached to the base of the pupa. The pupa is covered in black setae. It is black except for the pale inter-segmental membranes. There are prominent white tubular abdominal spiracles, openings to the air ducts (trachea). Adults hatch from pupae and mate. The length of time of each life stage depends on temperature, being shorter at higher temperatures (Martin, 2018).

2.1.2.6. Nature of damage

Both adult and grubs scrap the lower epidermis of leaves in characteristic manner leaving behind stripes of uneaten areas. The leaves give a stifled appearance. In severe infestation all leaves may be eaten off leaving only the veins intact (Skeletonization) and plants may wither.

2.1.3. Aphid

2.1.3.1. Scientific classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hemiptera

Family: Aphididae

Genus: *Aphis*

Specis: *A. fabae*

2.1.3.2. Origin and distribution

Aphids are distributed worldwide, but are most common in temperate zones. In contrast to many taxa, aphid species diversity is much lower in the tropics than in the temperate zones (Zyla *et al*., 2017). They can migrate great distances, mainly through passive dispersal by riding on winds. For example, the currant lettuce aphid, *Nasonovia ribisnigri*, is believed to have spread from New Zealand to Tasmania in this way (Pip Courtney, 2005). Aphids have also been spread by human transportation of infested plant materials.

Winged aphids may also rise up in the day as high as 600 m where they are transported by strong winds (Berry and Taylor, 1968; Isard *et al*., 1990). For example, the currant-lettuce aphid, *Nasonovia ribisnigri*, is believed to have spread from New Zealand to Tasmania around 2004 through easterly winds (Hill, L. 2012). Aphids have also been spread by human transportation of infested plant materials, making some species nearly cosmopolitan in their distribution (John, *et al*. 2009).

The black bean aphid may have originated in Europe and Asia, but it is now one of the most widely distributed species of aphids. It is found throughout temperate areas of Western Europe, Asia, and North America and in the cooler parts of Africa, the Middle East, and South America (AphlD, 2012). In the warmer parts of its range, apterous individuals can survive the winter and they may continue to reproduce asexually all year round (HYPP, 2013). It is known to be migratory (Johnson, C. G., 1963).

2.1.3.3. Host range

The black bean aphid can feed on a wide variety of host plants. Its primary hosts on which the eggs overwinter are shrubs such as the spindle tree (*Euonymus europaeus*), Viburnum species, or the mock-orange (*Philadelphus species*). Its secondary hosts, on which it spends the summer, include a number of crops including sugar beets, spinach, beans, runner beans, celery, potatoes, sunflowers, carrots, artichokes, tobacco, and tomatoes. It colonize more than 200 different species of cultivated and wild plants. Among the latter, it shows a preference for poppies (*Papaver species*), burdock (*Arctium tomentonum*), fat-hen (*Chenopodium album*), saltbush (*Atriplex rosea*), chamomile (*Matricaria chamomilla*), thistles (*Cirsium arvense*) (Berim, M. N., 2009), and docks (*Rumex* spp.) (RIR, 2013).

Two conflicting factors are involved in host preferences, the species and the age of the leaf. Offered spindle and beet leaves on growing plants throughout the year, winged aphids moved from one to the other depending on the active growth state of each and the senescence of each host plant. Thus, in late summer and autumn, the beet leaves were old and unattractive to the aphids in comparison with the leaves of the spindle, whereas in spring, the young unfolding leaves of the beet were more attractive than those of the spindle (Kennedy and Booth, 1951).

2.1.3.4. Life cycle

The black bean aphid has both sexual and asexual generations in its life cycle. It also alternates hosts at different times of year. The primary host plants are woody shrubs, and eggs are laid on these by winged females in the autumn. The adults then die and the eggs overwinter. The aphids that hatch from these eggs in the spring are wingless females known as stem mothers. These are able to reproduce asexually, giving birth to live offspring, nymphs, through parthenogenesis (Chinery and Michael, 1993). The lifespan of a parthenogenetic female is about 50 days and during this period, each can produce as many as 30 young (Berim, M. N., 2009). The offspring are also females and able to reproduce without mating, but further generations are usually winged forms. These migrate to their secondary host plants, completely different species that are typically herbaceous plants with soft, young growth (HYPP, 2013; Chinery and Michael, 1993; Berim, M. N., 2009).

Further parthenogenesis takes place on these new hosts on the undersides of leaves and on the growing tips. All the offspring are female at this time of year and large populations of aphids develop rapidly with both winged and wingless forms produced throughout the summer. Winged individuals develop as a response to overcrowding and they disperse to new host plants and other crops. By midsummer, the number of predators and parasites has built up and aphid populations cease to expand (RIR, 2013). As autumn approaches, the winged forms migrate back to the primary host plants. Here, both males and sexual females are produced parthogenetically, mating takes place, and these females lay eggs in crevices and under lichens to complete the lifecycle. Each female can lay six to ten black eggs which can survive temperatures as low as −32 °C (−26 °F) (HYPP, 2013; Chinery and Michael, 1993; Berim, M. N., 2009). More than 40% of the eggs probably survive the winter, but some are eaten by birds or flower bugs, and others fail to hatch in the spring (Way and Banks, 1964).

2.1.3.5. 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. Leaf roller

2.1.4.1. Scientific classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Tortricidae

Genus: *Archips*

Specis: *A. semiferanus*

2.1.4.2. Origin and distribution

Archips semiferanus is found in the eastern United States and adjoining portions of southeastern Canada. It has been found in US states including Connecticut, Massachusetts, New York, Pennsylvania, Texas, Virginia, and West Virginia (USDAFS, 1998; Drees, *et al*., 2009). They may have been introduced to the United Kingdom (Walker, 1863). In 2001 recent outbreaks had occurred in Cambria, Cameron, Clearfield, Clinton, and Warren counties in Pennsylvania (John, Y. 2001).

2.1.4.3. Host range

Fruit tree leaf roller feeds on a wide variety of deciduous trees and shrubs are hosts, including apple, crabapple, honey locust, ash and linden. Oak leaf roller is associated with Gambel oak; boxelder leaf roller with boxelder.

2.1.4.4. Life cycle

Oak leaf roller moths lay their eggs in July each year, in groups of 40 to 50. The female covers the eggs with hairs from her body; they are deposited on "the base of large branches and rough bark patches on both tree trunks and limbs" (Talerico *et al.*, 1978). The flat egg masses are white-gray in color and oval shaped, and are about 4.8 millimetres (0.19 in) across. The eggs overwinter and hatch in spring of the next year. The larvae (or caterpillars) emerge in April and initially eat the buds of oak trees and young leaves inside them (Talerico *et al.,* 1978; USDAFS, 2011).

When fully grown, the larvae are between 25 to 29 millimetres (0.98 to 1.14 in) long with a body that can be yellow-green or darker shades of green. Other identifying characteristics in the larvae include pale legs and a head that is either black or has "a dark eye patch or a dark bar" (Talerico *et al*., 1978; USDAFS, 2011; USDAFS, 1998). The larvae feed and nest inside leaves which they have rolled or folded until they are ready to pupate in mid-June. The larvae pupate in cocoons which are found inside the rolled leaves or in "bark crevices" (USDAFS, 2011).

After a week or two in the pupal stage, the adult moths emerge in late June or early July. The moths are small with a wingspan of 18 to 22 millimetres (0.71 to 0.87 in); the wings have a characteristic bell shape (USDAFS, 1998). Wing color can vary considerably. Forewings are a mixture of "creamy brown and gray" with gray found at the wingtips (Talerico *et al.*, 1978). The forewings have a darker band of brown or gray crossing obliquely. The adults mate and lay eggs to start the next generation. The moths produce only one generation annually (Talerico *et al.*, 1978; USDAFS, 2011).

In Texas, the timing of the various stages of the life cycle starts earlier, and other differences in behavior are seen. Since spring comes earlier in Texas, the eggs are laid in May and hatch in mid-March of the next year. The larvae can be dislodged from trees and dangle beneath them from silk threads. Although the larvae cannot harm humans, most people in Texas will avoid walking under oak trees to avoid them. The pupae of oak leaf rollers in Texas are also found on branch tips and weeds near the tree (Drees, *et al*. 2009).

2.1.4.5. Nature of damage

Larvae are active early in the season and chew leaves of a wide variety of plants. Older larvae have the habit of curling over the edge of leaves and fastening with silk to create a rolled leaf shelter. Damage by leaf rollers is usually transitory and mostly cosmetic. However, oak leaf roller, often in combination with species such as the oak looper and speckled green fruit worm, have caused episodes of extensive defoliation to native oak stands.

The caterpillars, which are range from pale to dark green have a black head. They are usually found within the folded leaves where they feed, chewing in a skeletonizing manner. When disturbed they can move vigorously and often will drop out of the leaf on a strand of silk. On fruit trees larvae of the fruit tree leaf roller may chew pits in developing fruit causing them to prematurely drop or grow in a distorted manner.

2.2. Management

The management of (*Amrasca biguttula biguttula*) through various non-chemical method namely, cultural, mechanical, biological and host plant resistant etc. was limited throughout the world. The research work on non-chemical control measure of this insect pest was also scanty. The farmers of Bangladesh usually apply six to eight schedule based insecticide sprays against this insect pests throughout the season. But this kind of insect pests control strategy relying solely on chemical protection had got many limitations and undesirable side effects (Hussain 1993, 1984) and this in the long run led to many insecticides related complications (Frisbie, 1984) such as direct toxicity to beneficial insects, fishes and other nontarget organism (Munakata, 1997; Goodland *et al*., 1985, Pimentel, 1981), human health hazards (Bhaduri *et a1.*, 1989) resurgence of pests (Husain, 1993; Luckmann and Metcalf, 1975) outbreak of secondary pest (Hagen and Franz, 1973) and environmental pollution (Fishwick, 1988; Kavadia *et at.*, 1984). To overcome these problems botanical insecticide soaprvater and water are now used in many developed and developing countries for combating this pest infestation with the aim of increasing crop yield.

Verticillium lecanii. In sustainable agriculture, prevention strategies are one of the most important tactics that growers can employ to avert aphid infestation. These include cultural techniques such as use of physical barriers, removal of crop in space and time, mulching, crop rotation, border crops and cover crops. Both synthetic and living mulches have been shown to reduce population of alate aphids reaching/landing on plants and hence reducing the incidence of aphid-transmitted viruses. Crops receiving high levels of nitrogen are more susceptible (attractive) to aphids; therefore, slow release fertilizers may be an alternative to avoid high aphid infestations. Aphids receive visual cues to land on crops when there is a clearly defined contrast in color between tilled bare soil and the lush foliage of crops. Living mulches reduce the contrast between the bare ground and the plant foliage so aphids do not detect their host. These mulches provide additional feeding sites for viruliferous aphids (aphids carrying virus) around the crop and hence reduce the incidence and spread of aphid-borne non-persistently transmitted viruses (Toba *et al.,* 1977).

2.2.1. Plant extracts for sucking insect pests management

Johnson (2001) assigned that, mealybugs can be controlled using the biocontrol agent, e.g. Botanical pesticides are the most cost effective and environmentally safe inputs in Integrated Pest Management (IPM) strategies. 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 (Narayanasamy, 2002). 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. Pink mealybug infests the mulberry plants and cause Tukra diseases that leads to qualitative loss of leaves. Hence a study was carried out to evaluate the efficacy of various indigenous native plant extracts for their repellency property against pink mealybug, *Maconellicoccus hirsutus* (Green) at the Tamil Nadu Agricultural University, Coimbatore. The native botanicals such as Andrographis leaf extract, Leucas leaf extract, Neem seed kernel extract, vitex leaf extract, fish oil rosin soap, ocimum leaf extract and lawsonia leaf extract at different dose levels viz., 1, 2, 4, 8 and 10 percent respectively. After 48 hours (Hour of release) the highest repellency was recorded in case of Andrographis leaf extract (99.0%) followed by Leucas leaf extract and NSKE (99.0%). Vitex leaf extract and FORS showed on par results among various treatments. The ocimum leaf extract (90.1%) also recorded a moderate repellent effect and the least repellency was recorded in case of Lawsonia leaf extract (81.3%). Similar trend was recorded during 24 hour of release also. As the dose increases the repellent effect also increased irrespective of the native botanical extracts against mealybugs (Sathyaseelan and Bhaskaran, 2010).

There are various insecticides that can be used to control aphids. Nowadays, there are many plant extracts and plant products that are eco-friendly and control aphids as effectively as chemical insecticides. Shreth *et al.,* 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.

With the continued robust growth of the global bio-pesticide market, Azadirachtin is uniquely positioned to become a key insecticide to expand in this market segment. In the USA, actual or impending cancellation of some organophosphate and Carbamate insecticides that had either lost patent protection or were not being re-registered in many markets because of the food quality protection Act of 1996, had opened new opportunities for bio-pesticides and reduced risks of pesticides in general. The broad-spectrum activity of Azadirachtin at low use rates (125-140g a.i. ha^{-1}) coupled with the insect growth regulator activity (in all larval /nymphal instars including the pupal stages) and unique mode of action (ecdysone disruptor) made Azadirachtin an ideal candidate for insecticide resistance, integrated pest control and organic pest control programs. The pest control potential demonstrated by various extracts and compounds isolated from the kernels and leaves of the neem plant (*Azadirachta indica*, (Meliaceae)) seem to be of tremendous importance for agriculture in developing countries. Laboratory and field trial data had revealed that neem extracts were toxic to over 400 species of insect pests; some of which had developed resistance to conventional pesticides, e.g. sweet potato whitefly (*Bemisia tabaci* Genn. Homoftera: Aleyrodidae), the diamond back moth (*Plutella xylostella* L. Lepidoptera: Plutellidae) and cattle ticks (*Amblyomma cajennense* F. Acarina: Ixodidae and *Tsoaphilus microplus* Canestrini. Acarina: Ixodidae). The compounds isolated from the neem plant manifested their effects on the test organisms in many ways, e.g. as antifeedants, growth regulators, repellents; toxicants and chemosterilants. This review strived to assess critically the pest control potential of neem extracts and compounds for their use in the tropics. This assessment was based on the formulation, stability and phytotoxicity information available on the wide range of pests against which neem extracts and compounds had proven to be toxic, toxicity to non-target organisms, e.g. parasitoids, pollinators, mammals and fish. (Lawrence *et al.*, 1996).

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 (John and Immaraju, 1997). 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 (Hillocks, l995; Gahukar, 2000). Indigenous plant materials were cheaper and hazard free in comparison to chemical insecticide (Saxena *et al.,* 1992). These were also easily available in everywhere in our country. Ofori and Sackey (2003) reported that acetylic, aqueous neem seed extract reduced the *Amrasca biguttula* on okra. 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* (Mote and Bhavikatti, 2003).

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 (Singh and Kumar, 2003). Schneider and Madel (1992) reported that 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. Patel and Patel (1998) reported that application of Quinalphos and Triazophos resulted in a resurgence of *A. bigututa* on okra and abergine (Brinjal), while Endosulfan at 0.07% and Repelin (based on *Azadirachta indica*) l% were highly effective. Nandagopal and Soni (1992) observed that 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 (Hossain *et al.*, 2003).

CHAPTER III

MATERIALS AND METHODS

The experiment on the population dynamics and management of sucking insect pests in brinjal, Homoptera, Cicadellidae was carried out at the experiment field of the Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during November, 2017 to March, 2018. The materials and methods adopted in this study are discussed in the following sub headings:

3.1. Location

The experimental site was located at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from November, 2017 to March, 2018. The experimental field was located at 90°335’ east longitude and 23° 774’ north latitude at a height of 4 meter above the sea level. The land was medium high and well drained.

3.2. Climate

The experimental site was situated in the sub-tropical climatic zone, characterized by lower rainfall during the month of November 2017 to March 2018. Monthly maximum and minimum temperature, relative humidity and total rainfall recorded during the period of study at the SAU experimental farm have been presented in the Appendix I. The recorded and calculated as monthly average temperature, relative humidity and rainfall for the crop growing period of experiment were noted from the Bangladesh Meteorological Department (climate division), Agargaon, Dhaka-1207 and has been presented.

3.3. Soil

The soil of the study was silty clay in texture. The area represents the agroecological zone of “Madhupur tract” (AEZ No. 28). Organic matter content was very low (0.82%) and soil pH varied from 5.47 to 5.63.

3.4. Design and layout

The study was conducted considering eight treatments including a control for controlling sucking pest at seedling to harvesting stage. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in the field of the Entomology Department. The whole field was divided three blocks of equal size and each block was sub divided into nine plots. The unit plot size was 3m × 2m accommodating twelve pits per plot. The distance between row to row was 100 cm and that of the plants to plants was 70 cm.

