ECO FRIENDLY PEST MANAGEMANT OF TOMATO

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CERTIFICATE

This is to certify that thesis entitled, "**ECO FRIENDLY PEST MANAGEMANT OF TOMATO** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by, **ISTIKA RAHMAN,REGISTRATION NO. 12-04927** 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

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ABSTRACT

The experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2018 to March, 2019 to evaluate the ecofriendly pest management of tomato (BARI Tomato-14). The experiment consisted of six different ecofriendly treatment along with untreated control and was laid out in Randomized Complete Block Design (RCBD) with three replications. The seven treatments were T_1= Untreated control, T_2= Neemoil suspension spray, T_3= Garlic oil, T_4= Black seed oil, T_5= Marigold intercropping, T_6= Netting at seedling stage, T_7=Tobacco leaf powder extract spray. The data were statistically analyzed by MSTAT-C and means were separated by Duncan's Multiple Range Test (DMRT) test at 5% levels of probability. Four insect pests were found in tomato cultivation viz. white fly, aphid, fruit borer and leaf miner. The lowest number of white fly per plant (3.13, 3.01 and 2.49) and the highest control percentage of white fly (87.89, 89.31 and 89.31) was observed in treatment T_2at vegetative, flowering and reproductive stage. The lowest number of aphid per plant (1.20, 1.20 and 1.01) and the highest control percentage of aphid per plant (94.23, 94.41 and 94.98) was found from treatment T_2at all stages of plant. At the vegetative, flowering and reproductive stage, the lowest number of fruit borer per plant (1.02, 1.61 and 0.90) and the highest control percentage of fruit borer per plant (90.04, 90.65 and 91.59) was found from treatment T_2. The lowest number of leaf minerper plant (0.69, 0.60 and 0.65) in treatment $T_2$and the highest control percentage of leaf minerper plant (93.52, 87.27 and 84.69) was found from treatment T_2. Number of fruit, Individual fruit weightand yieldof tomato varied significantly due to different treatment and the highest yield (55.28 t ha^{-1}) wasobtained from T_2.Treatment T_2 was the most suitable for controlling white fly, aphid, fruit borer and leaf minerand yield of tomato was also highest in treatment T_2as compared to other 6 treatments.

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CHAPTER I

INTRODUCTION

Bangladesh is predominantly an agriculture based country. But it has a huge deficit in vegetable production. Total annual vegetable production of Bangladesh is 1.6 million M tones in winter and 1.5 million M tones in summer season while the cultivated area of Bangladesh 0.47 million acres in winter and 0.65 million acres in summer season (BBS, 2012). The consumption of vegetable in Bangladesh is about 50 g day^{-1} capita^{-1}, which is the lowest amongst the countries of South Asia and South Africa (Rekhi, 1997). But dietitian recommended a daily allowance of 285 g vegetable for an adult person for a balance diet (Ramphall and Gill, 1990). Here people have been suffering from inadequate supply of vegetables since decades. As a result, chronic malnutrition is often seen in Bangladesh.

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important, popular and nutritious vegetable crops in Bangladesh which belongs to the family Solanaceae. It is widely grown not only in Bangladesh, but also in every parts of the world. Tomato ranks third in terms of world vegetables production (FAO, 1997).The largest producer China (41,864,750 tons), accounted for about one quarter