3.5. Land preparation

The soil of the experimental field was well prepared thoroughly followed by plowing and cross plowing, leveling and laddering to have a good tilth. All weeds and debris of previous crops were removed and land was finally prepared with the addition of basal dose of well decomposed cow dung. The plots were raised by 10 cm from the soil surface keeping the drain around the plots.

3.6. Manuring and fertilization

The following doses of manure and fertilizers were applied as per recommendation of Rashid (1999) for brinjal.

Manure/ Fertilizers	**Dose per ha**
Cow-dung	10 tons
Urea	360 Kg
Triple Super Phosphate (TSP)	150 Kg
Muriate of Potash	250 Kg

The full dose cow-dung and TSP were applied as basal dose during final land preparation. One-third of the MP and urea were applied in the pits one week before transplanting and rest of the MP and urea were applied as the top dressing at 21, 35 and 50 days after transplanting.

3.7. Raising of seedling and transplanting

Brinjal seed (Vatiety: BARI brinjal-1, Uttara) were collected from BARI, Gazipur, Dhaka. A small seedbed measuring 5m × 1m was prepared and seeds were sown in the nursery bed at SAU Entomology field on 17 November 2017. Standard seedling raising practice was followed (Rashid, 1999). The plots were lightly irrigated regularly for ensuring seed proper development of the seedlings. The seedbed was mulched for ensuring proper seed germination, proper growth and development of the seedlings. Thirty-days-old healthy seedlings were transplanted in polybag for hardening. After twenty days that seedlings were transplanted on 29 December 2017 in the experimental field.

3.8. Intercultural operations

3.8.1. Gap filling

At the time of transplanting a few seedlings were transplanted in the border of the experimental plots for gap filling. Very few numbers of seedlings were damaged after transplanting and such seedling were replaced by healthy seedlings from the same planted earlier on the border of the experimental plot. The seedlings were transplanted with a mass of soil roots to minimize the transplanting shock.

3.8.2 Irrigation

After transplanting light irrigation was given to each plot. Supplementary irrigation was applied at an interval of 2-3 days. Stagnant water was effectively drained out at the time of over irrigation. The urea was top dressed in three splits as mentioned earlier.

3.8.3 Weeding

Weeding was done as and when necessary to break the soil crust and to keep the plots free from weeds. First weeding was done after 20 days of planting and the rest were carried out at an interval of 15 days to keep the plot free from weeds.

3.8.4 Earthing up

Earthing up was done in each plot to provide more soil at the base of each plant. It was done 40 and 60 days after transplanting.

3.9. Treatment for control measures

The experiment was evaluated to determine the efficacy of different botanical products and some chemical insecticides to compare with each other in considering the less hazardous but effective control measures against major insect pests, such as leaf hopper, aphid, epilachna beetle, leaf roller etc. of brinjal. The botanical based treatments and chemical insecticides as well as their doses to be used in the study are given bellow:-

T_1= Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval

T_2= Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval

T_3= Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days interval

T_4= Spraying of Marshal 25 EC@ 3.0 ml/L of water at 7 days interval

T_5= Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval

T_6= Spraying of Imitaf 20 SL @ 0.1 ml/L of water at 7 days interval

T_7= Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval

T_8= Untreated control.

3.10. Treatment preparation

3.10.1. Neem oil

The Neem oil was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the local market of Agargoan bazaar, Dhaka. All sprays were made according to the methods described earlier. For each 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 within the spray machine was shacked well and sprayed on the upper and lower surface of the plants of the treatment until the drop run off from the plant. Three liters spray material was required to spray in three plot of each replication.

3.10.2. Neem seed kernel

The mature and dried neem seeds were collected from the neem tree found in the Horticulture garden of SAU. Then seeds were roasted by electric oven. Then the seed kernel was separated and taken into the electric blender for blending. 250 gm of neem seed kernel powder was taken into a beaker and 250 ml water was added into the beaker. Then the beaker was shaken by electric stirrer for mixing up thoroughly the mixture. The aqueous mixture then filtered using Whatmen paper filter and preserved the aqueous extracts of neem seed kernel in the refrigerator at 4^0c for spraying in the field.

3.10.3. Bioneem plus

The bioneem plus was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the local market of Agargoan bazaar, Dhaka. All sprays were made according to the methods described earlier. For each bioneem plus application, 15 ml bioneem plus (@ 3.0 ml/L of water i.e. 0.3% per 5 liter of water was used. The mixture within the spray machine was shacked well and sprayed on the upper and lower surface of the plants of the treatment until the drop run off from the plant. Three liters spray material was required to spray in three plot of each replication.

3.11. Treatment application

T_1: 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 20 DAT.

T_2: Neem seed kernel extract @ 3.0 ml/L of water was sprayed at 7 days. Under this treatment, neem seed kernel extract was applied @ 15 ml /5L of water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_3: Bioneem plus @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, bioneem plus 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 20 DAT.

T_4: Marshal 25 EC @ 3.00 ml/L of water was sprayed at 7 days interval. For this treatment 15.0 ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 20 DAT.

T_5: Actara 25 WG @ 0.2 gm/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 20 DAT.

T_6: Emitaf 20 SL @ 0.1 ml/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 20 DAT.

T_7: Ripcord 20 EC @ 1.0 ml/L of water was sprayed at 7 days interval. For this treatment 5.0 ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 20 DAT.

T_8: Untreated control. There was no any control measure was applied in brinjal field.

3.12. Data collection

Data were collected some pre-selected parameters like number of leaves and branches per plant, number of fruits/plant, fruit length and diameter, weight of individual fruits and fruit yield of brinjal. The number of aphid, leaf hopper, epilachna beetle and leaf roler was counted from treated and untreated plots of brinjal throughout the cropping season starting from 20 days after transplanting. Adults and nymphs of sucking insects were counted from a 30 random sample of five plants taken from each plot. Five leaves were chosen randomly from each plant, two from the bottom (older leaves), one from the middle and two from the top (younger leaves). The lower surface of the leaf was thoroughly examined for the presence of insects. Counts were made before 08.00 hr (Bangladesh local time) to avoid the excessive mobility of the adult insects after this time, but nevertheless, the migration of the fast moving and mobile adults from one plot to the other could not be totally avoided. The data were pooled over the cropping season and the population density was expressed as number of individuals per five leaves of the plant selected from each plot and tagged. The selected plants were observed regularly at weekly intervals in the morning. Healthy and infested leaves and number of branches per/plant were counted for estimating the infestation intensity. The data were converted to mean healthy and infested leaves and number of braches per plant. Fruits were harvested at 7 days intervals and the number of fruits was recorded for each plot. Twenty fruits were selected randomly from each plot; length, diameter and weight of the selected fruit were recorded at each harvest. The data were pooled over the cropping season; length, diameter and weight of individual fruit were estimated. The total weight of fruit was recorded every harvest, right from the beginning of the first harvest and continued until the end of the growing season. The cumulative yield of fruits per plot from 12 harvests was calculated and it was then expressed as t/ha. The population of spiders and lady bird beetles were counted by randomly selected five branches from 5 plants of each plot at weekly interval. Assessment of treatment effects the performance profile of each treatment was judged by the reduction of the insect population densities in the treated plots and it was further confirmed by the comparison to yield contributing characters such as number of leaves and branches per plant, number of fruits/plant, fruit length and diameter, weight of individual fruits and yield obtained in each case at the end of the cropping cycle.

The infested leaves were calculated by the following procedure:

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

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

The infested plants were calculated by the following procedure:

Number of infested plants was counted from total plot and percent plant infestation by sucking and foliage insect pests of brinjal were calculated as follows:

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

Percent edible fruit weight calculated by the following procedure:

Percent edible fruit weight of total infested fruit weight infestated by sucking and foliage insect pests of brinjal were calculated as follows:

% Edible fruit weight = $\frac{Edible\ fruit\ weight}{Total\ infested\ fruit\ weight} \times 100$

Percent non-edible fruit weight calculated by the following procedure:

Percent non-edible fruit weight of total infested fruit weight infestated by sucking and foliage insect pests of brinjal were calculated as follows:

% Non-edible fruit weight = $\frac{Non\text{-}edible\ fruit\ weight}{Total\ infested\ fruit\ weight} \times 100$

Percent reduction of brinjal infestation over control

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

$$\%\ \text{Reduction over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where, X_1 = the mean value of the treated plot

X_2 = the mean value of the untreated plot

3.13. Statistical analysis

Data were analyzed by using MSTAT-C software for analysis of variance after square root transformation. ANOVA was made by F variance test and the pair comparisons were performed by Duncan Multiple Range Test (DMRT).

CHAPTER IV

RESULTS OF DISCUSSION

The study was conducted to evaluate the effectiveness of botanicals for eco-friendly management of sucking and foliage insect pests of brinjal in the field under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2017 to March 2018. The results have been presented and discussed, and possible interpretations have been given under the following sub-headings:

4.1 Infestation of leaf hopper of brinjal

4.1.1 Number of leaf hopper per plant

The significant variations were observed among different treatments used for the management practices in terms of number of leaf hopper at different growing stage. At vegetative stage significantly the lowest number of leaf hopper was recorded in T_7 (8.20 leaf hopper/plant), which was followed by T_5 (8.87 leaf hopper/plant), T_4 (9.17 leaf hopper/plant) and T_1 (9.33 leaf hopper/plant). On the other hand, the highest number of leaf hopper was recorded in T_8 (14.27 leaf hopper/plant), which were followed by T_3 (11.30 leaf hopper/plant), T_6 (10.57 leaf hopper/plant) and T_2 (9.70 leaf hopper/plant) respectively. More or less similar trends of number of leaf hopper were also recorded at early fruiting stage, mid fruiting stage and late fruiting stage (Table 1).

In case of mean number of leaf hopper per plant significantly the lowest number of leaf hopper was recorded in T_7 (5.72 leaf hopper/plant), which was followed by T_5 (6.23 leaf hopper/plant), T_4 (6.64 leaf hopper/plant) and T_1 (6.91 leaf hopper/plant) respectively. On the other hand, the highest number of leaf hopper was recorded in T_8 (13.53 leaf hopper/plant), which was significantly different from all other treatments (Table 1). Considering the percent reduction of incidence of leaf hopper per plant, the highest 57.72% reduction over control was achieved in T_7 followed by T_5 (53.95%) and T_4 (50.92%). On the other hand, the minimum reduction of incidence of leaf hopper over control was found in T_3 (35.48%) followed by T_6 (39.99%). Considering among the nonchemical treatment T_1 showed better performance on the incidence of leaf hopper/plant (6.91) and percent reduction of incidence over control of leaf hopper/plant (48.93) in both (Table 1).

Table 1: Effect of management practices of number of leaf hopper on fully opened leaves per plant

Treatments	No. of Leaf hopper per plant					
	Vegetative stage	Early fruiting stage	Mid fruiting Stage	Late fruiting stage	Mean	Incidence reduction over control (%)
T_1	9.33 e	8.67 e	5.01 e	4.57 e	6.91 e	48.93
T_2	9.70 d	8.83 d	5.37 d	5.13 d	7.26 d	46.34
T_3	11.30 b	9.83 b	7.17 b	6.60 b	8.73 b	35.48
T_4	9.17 f	8.33 f	4.87 f	4.20 f	6.64 f	50.92
T_5	8.87 g	7.87 g	4.30 g	3.87 g	6.23 g	53.95
T_6	10.57 c	9.33 c	6.73 c	5.83 c	8.12 c	39.99
T_7	8.20 h	7.13 h	3.93 h	3.60 h	5.72 h	57.72
T_8	14.27 a	14.73 a	13.23 a	11.90 a	13.53 a	
CV (%)	0.76	0.62	1.00	1.68	0.53	
LSD (0.05)	0.13	0.09	0.11	0.16	0.08	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From the above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) performed best result in reducing number of leaf hopper per plant over control (57.72%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the number of leaf hopper over control (48.93%). As a result, the order of rank of efficacy of the treatments applied against brinjal leaf hopper including untreated control in terms of reducing number of brinjal leaf hopper per plant was $T_7 > T_5 > T_4 > T_1 > T_2 > T_6 > T_3 > T_8$.

4.1.2 Infestation of leaves by brinjal leaf hopper per five plants

The significant variations were observed among different treatments used for the management practices in terms of number of infested leaves by leaf hopper at different growing stage. The highest number of leaves per five plants was recorded in T_1 (59.30 leaves/five plants), which was statistically different from other treatments and followed by T_5 (55.20 leaves/five plants), T_8 (51.70 leaves/five plants) and T_4 (50.30 leaves /five plants). On the other hand, the lowest number of leaves per five plants was recorded in T_3 (40.60 leaves /five plants), which was statistically different from other treatments and followed by T_6 (41.40 leaves /five plants), T_2 (42.47 leaves /five plants) and T_7 (47.10 leaves/five plants) (Table 2).

In case of number of infested leaves, the highest number of infested leaves per five plants was recorded in T_8 (17.00 leaves/five plants), which was statistically different from other treatments and followed by T_1 (14.00 leaves/five plants), T_3 (13.00 leaves/five plants) and T_6 (12.33 leaves /five plants). On the other hand, the lowest number of infested leaves per five plants was recorded in T_7 (6.33 leaves /five plants), which was statistically different from other treatments and followed by T_5 (8.67 leaves /five plants), T_4 (9.33 leaves /five plants) and T_2 (11.33 leaves/five plants) (Table 2).

In case of percent infestation of leaves per five plants, the highest percentage was recorded in T_8 (32.88%) untreated control, which was significantly similar with T_3 (32.02%) and T_6 (29.79%) and followed by T_2 (26.69%). On the other hand, the lowest percentage was recorded in T_7

(13.45%), which was significantly similar with T_5 (15.70%) and T_4 (18.56%) and followed by T_1 (23.61%) (Table 2). Considering the percent reduction of number of infested leaves by leaf hopper per plant, the highest 59.09% reduction over control was achieved in T_7 followed by T_5 (52.25%) and T_4 (43.55%). On the other hand, the minimum reduction of leaf infestation over control was found in T_3 (2.62%) followed by T_6 (9.40%).

Table 2: Effect of management practices on infestation of fully opened leaves by leaf hopper per five plants

Treatments	Infestation of leaves by leaf hopper per five plants			
	No. of total leaves	No. of infested leaves	% infestation	Infestation reduction over control (%)
T_1	59.30 a	14.00 b	23.61 d	28.19
T_2	42.47 f	11.33 d	26.69 c	18.83
T_3	40.60 h	13.00 bc	32.02 ab	2.62
T_4	50.30 d	9.33 e	18.56 e	43.55
T_5	55.20 b	8.67 e	15.70 ef	52.25
T_6	41.40 g	12.33 cd	29.79 b	9.40
T_7	47.10 e	6.33 f	13.45 f	59.09
T_8	51.70 c	17.00 a	32.88 a	
CV (%)	0.22	7.38	7.10	
LSD (0.05)	0.19	1.43	2.89	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) reduced the number of infested leaves by leaf hopper per five plants over control (59.09%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the number of infested leaves by leaf hopper per five plants over control (28.19%). As a result, the order of rank of efficacy of the treatments applied against brinjal leaf hopper including untreated control in terms of reducing number of infested leaves by leaf hopper per five plants was T_7> T_5> T_4> T_1> T_2> T_6> T_3> T_8.

4.1.3 Infestation plants by leaf hopper

The significant variations were not observed among different treatments used for the management practices in terms of number of total plants at different growing stage. In case of number of infested plants, the highest number of plants per plot was recorded in T_8 (6.33 plants/plot), which was statistically similar with T_6 (5.33 plants/plot), T_3 (5.33 plants/plot) and T_4 (4.33 plants/plot). On the other hand, the lowest number of plants per plot was recorded in T_7 (1.67 plants /plot), which was statistically similar with T_1 (2.67 plants/plot), T_2 (3.67 plants/plot) and T_5 (3.67 plants/plot) (Table 3).

In case of percent infestation of plants per plot, the highest percentage was recorded in T_8 (52.78%) comprised of untreated control, which was significantly similar with T_6 (44.45%), T_3 (44.45%) and T_4 (36.11%). On the other hand, the lowest number of plants per plot was recorded in T_7 (13.89%), which was statistically similar with T_1 (22.22%), T_2 (30.55%) and T_5 (30.55%) (Table 3).Considering the percent reduction of number of leaf hopper per plant, the highest 73.68% reduction over control was achieved in T_7 followed by T_1 (57.90%) and T_5 (42.12%). On the other hand, the minimum reduction of leaf infestation over control was found in T_3 (15.78%) followed by T_6 (15.78%).

Table 3: Effect of management practices of infestation of plants by leaf hopper per plot

Treatments	Infestation of plants by leaf hopper per plot			
	No. of total plants	No. of infested plants	% infestation	Infestation reduction over control (%)
T_1	12.00 a	2.67 de	22.22 de	57.90
T_2	12.00 a	3.67 cd	30.55 cd	42.12
T_3	12.00 a	5.33 ab	44.45 ab	15.78
T_4	12.00 a	4.33 bc	36.11 bc	31.58
T_5	12.00 a	3.67 cd	30.55 cd	42.12
T_6	12.00 a	5.33 ab	44.45 ab	15.78
T_7	12.00 a	1.67 e	13.89 e	73.68
T_8	12.00 a	6.33 a	52.78 a	
CV (%)	00	14.61	14.61	
LSD (0.05)	0.05	1.02	8.48	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) reduced the number of infested plants by leaf hopper per plot over control (73.68%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the number of infested plants by leaf hopper per plot over control (57.90%). As a result, the order of rank of efficacy of the treatments applied against brinjal leaf hopper including untreated control in terms of reducing number of infested plant by leaf hopper per plot was T_7> T_1> T_5> T_2> T_4> T_6> T_3> T_8.

4.2 Infestation of aphid of brinjal

4.2.1 Number of aphid per plant

The significant variations were observed among different treatments used for the management practices in terms of number of aphid at different growing stage. At vegetative stage, the lowest number of aphid was recorded in T_7 (3.70 aphid/plant), which was followed by T_5 (4.20 aphid/plant), T_4 (4.40 aphid/plant) and T_1 (4.83 aphid/plant). On the other hand, the highest number of aphid was recorded in T_8 (8.00 aphid/plant), which was followed by T_3 (6.20 aphid/plant), T_6 (5.73 aphid/plant) and T_2 (5.23 aphid/plant). More or less similar trends of number of leaf hopper were also recorded at early fruiting, mid fruiting stage and late fruiting stage (Table 4).

In case of mean number of leaf hopper per plant, the highest number of aphid was recorded in T_8 (7.65 aphid/plant) comprised of untreated control, which was significantly different from all other treatments and followed by T_3 (5.54 aphid/plant), T_6 (5.06 aphid/plant) and T_2 (4.38 aphid/plant). On the other hand, the lowest mean leaf infestation by number was recorded in T_7 (2.79 aphid/plant), which was significantly different from all other treatments and followed by T_5 (3.27 aphid/plant), T_4 (3.61 aphid/plant) and T_1 (3.89 aphid/plant) (Table 4). Considering the percent reduction of number of aphid per plant, the highest 63.53% reduction over control was achieved in T_7 followed by T_5 (57.25%) and T_4 (52.81%). On the other hand, the minimum reduction of leaf infestation over control was found in T_3 (27.58%) followed by T_6 (33.86%).

Table 4: Effect of management practices of number of aphid on fully opened leaves per plants

Treatments	No. of aphids per plant					
	Vegetative stage	Early fruiting stage	Mid fruiting Stage	Late fruiting stage	Mean	Incidence reduction over control (%)
T_1	4.83 e	4.17 e	3.73 e	2.83 e	3.89 e	49.15

T_2	5.23 d	4.87 d	4.13 d	3.27 d	4.38 d	42.75
T_3	6.20 b	6.13 b	5.17 b	4.63 b	5.54 b	27.58
T_4	4.70 f	3.83 f	3.27 f	2.63 f	3.61 f	52.81
T_5	4.20 g	3.50 g	3.03 g	2.33 g	3.27 g	57.25
T_6	5.73 c	5.63 c	4.73 c	4.13 c	5.06 c	33.86
T_7	3.70 h	3.20 h	2.53 h	1.73 h	2.79 h	63.53
T_8	8.00 a	9.17 a	7.63 a	5.80 a	7.65 a	
CV (%)	1.48	1.27	1.04	1.76	0.8	
LSD (0.05)	0.13	0.11	0.08	0.11	0.05	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) reduced the number of aphid per five plants over control (63.53%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the number of aphid per five plants over control (49.15%). As a result, the order of rank of efficacy of the treatments applied against aphid including untreated control in terms of reducing number of aphid per five plants was $T_7 > T_5 > T_4 > T_1 > T_2 > T_6 > T_3 > T_8$.

4.2.2 Infestation of leaves by aphid per plant

The significant variations were observed among different treatments used for the management practices in terms of number of infested leaves by aphid at different growing stage. The highest number of leaves per five plants was recorded in T_1 (59.30 leaves/five plants), which was statistically different from other treatments and followed by T_5 (55.20 leaves/five plants), T_8 (51.70 leaves/five plants) and T_4 (50.30 leaves /five plants). On the other hand, the lowest number of leaves per five plants was recorded in T_3 (40.60 leaves /five plants), which was statistically different from other treatments and followed by T_6 (41.40 leaves /five plants), T_2 (42.47 leaves /five plants) and T_7 (47.10 leaves/five plants) (Table 5).

In case of number of infested leaves, the highest number of infested leaves per five plants was recorded in T_8 (16.67 leaves/five plants), which was statistically different from other treatments and followed by T_1 (10.67 leaves/five plants), T_3 (10.33 leaves/five plants) and T_6 (9.33 leaves /five plants). On the other hand, the lowest number of infested leaves per five plants was recorded in T_7 (5.67 leaves /five plants), which was statistically different from other treatments and followed by T_5 (8.00 leaves /five plants), T_4 (8.33 leaves /five plants) and T_2 (8.67 leaves/five plants) (Table 5).

In case of percent infestation of leaves per five plants, the highest percentage was recorded in T_8 (32.24%) comprised of untreated control, which was statistically different from other treatments and followed by T_3 (25.45%), T_6 (22.54%) and T_2 (20.41%). On the other hand, the lowest percentage was recorded in T_7 (12.03%), which was statistically different with other treatments and followed by T_5 (14.49%), T_4 (16.57%) and T_1 (17.99%) (Table 5). Considering the percent reduction of number of aphid per plant, the highest 62.67% reduction over control was achieved in T_7 followed by T_5 (55.05%) and T_4 (48.60%). On the other hand, the minimum reduction of leaf infestation over control was found in T_3 (21.05%) followed by T_6 (30.06%).

Table 5: Effect of management practices on infestation of fully opened leaves by aphid per five plants

Treatments	Infestation of leaves by aphid per five plants			
	No. of total leaves	No. of infested leaves	% infestation	Infestation reduction over control (%)
T_1	59.30 a	10.67 b	17.99 e	44.20
T_2	42.47 f	8.67 cd	20.41 d	36.68

T_3	40.60 h	10.33 b	25.45 b	21.05
T_4	50.30 d	8.33 d	16.57 f	48.60
T_5	55.20 b	8.00 d	14.49 g	55.05
T_6	41.40 g	9.33 c	22.54 c	30.06
T_7	47.10 e	5.67 e	12.03 h	62.67
T_8	51.70 c	16.67 a	32.24 a	
CV (%)	0.22	4.21	4.15	
LSD (0.05)	0.19	0.69	1.42	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) reduced the number of infested leaves by aphid per five plants over control (62.67%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the number of infested leaves by aphid per five plants over control (42.20%). As a result, the order of rank of efficacy of the treatments applied against aphid including untreated control in terms of reducing number of infested leaves by aphid per five plants was $T_7 > T_5 > T_4 > T_1 > T_2 > T_6 > T_3 > T_8$.

4.2.3. Infestation plants by aphid

The significant variations were not observed among different treatments used for the management practices in terms of number of total plants at different growing stage. In case of number of infested plants, the highest number of plants per plot was recorded in T_8 (6.33 plants/plot), which was statistically similar with T_6 (5.67 plants/plot), T_3 (5.33 plants/plot), T_4 (4.33 plants/plot) and T_2 (4.33 plants/plot). On the other hand, the lowest number of infested plants per plot was recorded in T_7 (1.67 plants /plot), which was statistically similar with T_1 (3.33 plants/plot) and T_5 (3.33 plants/plot) (Table 6).

In case of percent infestation of plants per plot, the highest percentage was recorded in T_8 (52.78%) untreated control, which was significantly similar with T_6 (47.22%), T_3 (44.45%) T_4 (36.11%) and T_2 (36.11%). On the other hand, the lowest number of infested plants per plot was recorded in T_7 (13.89%), which was statistically different from other treatments and followed by T_1 (27.78%) and T_5 (27.78%) (Table 6). Considering the percent reduction of number of aphid per plant, the highest 73.68% reduction over control was achieved in T_7 followed by T_1 (47.37%) and T_5 (47.37%). On the other hand, the minimum reduction of leaf infestation over control was found in T_6 (10.53%) followed by T_6 (15.78%).

Table 6: Effect of management practices of infestation of plants by aphid per plot

Treatments	Infestation of plants by aphid per plot			
	No. of total plants	No. of infested plants	% infestation	Infestation reduction over control (%)
T_1	12.00 a	3.33 d	27.78 d	47.37
T_2	12.00 a	4.33 c	36.11 c	31.58
T_3	12.00 a	5.33 b	44.45 b	15.78
T_4	12.00 a	4.33 c	36.11 c	31.58
T_5	12.00 a	3.33 cd	27.78 cd	47.37
T_6	12.00 a	5.67 ab	47.22 ab	10.53
T_7	12.00 a	1.67 e	13.89 e	73.68
T_8	12.00 a	6.33 a	52.78 a	
CV (%)	0.0	12.84	12.84	
LSD (0.05)	0.05	0.93	7.76	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) reduced the number of infested plants by aphid per plot over control (73.68%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the number of infested plants by aphid per plot over control (47.37%). As a result, the order of rank of efficacy of the treatments applied against aphid including untreated control in terms of reducing number of infested plant by aphid per plot was T_7> T_1> T_5> T_2> T_4> T_3> T_6> T_8.

4.3 Infestation of epilachna beetle of brinjal

4.3.1 Number of epilachna beetle per plant

The significant variations were observed among different treatments used for the management practices in terms of number of epilachna beetle at different growing stage. At vegetative stage, the lowest number of epilachna beetle was recorded in T_7 (1.53 epilachna beetle/plant), which was followed by T_5 (2.17 epilachna beetle/plant), T_4 (2.27 epilachna beetle/plant) and T_1 (2.47 epilachna beetle/plant). On the other hand, the highest number of epilachna beetle was recorded in T_8 (4.10 epilachna beetle/plant), which was followed by T_3 (3.23 epilachna beetle/plant), T_6 (3.17 epilachna beetle/plant) and T_2 (2.63 epilachna beetle/plant). More or less similar trends of number of epilachna beetle were also recorded at early fruiting, mid fruiting stage and late fruiting stage (Table 7).

In case of mean number of epilachna beetle per plant, the highest number of epilachna beetle was recorded in T_8 (4.53 epilachna beetle/plant) comprised of untreated control, which was significantly different from all other treatments and followed by T_3 (2.94 epilachna beetle/plant), T_6 (2.68 epilachna beetle/plant) and T_2 (2.30 epilachna beetle/plant). On the other hand, the lowest mean leaf infestation by number was recorded in T_7 (1.14 epilachna beetle/plant), which was significantly different from all other treatments and followed by T_5 (1.55 epilachna beetle/plant), T_4 (1.77 epilachna beetle/plant) and T_1 (2.03 epilachna beetle/plant) (Table 7). Considering the percent reduction of number of epilachna beetle per plant, the highest 74.83% reduction over control was achieved in T_7 followed by T_5 (65.78%) and T_4 (60.93%). On the other hand, the minimum reduction of leaf infestation over control was found in T_3 (35.10%) followed by T_6 (40.84%).

Table 7: Effect of management practices of number of epilachna beetle on fully opened leaves per plant

Treatments	No. of epilachna beetle per plant					
	Vegetative stage	Early fruiting stage	Mid fruiting Stage	Late fruiting stage	Mean	Incidence reduction over control (%)
T_1	2.47 d	2.13 e	1.83 e	1.67 e	2.03 e	55.19
T_2	2.63 c	2.33 d	2.17 d	2.03 d	2.30 d	49.23
T_3	3.23 b	3.13 b	2.73 b	2.63 b	2.94 b	35.10
T_4	2.27 e	1.83 f	1.63 f	1.33 f	1.77 f	60.93
T_5	2.17 f	1.73 f	1.23 g	1.07 g	1.55 g	65.78
T_6	3.17 b	2.70 c	2.53 c	2.33 c	2.68 c	40.84
T_7	1.53 g	1.30 g	1.07 h	0.67 h	1.14 h	74.83
T_8	4.10 a	4.57 a	4.80 a	4.63 a	4.53 a	
CV (%)	2.06	2.80	2.20	2.26	1.14	
LSD (0.05)	0.09	0.12	0.08	0.08	0.05	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) reduced the number of epilachna beetle per plants over control (74.83%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the number of epilachna beetle per plants over control (55.19%). As a result, the order of rank of efficacy of the treatments applied against epilachna beetle including untreated control in terms of reducing number of epilachna beetle per plants was $T_7 > T_5 > T_4 > T_1 > T_2 > T_6 > T_3 > T_8$.

4.2.2 Infestation of leaves by epilachna beetle per plant

The significant variations were observed among different treatments used for the management practices in terms of number of leaves by epilachna beetle at different growing stage. The highest number of leaves per five plants was recorded in T_1 (59.30 leaves/five plants), which was statistically different from other treatments and followed by T_5 (55.20 leaves/five plants), T_8 (51.70 leaves/five plants) and T_4 (50.30 leaves /five plants). On the other hand, the lowest number of leaves per five plants was recorded in T_3 (40.60 leaves /five plants), which was statistically different from other treatments and followed by T_6 (41.40 leaves /five plants), T_2 (42.47 leaves /five plants) and T_7 (47.10 leaves/five plants) (Table 8).

In case of number of infested leaves, the highest number of infested leaves per five plants was recorded in T_8 (12.33 leaves/five plants), which was statistically different from other treatments and followed by T_1 (9.00 leaves/five plants), T_3 (9.00 leaves/five plants) and T_6 (8.33 leaves /five plants). On the other hand, the lowest number of infested leaves per five plants was recorded in T_7 (4.33 leaves /five plants), which was statistically different from other treatments and followed by T_5 (5.67 leaves /five plants), T_4 (7.00 leaves /five plants) and T_2 (7.00 leaves/five plants) (Table 8).

In case of percent infestation of leaves per five plants, the highest percentage was recorded in T_8 (23.86%) comprised of untreated control, which was statistically similar with T_3 (22.16%) and followed by T_6 (20.13%). On the other hand, the lowest percentage was recorded in T_7 (9.20%), which was statistically similar with T_5 (10.27%) and followed by T_4 (13.91%), T_1 (15.18%) and T_2 (16.48%) (Table 8). Considering the percent reduction of number of epilachna beetle per plant, the highest 61.44% reduction over control was achieved in T_7 followed by T_5 (56.96%) and T_4 (41.70%). On the other hand, the minimum reduction of leaf infestation over control was found in T_3 (7.12%) followed by T_6 (15.63%).

Table 8: Effect of management practices on infestation of fully opened leaves by epilachna beetle per five plants

Treatments	Infestation of leaves by epilachna beetle per five plants			
	No. of total leaves	No. of infested leaves	% infestation	Infestation reduction over control (%)
T_1	59.30 a	9.00 b	15.18 c	36.38
T_2	42.47 f	7.00 c	16.48 c	30.93
T_3	40.60 h	9.00 b	22.16 ab	7.12
T_4	50.30 d	7.00 c	13.91 c	41.70
T_5	55.20 b	5.67 d	10.27 d	56.96
T_6	41.40 g	8.33 b	20.13 b	15.63
T_7	47.10 e	4.33 e	9.20 d	61.44
T_8	51.70 c	12.33 a	23.86 a	
CV (%)	0.22	8.75	9.25	
LSD (0.05)	0.19	1.16	2.56	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) reduced the number of infested leaves by epilachna beetle per five plants over control (61.44%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the number of infested leaves by epilachna beetle per five plants over control (36.38%). As a result, the order of rank of efficacy of the treatments applied against epilachna beetle including untreated control in terms of reducing number of infested leaves by epilachna beetle per five plants was $T_7 > T_5 > T_4 > T_1 > T_2 > T_6 > T_3 > T_8$.

4.3.3 Infestation plants by epilachna beetle

The significant variations were not observed among different treatments used for the management practices in terms of number of total plants at different growing stage. In case of number of infested plants, the highest number of plants per plot was recorded in T_8 (4.33 plants/plot), which was statistically different from other treatments and followed by T_3 (3.67 plants/plot), T_6 (2.67 plants/plot), T_4 (2.33 plants/plot), T_6 (2.67 plants/plot) and T_2 (4.33 plants/plot). On the other hand, the lowest number of infested plants per plot was recorded in T_7 (1.00 plants/plot), which was statistically similar with T_1 (1.33 plants/plot) and T_5 (1.00 plants/plot) (Table 9).

In case of percent infestation of plants per plot, the highest percentage was recorded in T_8 (36.11%) comprised of untreated control, which was significantly similar with T_3 (30.55%), T_6 (22.22%), T_2 (22.22%) and T_4 (19.45%). On the other hand, the lowest percentage was recorded in T_7 (8.33%), which was statistically different from other treatments and followed by T_5

(8.33%) and T_1 (11.11%) (Table 9). Considering the percent reduction of infestation of plant by epilachna beetle per plot, the highest 76.93% reduction over control was achieved in T_7 followed by T_5 (76.93%) and T_5 (69.23%). On the other hand, the minimum reduction of plant infestation over control was found in T_3 (15.40%) followed by T_6 (38.47%) and T_2 (38.47%).

Table 9: Effect of management practices on infestation of plants by epilachne beetle per plot

Treatments	Infestation of plants by epilachne beetle per plot			
	No. of total plants	No. of infested plants	% infestation	Infestation reduction over control (%)
T_1	12.00 a	1.33 d	11.11 d	69.23
T_2	12.00 a	2.67 c	22.22 c	38.47
T_3	12.00 a	3.67 b	30.55 b	15.40
T_4	12.00 a	2.33 c	19.45 c	46.14
T_5	12.00 a	1.00 d	8.33 d	76.93
T_6	12.00 a	2.67 c	22.22 c	38.47
T_7	12.00 a	1.00 d	8.33 d	76.93
T_8	12.00 a	4.33 a	36.11 a	
CV (%)	00	14.89	14.89	
LSD (0.05)	0.05	0.60	4.98	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) reduced the percentage of infested plant by epilachna beetle per plot over control (76.93%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the percentage of infested plants by epilachna beetle per plot over control (69.23%). As a result, the order of rank of efficacy of the treatments applied against epilachna beetle including untreated control in terms of reducing percentage of infested plants by epilachna beetle per plot was $T_7 > T_5 > T_1 > T_4 > T_2 > T_6 > T_3 > T_8$.

4.4 Infestation of leaf roller of brinjal

4.4.1 Number of leaf roller per plant

The significant variations were observed among different treatments used for the management practices in terms of number of leaf roller at different growing stage. At vegetative stage, the lowest number of leaf roller was recorded in T_7 (3.13 leaf roller/plant), which was followed by T_5 (3.53 leaf roller/plant), T_4 (3.83 leaf roller/plant) and T_1 (4.13 leaf roller/plant). On the other hand, the highest number of leaf roller was recorded in T_8 (6.13 leaf roller/plant), which was followed by T_3 (5.20 leaf roller/plant), T_6 (4.77 leaf roller/plant) and T_2 (4.43 leaf roller/plant). More or less similar trends of number of leaf roller were also recorded at early fruiting, mid fruiting stage and late fruiting stage (Table 10).

In case of mean number of leaf roller per plant, the highest number of leaf roller was recorded in T_8 (5.25 leaf roller/plant) comprised of untreated control, which was significantly different from all other treatments and followed by T_3 (4.20 leaf roller/plant), T_6 (3.78 leaf roller /plant) and T_2 (3.63 leaf roller/plant). On the other hand, the lowest mean number of leaf roller was recorded in T_7 (2.12 leaf roller/plant), which was significantly different from all other treatments and followed by T_5 (2.45 leaf roller/plant), T_4 (2.80 leaf roller/plant) and T_1 (3.03 leaf roller/plant) (Table 10). Considering the percent reduction of number of leaf roller per plant, the highest 59.62% reduction over control was achieved in T_7 followed by T_5 (53.33%) and T_4 (46.67%). On the other hand, the minimum reduction of leaf infestation over control was found in T_3 (20.00%) followed by T_6 (28.00%).

Table 10: Effect of management practices against number of leaf roller on fully opened leaves per plant

Treatments	No. of Leaf roller per plant					
	Vegetative stage	Early fruiting stage	Mid fruiting Stage	Late fruiting stage	Mean	Incidence reduction over control (%)
T_1	4.13 e	3.37 e	2.83 e	1.77 e	3.03 e	42.29
T_2	4.43 d	3.70 d	3.13 d	2.17 d	3.63 d	30.86
T_3	5.20 b	4.53 b	3.87 b	3.20 b	4.20 b	20.00
T_4	3.83 f	3.17 f	2.63 f	1.53 f	2.80 f	46.67
T_5	3.53 g	2.83 g	2.17 g	1.23 g	2.45 f	53.33
T_6	4.77 c	4.17 c	3.53 c	2.63 c	3.78 c	28.00
T_7	3.13 h	2.53 h	1.73 h	1.07 h	2.12 h	59.62
T_8	6.13 a	5.83 a	4.80 a	4.20	5.25 a	
CV (%)	1.27	1.79	2.06	2.88	0.89	
LSD (0.05)	0.09	0.12	0.11	0.11	0.05	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) reduced the number of leaf roller per plant over control (59.62%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the number of leaf roller per plant over control (42.29%). As a result, the order of rank of efficacy of the treatments applied against leaf roller including untreated control in terms of reducing number of leaf roller per plant was $T_7 > T_5 > T_4 > T_1 > T_2 > T_6 > T_3 > T_8$.

4.4.2 Infestation of leaves by leaf roller per plant

The significant variations were observed among different treatments used for the management practices in terms of number of infested leaves by leaf roller at different growing stage. The highest number of leaves per five plants was recorded in T_1 (59.30 leaves/five plants), which was statistically different from other treatments and followed by T_5 (55.20 leaves/five plants), T_8 (51.70 leaves/five plants) and T_4 (50.30 leaves /five plants). On the other hand, the lowest number of leaves per five plants was recorded in T_3 (40.60 leaves /five plants), which was statistically different from other treatments and followed by T_6 (41.40 leaves /five plants), T_2 (42.47 leaves /five plants) and T_7 (47.10 leaves/five plants) (Table 11).

In case of number of infested leaves, the highest number of infested leaves per five plants was recorded in T_8 (10.67 leaves/five plants), which was statistically different from other treatments and followed by T_6 (6.67 leaves/five plants), T_3 (6.33 leaves/five plants), T_1 (6.00 leaves/five plants) and T_4 (5.67 leaves /five plants). On the other hand, the lowest number of infested leaves per five plants was recorded in T_7 (2.67 leaves /five plants), which was statistically different from other treatments and followed by T_5 (4.00 leaves /five plants) and T_2 (5.33 leaves/five plants) (Table 11).

In case of percent infestation of leaves per five plants, the highest percentage was recorded in T_8 (20.64%) comprised of untreated control, which was statistically different from other treatments and followed by T_6 (16.10%), T_3 (15.60%), T_2 (12.55%), T_4 (11.26%) and T_1 (10.12%). On the other hand, the lowest percentage was recorded in T_7 (5.66%), which was statistically similar with T_5 (7.25%) (Table 11). Considering the percent reduction of number of leaf roller per plant, the highest 72.58% reduction over control was achieved in T_7 followed by T_5 (64.87%) and T_1 (50.97%). On the other hand, the minimum reduction of leaf infestation over control was found in T_6 (22.00%) followed by T_3 (24.42%).

Table 11: Effect of management practices of infestation of fully opened leaves by leaf roller per five plants

Treatments	Infestation of leaves by leaf roller per five plants			
	No. of total leaves	No. of infested leaves	% infestation	Infestation reduction over control (%)
T_1	59.30 a	6.00 bc	10.12 c	50.97
T_2	42.47 f	5.33 c	12.55 c	39.20
T_3	40.60 h	6.33 bc	15.60 b	24.42
T_4	50.30 d	5.67 bc	11.26 c	45.45
T_5	55.20 b	4.00 d	7.25 d	64.87
T_6	41.40 g	6.67 b	16.10 b	22.00
T_7	47.10 e	2.67 e	5.66 d	72.58
T_8	51.70 c	10.67 a	20.64 a	
CV (%)	0.22	11.66	11.30	
LSD (0.05)	0.19	1.165	2.37	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) reduced the number of infested leaves by leaf roller per five plants over control (72.58%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the number of infested leaves by leaf roller per five plants over control (50.97%). As a result, the order of rank of efficacy of the treatments applied against leaf roller including untreated control in terms of reducing number of infested leaves by leaf roller per five plants was $T_7 > T_5 > T_1 > T_4 > T_2 > T_3 > T_6 > T_8$.

4.4.3 Infestation plants by leaf roller

The significant variations were not observed among different treatments used for the management practices in terms of number of total plants at different growing stage. In case of number of infested plants, the highest number of plants per plot was recorded in T_8 (3.33 plants/plot), which was statistically similar with T_3 (3.33 plants/plot) and followed by T_6 (2.33 plants/plot), T_4 (2.00 plants/plot) and T_2 (2.00 plants/plot). On the other hand, the lowest number of infested plants per plot was recorded in T_7 (1.00 plants/plot) which was statistically similar with T_1 (1.00 plants/plot) and T_5 (1.00 plants/plot) (Table 12).

In case of percent infestation of plants per plot, the highest percentage was recorded in T_8 (27.78%) comprised of untreated control, which was significantly similar with T_3 (27.78%) and followed by T_6 (19.45%), T_4 (16.67%) and T_2 (16.67%). On the other hand, the lowest number of infested plants per plot was recorded in T_7 (8.33%), which was statistically similar with T_1 (8.33%) and T_5 (8.33%) (Table 12). Considering the percent reduction of number of infested plant per plot, the highest 70.01% reduction over control was achieved in T_7 and similar with T_1 (70.01%) and T_5 (70.01%). On the other hand, the minimum reduction of infestation of plant per plot over control was found in T_3 (0.00%) followed by T_6 (29.99%).

Table 12: Effect of management practices against infestation of plants by leaf roller per plot

Treatments	Infestation of plants by leaf roller per plot			
	No. of total plants	No. of infested plants	% infestation	Infestation reduction over control (%)
T_1	12.00 a	1.00 c	8.33 c	70.01
T_2	12.00 a	2.00 b	16.67 b	39.99
T_3	12.00 a	3.33 a	27.78 a	0.00
T_4	12.00 a	2.00 b	16.67 b	39.99
T_5	12.00 a	1.00 c	8.33 c	70.01
T_6	12.00 a	2.33 b	19.45 b	29.99
T_7	12.00 a	1.00 c	8.33 c	70.01
T_8	12.00 a	3.33 a	27.78 a	
CV (%)	00	17.68	17.67	
LSD (0.05)	0.05	0.60	4.98	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) reduced the percent of infested plant by leaf roller per plot over control (70.01%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the percent of infested plants by leaf roller per plot over control (70.01%). As a result, the order of rank of efficacy of the treatments applied against leaf roller including untreated control in terms of reducing percent of infested plants by leaf hopper per plot was $T_7 > T_1 > T_5 > T_2 > T_4 > T_6 > T_3 > T_8$.

4.5. Incidence of beneficial arthropods

4.5.1. Lady bird beetle

The significant variations were observed among the different treatments used for the management practices in terms of number of lady bird beetle. At vegetative stage, the highest number of lady bird beetle per plants was recorded in T_1 (3.17 lady bird beetle/plant), which was statistically similar with T_2 (3.10 lady bird beetle/plant) and followed by T_8 (2.73 lady bird beetle/plant) and T_3 (2.37 lady bird beetle/plant). On the other hand, the lowest number of lady bird beetle per plants was recorded in T_5 (1.23 lady bird beetle/plant) which was statistically different with other treatments and followed by T_7 (1.60 lady bird beetle/plant), T_4 (1.73 lady bird beetle/plant) and T_6 (2.17 lady bird beetle/plant) (Table 13). In case of early fruiting stage, the highest number of lady bird beetle per plants was recorded in T_1 (4.77 lady bird beetle/plant), which was statistically different from other treatments and followed by T_2 (4.37 lady bird beetle/plant), T_8 (4.17 lady bird beetle/plant) and T_3 (3.83 lady bird beetle/plant). On the other hand, the lowest number of lady bird beetle per plants was recorded in T_5 (2.30 lady bird beetle/plant) which was statistically different with other treatments and followed by T_7 (2.73 lady bird beetle/plant), T_4 (3.13 lady bird beetle/plant) and T_6 (3.57 lady bird beetle/plant) (Table 13). More or less similar trends of number of lady bird beetle per plants were also recorded at mid fruiting stage and late fruiting stage.

In case of mean number of lady bird beetle, the highest number of lady bird beetle per plants was recorded in T_1 (5.21 lady bird beetle/plant) comprised of untreated control, which was significantly different with other treatments and followed by T_2 (4.87 lady bird beetle/plant), T_8 (4.60 lady bird beetle/plant) and T_3 (4.16 lady bird beetle/plant). On the other hand, the lowest mean number of lady bird beetle per plants was recorded in T_5 (2.55 lady bird beetle/plant), which was significantly different from other treatments and followed by T_7 (3.00 lady bird beetle/plant), T_4 (3.32 lady bird beetle/plant) and T_6 (3.78 lady bird beetle/plant) (Table 13). Considering the percent increase or decrease of number of lady bird beetle per plants, the highest 13.26% increase over control was observed in T_1 followed by T_2 (5.87%). On the other hand, the minimum reduction of number of lady bird beetle over control was found in T_5 (44.57%) followed by T_7 (34.78%).

Table 13: Effect of management practices on incidence of lady bird beetle per plants

Treatments	Incidence of lady bird beetle per five plants					
	Vegetative stage	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean	Incidence increase over control (%)
T_1	3.17 a	4.77 a	5.27 a	7.63 a	5.21 a	13.26
T_2	3.10 a	4.37 b	4.83 b	7.17 b	4.87 b	5.87
T_3	2.37 c	3.83 d	4.13 d	6.30 d	4.16 d	-9.57
T_4	1.73 e	3.13 f	3.23 f	5.17 f	3.32 f	-27.83
T_5	1.23 g	2.30 h	2.43 h	4.23 h	2.55 h	-44.57
T_6	2.17 d	3.57 e	3.67 e	5.70 e	3.78 e	-17.83
T_7	1.60 f	2.73 g	2.80 g	4.83 g	3.00 g	-34.78
T_8	2.73 b	4.17 c	4.60 c	6.87 c	4.60 c	
CV (%)	3.29	1.86	1.78	1.24	1.04	
LSD (0.05)	0.13	0.12	0.12	0.13	0.08	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among different treatments the Actara 25 WG based treatment (T_5) reduced the highest incidence of lady bird beetle (44.57%) in the brinjal field. Conversely, the neem oil based treatment (T_1) performed as the least hazard. Management practices, which increased (13.26%) lady bird beetle in the brinjal field rather than synthetic treatments as well as other botanicals. As a result, the order of rank of efficacy of the treatments to increase number of lady bird beetle per plant was $T_1 > T_2 > T_8 > T_3 > T_6 > T_4 > T_7 > T_5$.

4.5.2. Spider

The significant variations were observed among the different treatments used for the management practices in terms of number of spider. At vegetative stage, the highest number of spider per plants was recorded in T_1 (2.67 spider/plant), which was statistically similar with T_2 (2.23 spider/plant) and followed by T_8 (1.80 spider/plant) and T_3 (1.67 spider/plant). On the other hand, the lowest number of spider per plants was recorded in T_5 (0.83 spider/plant) which was statistically different from other treatments and followed by T_7 (1.07 spider/plant), T_4 (1.17 spider/plant) and T_6 (1.27 spider/plant) (Table 14). More or less similar trends of number of spider per plants were also recorded at early fruiting stage, mid fruiting stage and late fruiting stage.

In case of mean number of spider, the highest number of spider per plants was recorded in T_1 (3.53 spider/plant) comprised of untreated control, which was significantly different with other treatments and followed by T_2 (3.20 spider/plant), T_8 (2.89 spider/plant) and T_3 (2.60 spider/plant). On the other hand, the lowest mean number of spider per plants was recorded in T_5 (0.96 spider/plant), which was significantly different from other treatments and followed by T_7 (1.74 spider/plant), T_4 (2.06 spider/plant) and T_6 (2.25 spider/plant) (Table 14). Considering the percent increase or decrease the number of spider per plants, the highest 22.15% increase over control was observed in T_1 followed by T_2 (10.73%). On the other hand, the minimum reduction of number of spider over control was found in T_5 (66.78%) followed by T_7 (39.79%).

Table 14: Effect of management practices on incidence of spider per plot

Treatments	Incidence of spider per plot					
	Vegetative stage	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean	Incidence increase over control (%)
T_1	2.67 a	3.27 a	3.93 a	4.23 a	3.53 a	22.15
T_2	2.23 b	3.07 b	3.43 b	4.07 b	3.20 b	10.73
T_3	1.67 d	2.43 d	2.87 d	3.43 d	2.60 d	-10.03
T_4	1.17 ef	2.17 e	2.17 f	2.73 f	2.06 f	-28.72
T_5	0.83 g	0.87 g	1.07 h	1.07 h	0.96 h	-66.78
T_6	1.27 e	2.23 e	2.33 e	3.17 e	2.25 e	-22.15
T_7	1.07 f	1.73 f	1.87 g	2.30 g	1.74 g	-39.79
T_8	1.80 c	2.73 c	3.17 c	3.87 c	2.89 c	
CV (%)	4.01	2.67	2.24	2.12	1.24	
LSD (0.05)	0.11	0.11	0.09	0.11	0.05	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among different treatments the Actara 25 WG based treatment (T_5) reduced the highest incidence of spider (66.78%) in the brinjal field. Conversely, the neem oil based treatment (T_1) performed as the least hazard. Management practices, which increased (22.15%) in the brinjal field rather than synthetic treatments as well as other botanicals. As a result, the order of rank of efficacy of the treatments to increase number of spider per plant was $T_1 > T_2 > T_8 > T_3 > T_6 > T_4 > T_7 > T_5$.

4.5.3. Ants

The significant variations were observed among the different treatments used for the management practices in terms of number of ants. At vegetative stage, the highest number of ants per plants was recorded in T_1 (3.83 ants/plant), which was statistically different from other treatments and followed by T_2 (3.40 ants/plant), T_8 (3.17 ants/plant) and T_3 (2.83 ants/plant). On the other hand, the lowest number of ants per plants was recorded in T_5 (1.67 ants/plant) which was statistically different from other treatments and followed by T_7 (1.73 ants/plant), T_4 (2.27 ants/plant) and T_6 (2.50 ants/plant) (Table 15). More or less similar trends of number of ants per plants were also recorded at early fruiting stage, mid fruiting stage and late fruiting stage.

In case of mean number of ants, the highest number of ants per plants was recorded in T_1 (4.05 ants/plant) comprised of untreated control, which was significantly different with other treatments and followed by T_2 (3.73 ants/plant), T_8 (3.45 ants/plant) and T_3 (3.20 ants/plant). On the other hand, the lowest mean number of ants per plants was recorded in T_5 (1.40 ants/plant), which was significantly different from other treatments and followed by T_7 (1.84 ants/plant), T_4 (2.23 ants/plant) and T_6 (2.52 ants/plant) (Table 15). Considering the percent increase or decrease the number of ants per plants, the highest 17.39% increase over control was observed in T_1 followed by T_2 (8.12%). On the other hand, the minimum reduction of number of ants over control was found in T_5 (59.42%) followed by T_7 (46.67%).

Table 15: Effect of management practices on incidence of ants per plot

Treatments	Incidence of ants per plot					
	Vegetative stage	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean	Incidence increase over control (%)
T_1	3.83 a	3.87 a	4.07 a	4.43 a	4.05 a	17.39
T_2	3.40 b	3.67 b	3.77 b	4.07 b	3.73 b	8.12

T_3	2.83 d	3.10 d	3.27 d	3.60 c	3.20 d	-7.25
T_4	2.27 f	2.53 f	2.30 f	1.80 e	2.23 f	-35.36
T_5	1.67 g	1.57 h	1.27 h	1.10 f	1.40 h	-59.42
T_6	2.50 e	2.73 e	2.63 e	2.20 d	2.52 e	-26.96
T_7	1.73 g	2.23 g	2.17 g	1.23 f	1.84 g	-46.67
T_8	3.17 c	3.30 c	3.60 c	3.73 c	3.45 c	
CV (%)	2.50	2.63	2.52	2.99	1.33	
LSD (0.05)	0.11	0.13	0.12	0.14	0.05	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; T_8 Untreated control.]

From these above findings it was revealed that among different treatments the Actara 25 WG based treatment (T_5) reduced the highest incidence of ants (59.42%) in the brinjal field. Conversely, the neem oil based treatment (T_1) performed as the least hazard. Management practices, which increased (17.39%) in the brinjal field rather than synthetic treatments as well as other botanicals. As a result, the order of rank of efficacy of the treatments to increase number of ats per plant was $T_1 > T_2 > T_8 > T_3 > T_6 > T_4 > T_7 > T_5$.

4.6. Yield attributes

4.6.1. Effect of management practices on fruit length of brinjal

The significant variations were observed among different treatments used for the management practices in terms of fruit length of brinjal at different growing stage. At early fruiting stage, the lowest fruit length of brinjal was recorded in T_8 (7.40 cm), which was followed by T_3 (8.82 cm), T_6 (9.16 cm) and T_2 (9.34 cm). On the other hand, the highest number of fruit length of brinjal was recorded in T_7 (10.34 cm), which was followed by T_5 (10.03 cm), T_4 (10.02 cm) and T_1 (9.84 cm). More or less similar trends of fruit length of brinjal were also recorded at mid fruiting stage and late fruiting stage (Table 16).

In case of mean fruit length of brinjal per five tagged plants, the highest fruit length of brinjal was recorded in T_7 (11.01 cm) comprised of untreated control, which was significantly different from all other treatments and followed by T_5 (10.29 cm), T_4 (9.99 cm) and T_1 (9.33 cm). On the other hand, the lowest mean fruit length of brinjal per five tagged plants was recorded in T_8 (5.21 cm), which was significantly different from all other treatments and followed by T_3 (6.99 cm), T_6 (7.88 cm) and T_2 (8.78 cm) (Table 16).

In case of percent infested fruit length of brinjal, the lowest percent was recorded in T_7 (3.96%) and followed by T_1 (4.47%), T_5 (5.67%) and T_4 (6.22%). On the other hand, the highest percent was recorded in T_8 (22.39%), which was significantly different from other treatments and followed by T_3 (8.76%), T_6 (7.85%) and T_2 (6.65%) (Table 16). Considering the percent reduction of fruit length of brinjal per five tagged plants, the highest 82.31% over control was achieved in T_7 followed by T_1 (80.04%) and T_5 (74.68%). On the other hand, the minimum reduction of fruit length of brinjal over control was found in T_3 (60.88%) followed by T_6 (64.94%).

Table 16. Effect of management practices on fruit length of brinjal during growing season

Treatments	Fruit length (cm)					
	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean	% of infested fruit length	Infestation reduction over control (%)
T_1	9.84 c	9.83 d	8.33 d	9.33 d	4.47 g	80.04
T_2	9.34 d	9.33 e	7.67 e	8.78 e	6.65 d	70.30
T_3	8.82 f	8.01 g	4.12 g	6.99 g	8.76 b	60.88
T_4	10.02 b	10.17 c	9.78 c	9.99 c	6.22 e	72.22
T_5	10.03 b	10.52 b	10.32 b	10.29 b	5.67 f	74.68
T_6	9.16 e	9.17 f	5.33 f	7.88 f	7.85 c	64.94
T_7	10.34 a	12.02 a	10.67 a	11.01 a	3.96 h	82.31
T_8	7.40 g	6.13 h	2.10 h	5.21 h	22.39 a	
CV (%)	0.44	0.15	0.49	0.09	1.57	

LSD (0.05)	0.76	0.05	0.05	0.05	0.22	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; $T_{8:}$ Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) in reduced infested fruit length per five plants over control (82.31%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the infested fruit length over control (80.04%).

4.6.2. Effect of management practices on fruit girth of brinjal

The significant variations were observed among different treatments used for the management practices in terms of fruit girth of brinjal per five tagged plants at different growing stage. At early fruiting stage, the lowest fruit girth of brinjal per five tagged plants was recorded in T_8 (10.66 cm), which was followed by T_3 (11.17 cm), T_6 (12.16 cm) and T_2 (12.33 cm). On the other hand, the highest fruit girth of brinjal per five tagged plants was recorded in T_7 (13.17 cm), which was statistically similar with T_4 (13.10 cm) and followed by T_5 (13.03 cm) and T_1 (12.67 cm). More or less similar trends of fruit girth of brinjal per five tagged plants were also recorded at mid fruiting stage and late fruiting stage (Table 17).

In case of mean fruit girth of brinjal per five tagged plants, the highest fruit girtth of brinjal was recorded in T_7 (13.31 cm) comprised of untreated control, which was significantly different from all other treatments and followed by T_5 (12.57 cm), T_4 (12.36 cm) and T_1 (12.02 cm). On the other hand, the lowest mean fruit girth of brinjal per five tagged plants was recorded in T_8 (9.28

cm), which was significantly different from all other treatments and followed by T_3 (10.72 cm), T_6 (11.44 cm) and T_2 (11.67 cm) (Table 17).

In case of percent infested fruit girth of brinjal, the lowest percent was recorded in T_7 (3.36%) and followed by T_5 (4.58%), T_1 (4.62%) and T_4 (4.73%). On the other hand, the highest percent was recorded in T_8 (12.38%), which was significantly different from other treatments and followed by T_6 (9.45%), T_3 (7.21%) and T_2 (6.58%) (Table 17). Considering the percent reduction of fruit girth of brinjal per five tagged plants, the highest 72.86% over control was achieved in T_7 followed by T_5 (63.00%) and T_1 (62.68%). On the other hand, the minimum reduction of fruit girth of brinjal over control was found in T_6 (23.67%) followed by T_3 (41.76%) and T_2 (46.85%).

Table 17. Effect of management practices on fruit girth of brinjal during growing season

Treatments	Fruit girth (cm)					
	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean	% of infested fruit girth	Infestation reduction over control (%)
T_1	12.67 c	12.07 d	11.33 d	12.02 d	4.62 e	62.68
T_2	12.33 d	11.50 e	11.17 e	11.67 e	6.58 d	46.85
T_3	11.17 f	10.67 g	10.33 g	10.72 g	7.21 c	41.76
T_4	13.10 ab	12.33 c	11.66 c	12.36 c	4.73 e	61.79
T_5	13.03 b	12.51 b	12.18 b	12.57 b	4.58 e	63.00
T_6	12.16 e	11.13 f	11.03 f	11.44 f	9.45 b	23.67
T_7	13.17 a	12.67 a	14.10 a	13.31 a	3.36 f	72.86
T_8	10.66 g	9.67 h	7.50 h	9.28 h	12.38 a	
CV (%)	0.32	0.36	0.36	0.19	3.62	
LSD (0.05)	0.08	0.08	0.08	0.05	0.40	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; $T_{8:}$ Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) reduced infested fruit girth per five tagged plants over control (72.86%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of reducing the infested fruit girth per five tagged plants over control (62.68%).

4.6.3. Effect of management practices on single fruit weight of brinjal

The significant variations were observed among different treatments used for the management practices in terms of single fruit weight of brinjal at different growing stage. At early fruiting stage, the lowest single fruit weight of brinjal was recorded in T_8 (17.31 gm), which was followed by T_3 (22.33 gm), T_6 (23.36 gm) and T_2 (26.17 gm). On the other hand, the highest single fruit weight of brinjal was recorded in T_7 (37.53 gm), which was followed by T_1 (33.82 gm), T_5 (32.33 gm) and T_4 (27.29 gm). More or less similar trends of single fruit weight of brinjal were also recorded at mid fruiting stage and late fruiting stage (Table 18).

In case of mean single fruit weight, the highest single fruit weight of brinjal was recorded in T_7 (39.00 gm) comprised of untreated control, which was significantly different from all other treatments and followed by T_5 (36.78 gm), T_1 (34.66 gm) and T_4 (31.78 gm). On the other hand, the lowest mean single fruit weight of brinjal was recorded in T_8 (19.11 gm), which was significantly different from all other treatments and followed by T_3 (23.22 gm), T_6 (24.66 gm) and T_2 (29.22 gm) (Table 18). Considering the percent increase of single fruit weight of brinjal, the maximum 104.08% over control was achieved in T_7 followed by T_5 (92.46%) and T_1 (81.37%). On the other hand, the minimum percent increase of single fruit weight of brinjal over control was found in T_3 (21.51%) followed by T_6 (29.04%).

Table 18. Effect of management practices on fruit girth of brinjal during growing season

Treatments	Single fruit weight per plant (gm)				
	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean	Fruit weight increase over control (%)
T_1	33.82 b	38.33 b	32.33 b	34.66 c	81.37
T_2	26.17 e	33.33 d	28.00 c	29.22 e	52.90
T_3	22.33 g	25.67 f	21.67 e	23.22 g	21.51
T_4	27.29 d	36.33 c	31.67 b	31.78 d	66.30
T_5	32.33 c	41.67 a	36.33 a	36.78 b	92.46
T_6	23.36 f	27.33 e	23.33 d	24.66 f	29.04
T_7	37.53 a	42.33 a	37.33 a	39.00 a	104.08
T_8	17.31 h	21.67 g	18.33 f	19.11 h	
CV (%)	1.88	1.84	2.27	1.46	
LSD (0.05)	0.87	1.03	1.01	0.73	

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; $T_{8:}$ Untreated control.]

From these above findings it was revealed that among the different treatments, T_7 (spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval) increased single fruit weight of brinjal over control (104.08%). Considering the botanical treatments, T_1 (spraying of Neem oil @ 3.0 ml/L of water at 7 days interval) performed as the best treatment in terms of increasing single fruit weight of brinjal over control (81.37%).

4.6.4. Effects of management practices on number of branch per plant, plant height per plot and yield

There were no significant variance among number of branch per plant and plant height per plot at brinjal field at different treatments throughout the growing season of brinjal cultivation.

In case of yield per plot, the highest yield was recorded in T_7 (1534.00 kg/plot) which was followed by T_1 (1475.00 kg/plot), T_5 (1312.00 kg/plot) and T_4 (1199.00 kg/plot). On the other hand, the lowest yield was recorded in T_8 (549.70 kg/plot) which was followed by T_3 (827.10 kg/plot), T_6 (988.30 kg/plot) and T_2 (1132.00 kg/plot).

Table 19. Effects of management practices on number of branch per plant, plant height per plot and yield

Treatments	Number of branch/ plant	Plant height (cm)/ plot	Yield (Kg/plot)	Yield (t/ha)
T_1	8.33 a	46.20 a	1475.00 b	24.59 b
T_2	7.33 a	40.73 a	1132.00 e	18.87 e
T_3	8.27 a	46.33 a	827.10 g	13.79 g
T_4	8.93 a	46.73 a	1199.00 d	19.98 d
T_5	8.33 a	48.07 a	1312.00 c	21.86 c
T_6	8.53 a	47.00 a	988.30 f	16.47 f
T_7	7.40 a	44.07 a	1534.00 a	25.57 a
T_8	8.47 a	45.27 a	549.70 h	9.16 h
CV (%)	10.25	8.86	0.09	0.09
LSD (0.05)	1.42	6.82	1.70	0.05

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Bioneem plus @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Marshal 25 EC @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval; T_6 : Spraying of Emitaf 20 SL @ 0.1 ml/L of water at 7 days interval; T_7 : Spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval; $T_{8:}$ Untreated control.]

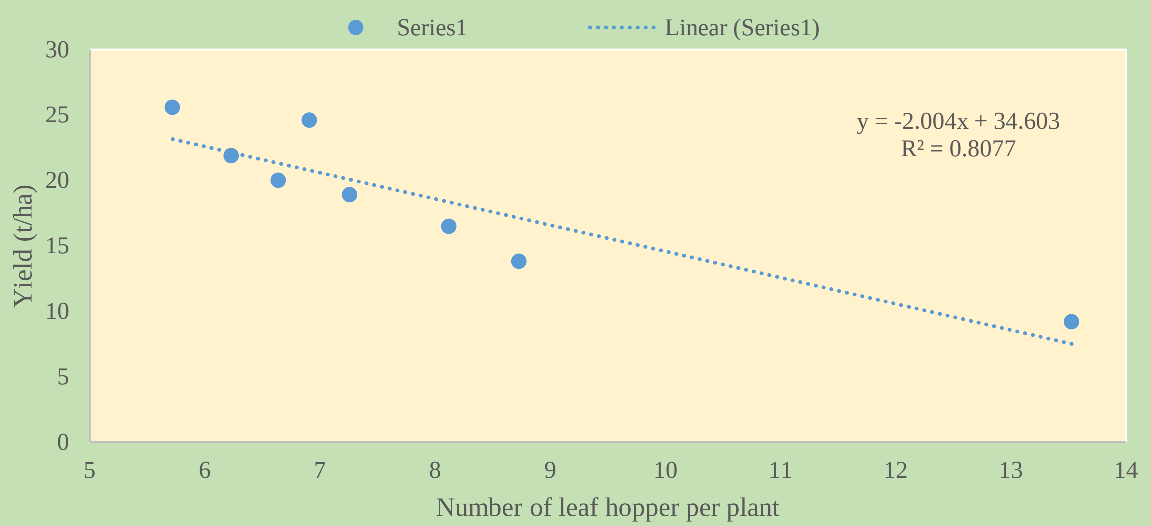
In terms of yield per hectares, the highest yield was recorded in T_7 (25.57 t/ha) which was followed by T_1 (24.59 t/ha), T_5 (21.86 t/ha) and T_4 (19.98 t/ha). On the other hand, the lowest yield was recorded in T_8 (9.16 t/ha) which was followed by T_3 (13.79 t/ha), T_6 (16.47 t/ha) and T_2 (18.87 t/ha). As a result, the order of rank of efficacy of the treatments applied against aphid including untreated control in terms of reducing number of aphid per plant was $T_7 > T_1 > T_5 > T_4 > T_2 > T_6 > T_3 > T_8$.

4.7. Relationship between number of insect and yield of brinjal

4.7.1. Leaf hopper

Correlation study was done to establish the relationship between number of leaf hopper per plant and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between the number of leaf hopper per plant and yield of brinjal (Figure 1). It was evident from the Figure 1 that the regression equation $y = -2.004x + 34.603$ gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8077) 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

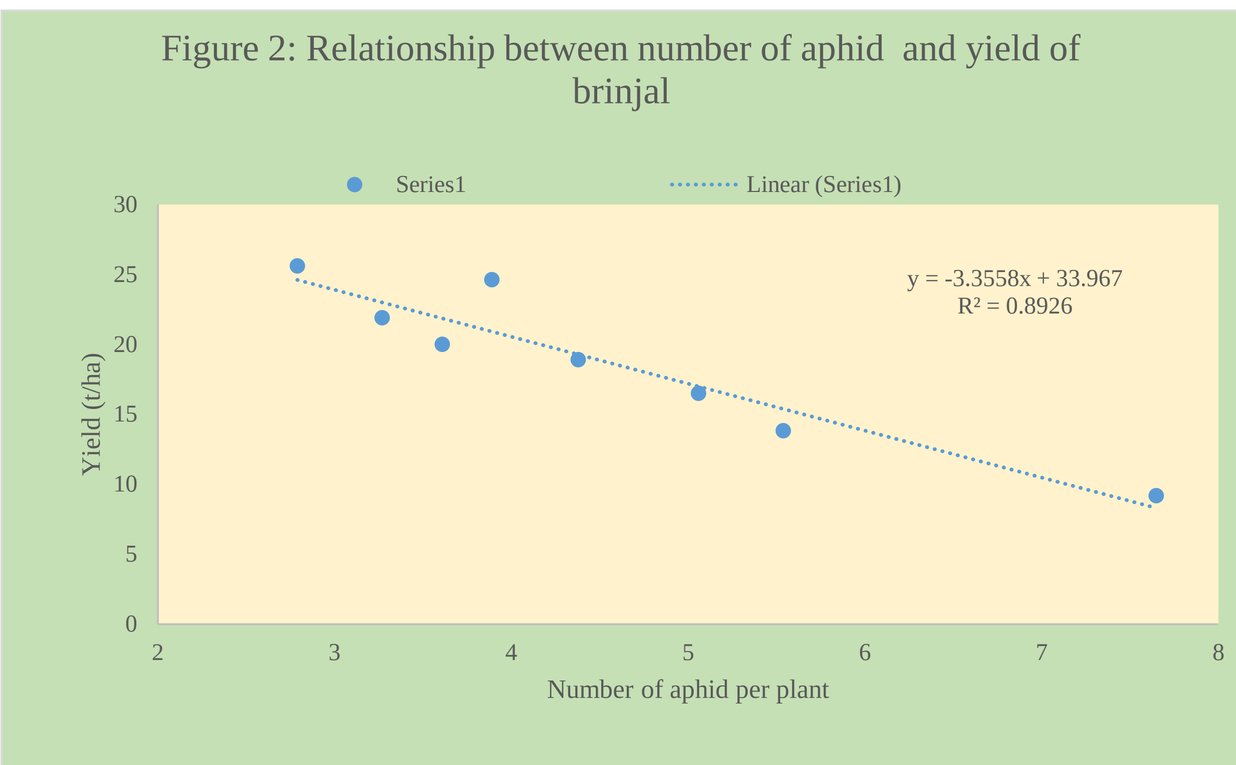
Figure 1: Relationship between number of leaf hopper and yield of brinjal



leaf hopper per plant and yield of brinjal, i.e., the yield decreased with the increase of the number of leaf hopper per plant during the growing season of brinjal.

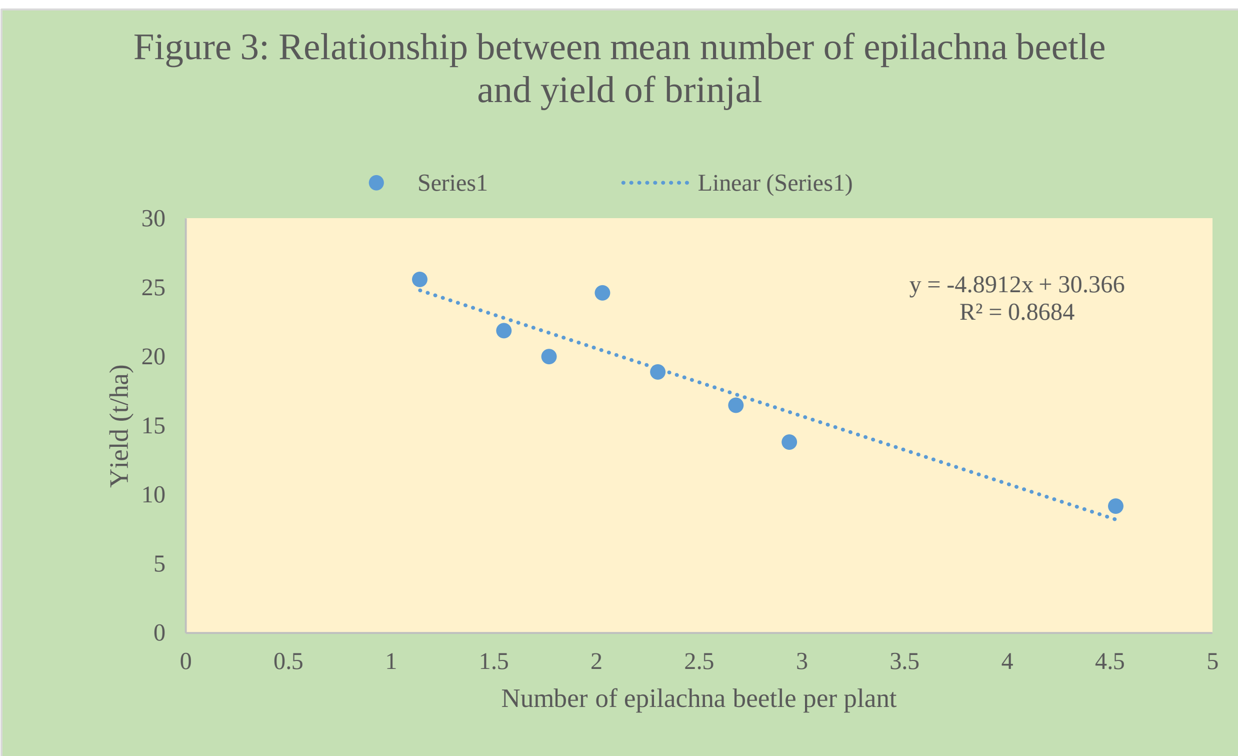
4.7.2. Aphid

Correlation study was done to establish the relationship between number of aphid per plant and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between the number of aphid per plant and yield of brinjal (Figure 2). It was evident from the Figure 2 that the regression equation y = -3.3558x + 33.967 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8926) 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 aphid per plant and yield of brinjal, i.e., the yield decreased with the increase of the number of aphid per plant during the growing season of brinjal.



4.7.3. Epilachna beetle

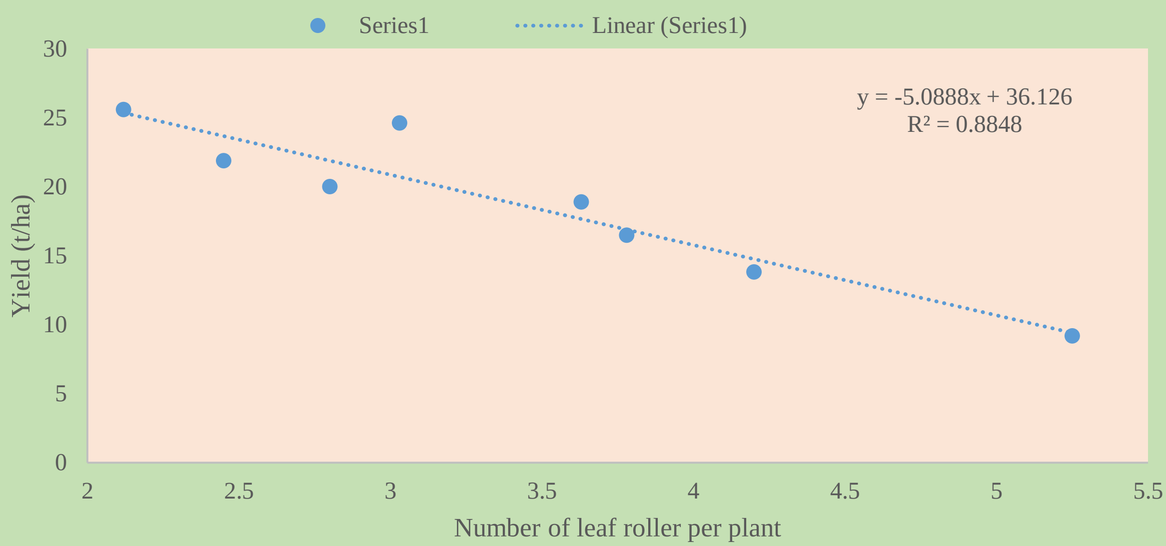
Correlation study was done to establish the relationship between number of epilachna beetle per plant and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between the number of epilachna beetle per plant and yield of brinjal (Figure 3). It was evident from the Figure 3 that the regression equation y = -4.8912x + 30.366 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8684) 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 epilachna beetle per plant and yield of brinjal, i.e., the yield decreased with the increase of the number of epilachna beetle per plant during the growing season of brinjal.



4.7.4. Leaf roller

Correlation study was done to establish the relationship between number of leaf roller per plant and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between the number of leaf roller per plant and yield of brinjal (Figure 4). It was evident from the Figure 4 that the regression equation y = -5.0888x + 36.126 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8848) 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 leaf roller per plant and yield of brinjal, i.e., the yield decreased with the increase of the number of leaf roller per plant during the growing season of brinjal.

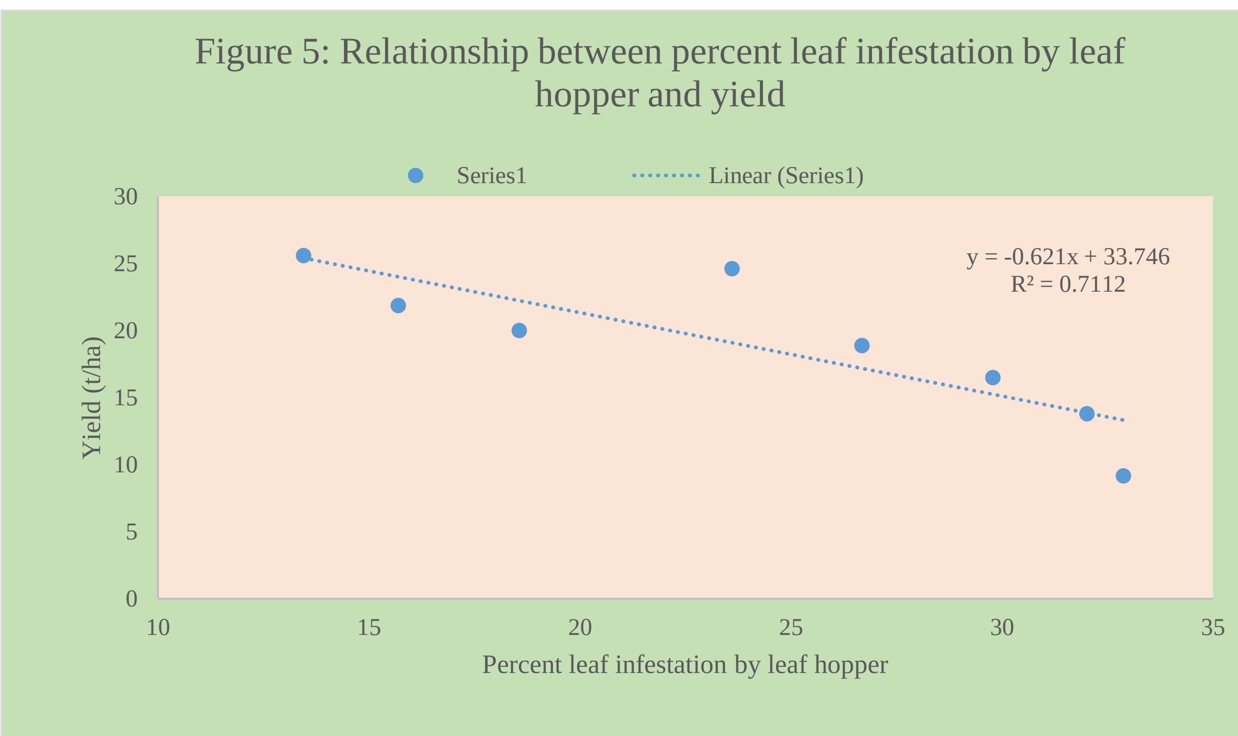
Figure 4: Relationship between number of leaf roller and yield of brinjal



4.8. Relationship between percent leaf infestation and yield

4.8.1. Leaf hopper

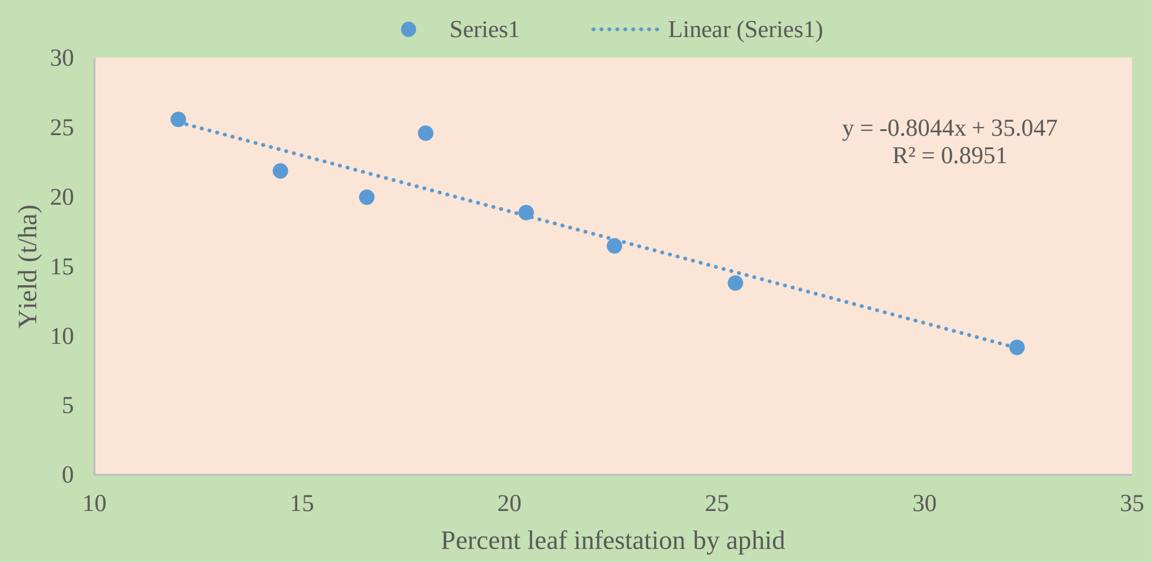
Correlation study was done to establish the relationship between percent leaf infestation by leaf hopper and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between percent leaf infestation by leaf hopper and yield of brinjal (Figure 5). It was evident from the Figure 5 that the regression equation y = -0.621x + 33.746 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.7112) 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 leaf infestation by leaf hopper and yield of brinjal, i.e., the yield decreased with the increase of percent leaf infestation by leaf hopper during the growing season of brinjal.



4.8.2. Aphid

Correlation study was done to establish the relationship between percent leaf infestation by aphid and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between percent leaf infestation by aphid and yield of brinjal (Figure 6). It was evident from the Figure 6 that the regression equation y = -0.8044x + 35.047 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8951) 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 leaf infestation by aphid and yield of brinjal, i.e., the yield decreased with the increase of percent leaf infestation by aphid during the growing season of brinjal.

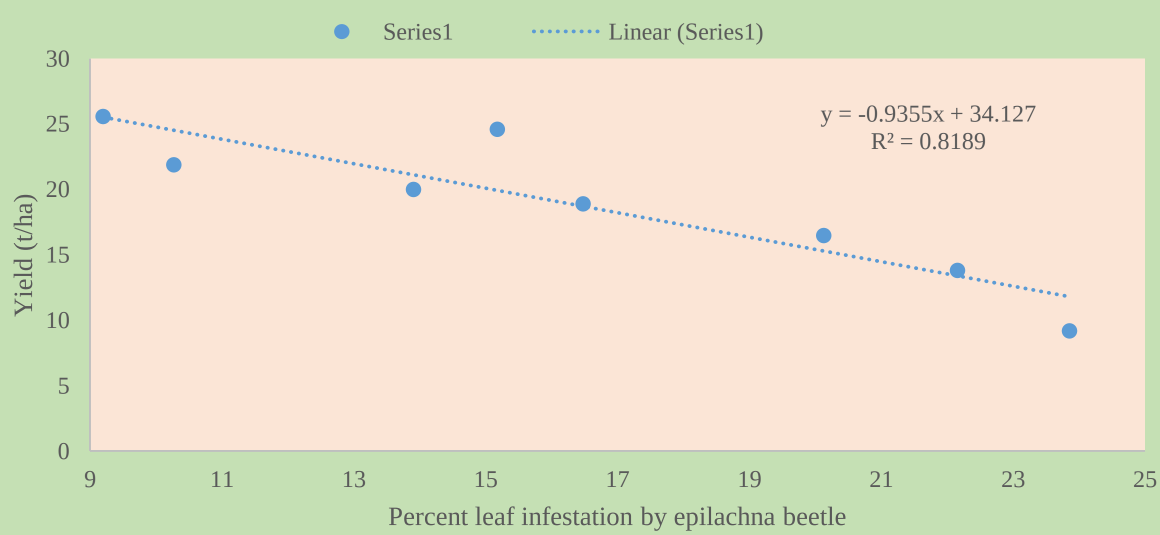
Figure 6: Relationship between percent leaf infestation by aphid and yield



4.8.3. Epilachna beetle

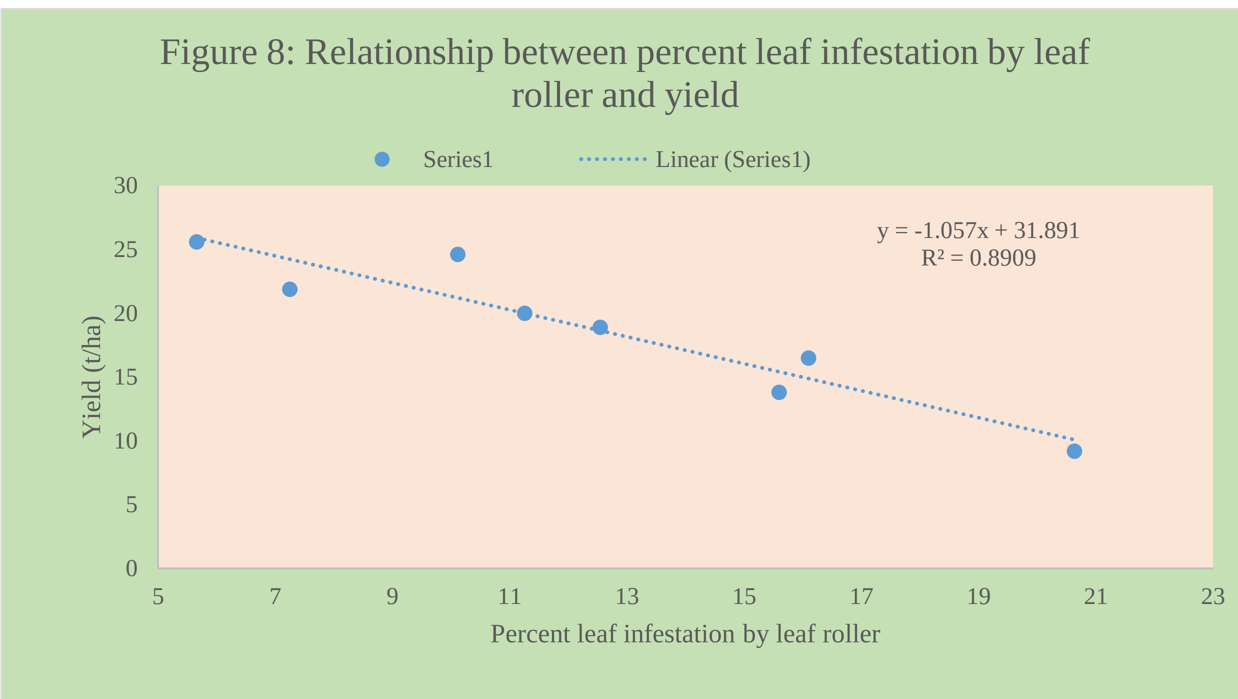
Correlation study was done to establish the relationship between percent leaf infestation by epilachna beetle and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between percent leaf infestation by epilachna beetle and yield of brinjal (Figure 7). It was evident from the Figure 7 that the regression equation y = -0.9355x + 34.127 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8189) 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 leaf infestation by epilachna beetle and yield of brinjal, i.e., the yield decreased with the increase of percent leaf infestation by epilachna beetle during the growing season of brinjal.

Figure 7: Relationship between percent leaf infestation by epilachna beetle and yield



4.8.4. Leaf roller

Correlation study was done to establish the relationship between percent leaf infestation by leaf roller and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between percent leaf infestation by leaf roller and yield of brinjal (Figure 8). It was evident from the Figure 8 that the regression equation y = -1.057x + 31.891 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8909) 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 leaf infestation by leaf roller and yield of brinjal, i.e., the yield decreased with the increase of percent leaf infestation by leaf roller during the growing season of brinjal.

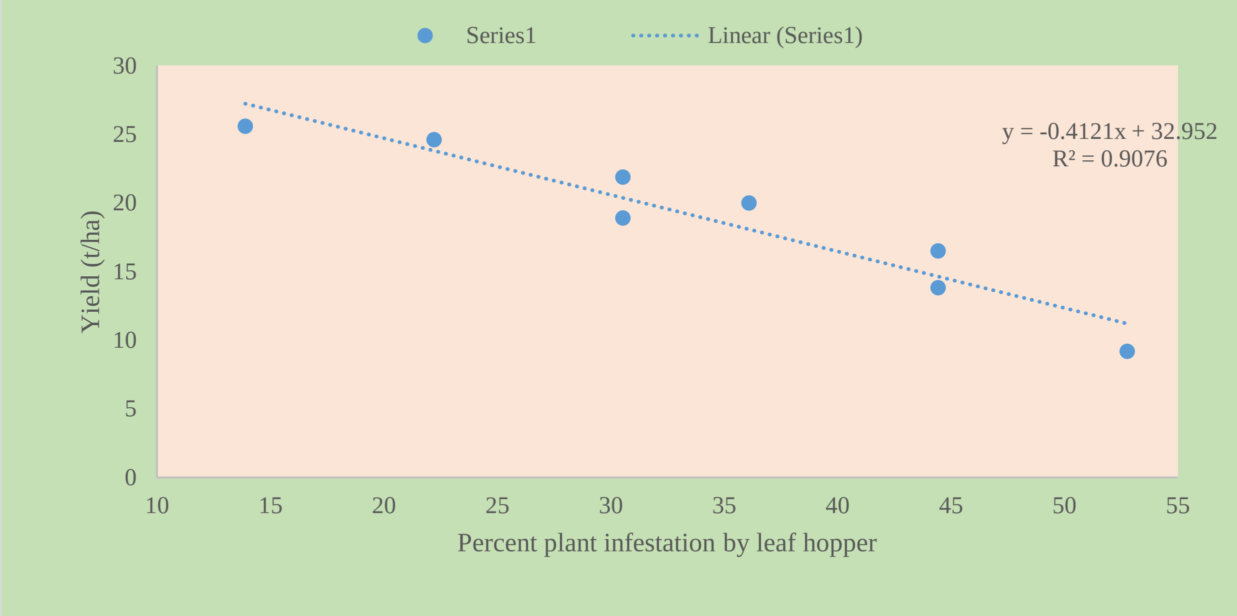


4.9. Relationship between percent plant infestation and yield

4.9.1. Leaf hopper

Correlation study was done to establish the relationship between percent plant infestation by leaf hopper and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between percent plant infestation by leaf hopper and yield of brinjal (Figure 9). It was evident from the Figure 9 that the regression equation y = -0.4121x + 32.952 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9076) 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 plant infestation by leaf hopper and yield of brinjal, i.e., the yield decreased with the increase of percent plant infestation by leaf hopper during the growing season of brinjal.

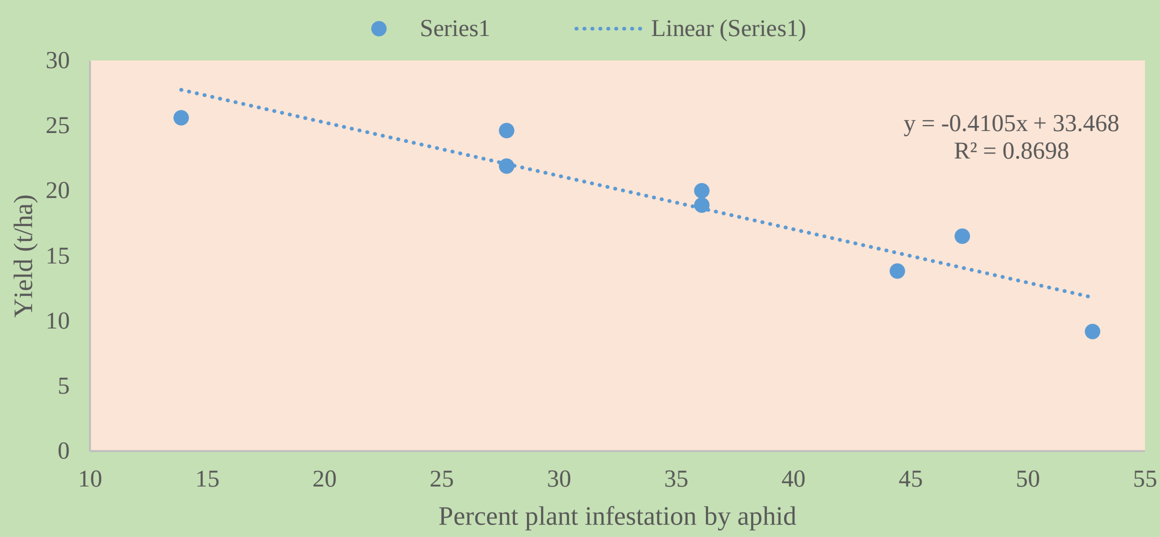
Figure 9: Relationship between percent plant infestation by leaf hopper and yield



4.9.2. Aphid

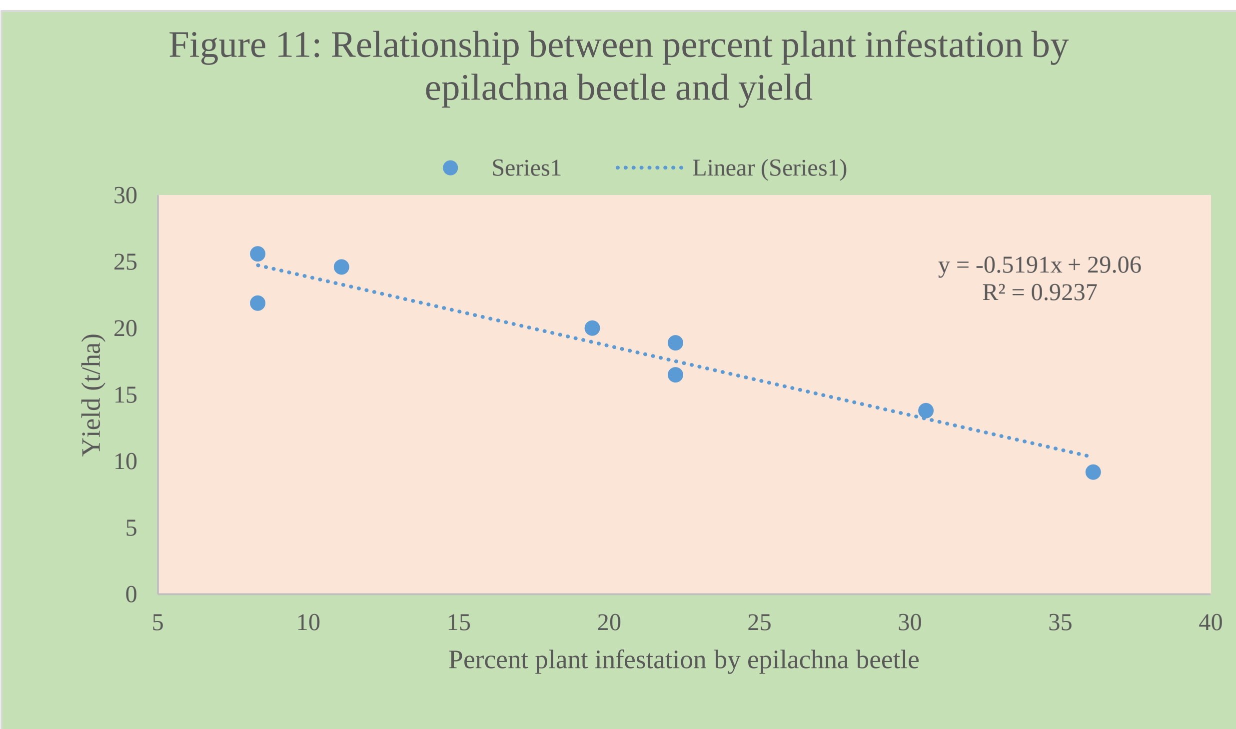
Correlation study was done to establish the relationship between percent plant infestation by aphid and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between percent plant infestation by aphid and yield of brinjal (Figure 10). It was evident from the Figure 10 that the regression equation y = -0.4105x + 33.468 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8698) 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 plant infestation by aphid and yield of brinjal, i.e., the yield decreased with the increase of percent plant infestation by aphid during the growing season of brinjal.

Figure 10: Relationship between percent plant infestation by aphid and yield



4.9.3. Epilachna beetle

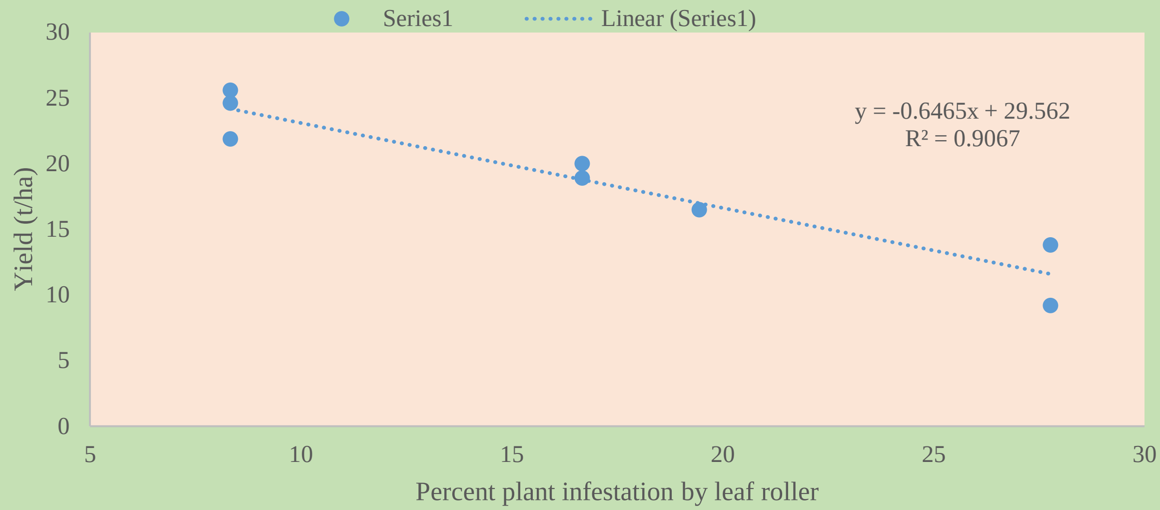
Correlation study was done to establish the relationship between percent plant infestation by epilachna beetle and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between percent plant infestation by epilachna beetle and yield of brinjal (Figure 11). It was evident from the Figure 11 that the regression equation y = -0.5191x + 29.06 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9237) 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 plant infestation by epilachna beetle and yield of brinjal, i.e., the yield decreased with the increase of percent plant infestation by epilachna beetle during the growing season of brinjal.



4.9.4. Leaf roller

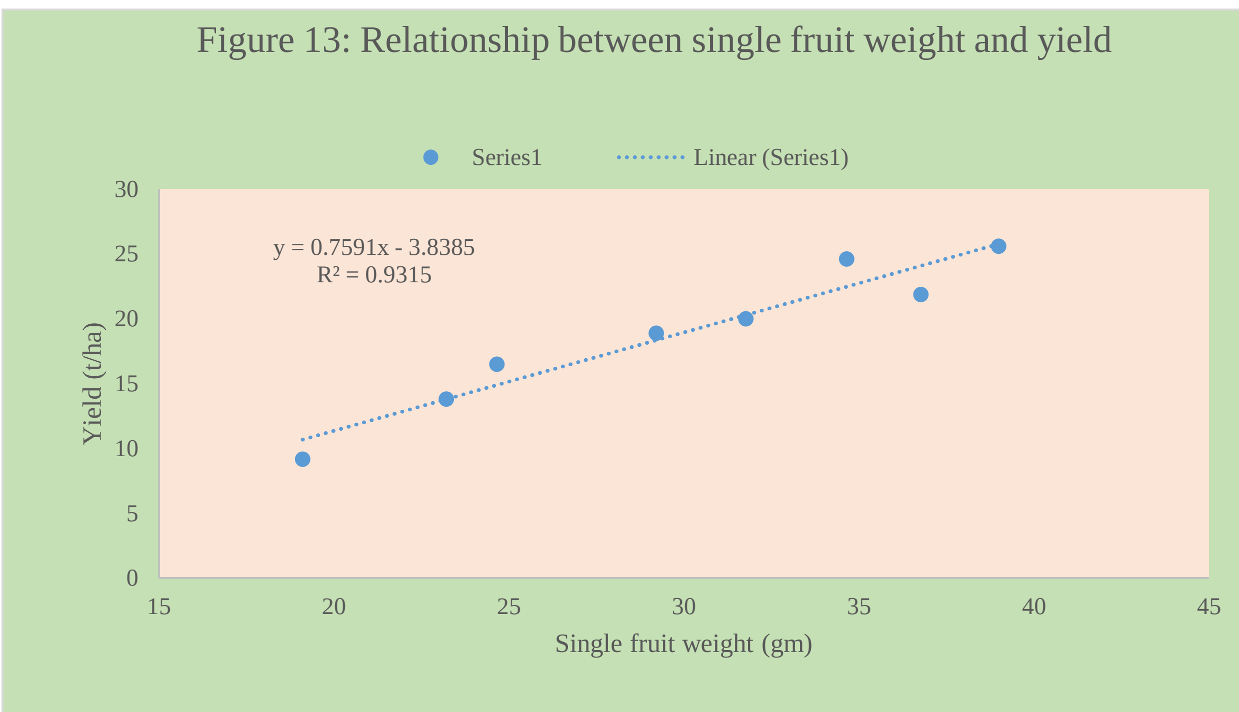
Correlation study was done to establish the relationship between percent plant infestation by leaf roller and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between percent plant infestation by leaf roller and yield of brinjal (Figure 12). It was evident from the Figure 12 that the regression equation y = -0.6465x + 29.562 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9067) 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 plant infestation by leaf roller and yield of brinjal, i.e., the yield decreased with the increase of percent plant infestation by leaf roller during the growing season of brinjal.

Figure 12: Relationship between percent plant infestation by leaf roller and yield



4.10. Relationship between single fruit weight and yield of brinjal

Correlation study was done to establish the relationship between single fruit weight and yield (t/ha) of brinjal during the management of sucking and foliage insects. From the study it was revealed that significant correlation was observed between single fruit weight and yield of brinjal (Figure 13). It was evident from the Figure 13 that the regression equation y = 0.7591x - 3.8385 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9315) 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 single fruit weight and yield of brinjal, i.e., the yield increased with the increase of single fruit weight during the growing season of brinjal.



CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2017 to March, 2018 to evaluate some management practices applied against sucking and foliage insect pests of brinjal. The experiment consisted of control measures with chemical and botanical.

SUMMARY

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing number of leaf hopper per plant over control (57.72%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the leaf infestation over control (48.93%). As a result, the order of rank of efficacy of the treatments applied against brinjal leaf hopper including untreated control in terms of reducing number of brinjal leaf hopper per plant was $T_7> T_5> T_4> T_1> T_2> T_6> T_3> T_8$.

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing the number of infested leaves by leaf hopper per five plants over control (59.09%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the number of infested leaves by leaf hopper per five plants over control (28.19%). As a result, the order of rank of efficacy of the treatments applied against brinjal leaf hopper including untreated control in terms of reducing number of infested leaves by leaf hopper per five plants was $T_7> T_5> T_4> T_1> T_2> T_6> T_3> T_8$.

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing the number of infested plants by leaf hopper per plot over control (73.68%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the number of infested plants by leaf hopper per plot over control (57.90%). As a result, the order of rank of efficacy of the treatments applied against brinjal leaf hopper including untreated control in terms of reducing number of infested plants by leaf hopper per plot was $T_7 > T_1 > T_5 > T_2 > T_4 > T_6 > T_3 > T_8$.

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing number of aphid per plant over control (63.53%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the leaf infestation over control (49.15%). As a result, the order of rank of efficacy of the treatments applied against aphid including untreated control in terms of reducing number of aphid per plant was $T_7 > T_5 > T_4 > T_1 > T_2 > T_6 > T_3 > T_8$.

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing the number of infested leaves by aphid per five plants over control (62.67%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the number of infested leaves by aphid per five plants over control (42.20%). As a result, the order of rank of efficacy of the treatments applied against aphid including untreated control in terms of reducing number of infested leaves by aphid per five plants was $T_7 > T_5 > T_4 > T_1 > T_2 > T_6 > T_3 > T_8$.

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing the number of infested plants by aphid per five plants over control (73.68%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the number of infested plants by aphid per five plants over control (47.37%). As a result, the order of rank of efficacy of the treatments applied against aphid including untreated control in terms of reducing number of infested plants by aphid per five plants was $T_7 > T_1 > T_5 > T_2 > T_4 > T_3 > T_6 > T_8$.

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing number of epilachna beetle per plant over control (74.83%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the number of epilachna beetle over control (55.19%). As a result, the order of rank of efficacy of the treatments applied against aphid including untreated control in terms of reducing number of aphid per plant was $T_7 > T_5 > T_4 > T_1 > T_2 > T_6 > T_3 > T_8$.

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing the number of infested leaves by epilachna beetle per five plants over control (61.44%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the number of infested leaves by epilachna beetle per five plants over control (36.38%). As a result, the order of rank of efficacy of the treatments applied against epilachna beetle including untreated control in terms of reducing number of infested leaves by epilachna beetle per five plants was $T_7 > T_5 > T_4 > T_1 > T_2 > T_6 > T_3 > T_8$.

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing the number of infested plants by epilachna beetle per five plants over control (76.93%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the number of infested plants by epilachna beetle per five plants over control (69.23%). As a result, the order of rank of efficacy of the treatments applied against epilachna beetle including untreated control in terms of reducing number of infested plants by epilachna beetle per five plants was $T_7 > T_5 > T_1 > T_4 > T_2 > T_6 > T_3 > T_8$.

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing number of leaf roller per plant over control (59.62%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the leaf infestation over control (42.29%). As a result, the order of rank of efficacy of the treatments applied against aphid including untreated control in terms of reducing number of aphid per plant was $T_7 > T_5 > T_4 > T_1 > T_2 > T_6 > T_3 > T_8$.

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing the number of infested leaves by leaf roller per five plants over control (72.58%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the number of infested leaves by leaf roller per five plants over control (50.97%). As a result, the order of rank of efficacy of the treatments applied against leaf roller including untreated control in terms of reducing number of infested leaves by leaf roller per five plants was $T_7 > T_5 > T_1 > T_4 > T_2 > T_3 > T_6 > T_8$.

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing the number of infested plants by leaf roller per plot over control (70.01%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the number of infested plants by leaf roller per plot over control (70.01%). As a result, the order of rank of efficacy of the treatments applied against leaf roller including untreated control in terms of reducing number of infested plants by leaf roller per plot was $T_7 > T_1 > T_5 > T_2 > T_4 > T_6 > T_3 > T_8$.

Actara 25 WG based treatment (T_5) reduced the highest incidence of lady bird beetle (44.57%) in the brinjal field. Conversely, the neem oil based treatment (T_1) performed as the least hazard. Management practices, which increased (13.26%) lady bird beetle in the brinjal field rather than synthetic treatments as well as other botanicals. As a result, the order of rank of efficacy of the treatments to increase number of lady bird beetle per plant was $T_1 > T_2 > T_8 > T_3 > T_6 > T_4 > T_7 > T_{5.}$

Actara 25 WG based treatment (T_5) reduced the highest incidence of field spider (66.78%) in the brinjal field. Conversely, the neem oil based treatment (T_1) performed as the least hazard. Management practices, which increased (22.15%) in the brinjal field rather than synthetic treatments as well as other botanicals. As a result, the order of rank of efficacy of the treatments to increase number of field spider per plant was $T_1 > T_2 > T_8 > T_3 > T_6 > T_4 > T_7 > T_{5.}$

Actara 25 WG based treatment (T_5) reduced the highest incidence of ants (59.42%) in the brinjal field. Conversely, the neem oil based treatment (T_1) performed as the least hazard. Management practices, which increased (17.39%) in the brinjal field rather than synthetic treatments as well as other botanicals. As a result, the order of rank of efficacy of the treatments to increase number of ants per plant was $T_1 > T_2 > T_8 > T_3 > T_6 > T_4 > T_7 > T_{5.}$

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing infested fruit length per five plants over control (82.31%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the infested fruit length over control (80.04%).

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval in reducing infested fruit girth per five tagged plants over control (72.86%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days interval performed as the best treatment in terms of reducing the infested fruit girth per five tagged plants over control (62.68%).

The treatment T_7 comprised with spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days in increasing single fruit weight of brinjal over control (104.08%). Considering the botanical treatments, T_1 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days performed as the best treatment in terms of increasing single fruit weight of brinjal over control (81.37%).

There were no significant variance among number of branch per plant and plant height per plot at brinjal field at different treatments throughout the growing season of brinjal cultivation.

The treatment T_7 (25.57 t/ha) which was followed by T_1 (24.59 t/ha), T_5 (21.86 t/ha) and T_4 (19.98 t/ha). On the other hand, the lowest yield was recorded in T_8 (9.16 t/ha) which was followed by T_3 (13.79 t/ha), T_6 (16.47 t/ha) and T_2 (18.87 t/ha). As a result, the order of rank of efficacy of the treatments applied against aphid including untreated control in terms of reducing number of aphid per plant was $T_7 > T_1 > T_5 > T_4 > T_2 > T_6 > T_3 > T_8$.

CONCLUSION

From the present study, it may be concluded that incidence of sucking and foliar insects (leaf hopper, aphid, epilachna beetle, leaf roller etc.) of brinjal was significantly varied among the treatments. The overall study revealed that the highest performance was achieved from T_7 spraying of Ripcord 20 EC @ 1.0 ml/L of water at 7 days interval. T_5 spraying of Actara 25 WG @ 0.2 gm/L of water at 7 days interval and T_1 spraying of Neem oil @ 3.0 ml/L of water at 7 days interval also showed better performance against sucking and foliar insects of brinjal. T_1 might increase the number of beneficial arthropods (lady bird beetle, field spider, ants etc.), weight of single fruit, length of fruit, girth of fruit and yield. Considering the results of the present study and environmental issues it can be concluded that T_1 can be used for the management of sucking and other foliar insect pests of brinjal.

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

1. Chemical insecticides should be less used for management practices against sucking and foliar insects of brinjal.
2. Botanical insecticides should be more used to increase the number of beneficial arthropods in the brinjal field.
3. Further study should be needed in different locations of Bangladesh for accuracy of the results obtained from the present experiment.

CHAPTER VI

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CHAPTER VII

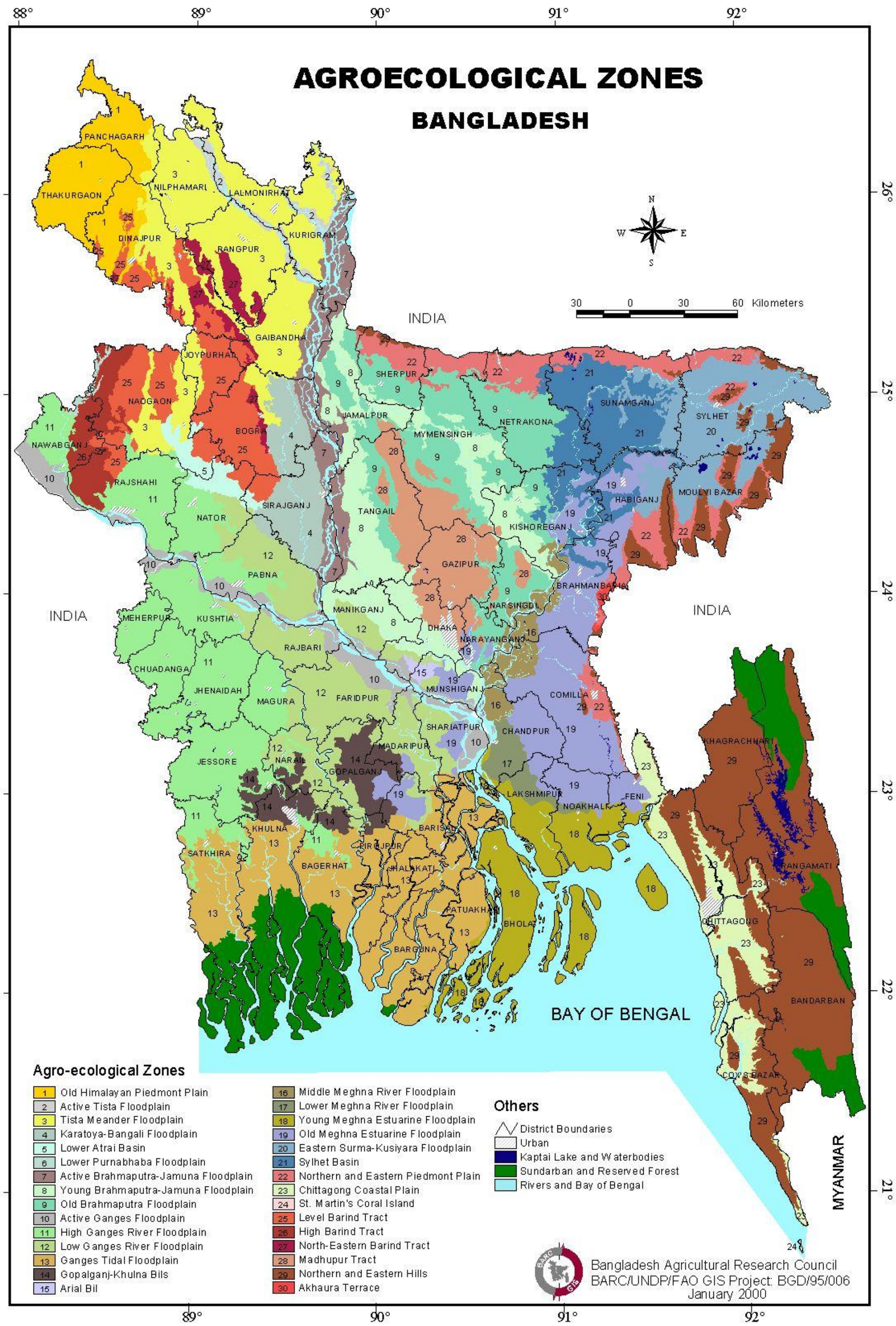
APPENDICES

Appendix I: Monthly record of air temperature, rainfall and relative humidity of the experimental site during the period from November 2017 to March 2018

Month	Temperature (℃)		Relative humidity (%)	Rainfall (mm) (Total)
	Maximum	Minimum		
November	30.2	20.6	67	6.0
December	26.8	17.1	76	33.0
January	23.6	12.6	68	0.0
February	29.2	18.1	61	20.0
March	33.3	22.3	59	3.0

Source: Bangladesh Meteorological Department (Climate and Weather Division), Agargoan, Dhaka- 1207.

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



Source: Bangladesh Agricultural Research Council, Khamarbari, Dhaka.

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

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

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.54
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

APPENDIX IV: Some plates of the study

Plate 1: Seedlings on seedbed

Plate 2: Transplanted seedlings of brinjal on poly bag

Plate 3: Main field of brinjal

Plate 4: Experimental working at main field of brinjal

Plate 5: Data collection

Plate 6: Leaf hopper on brinjal leaf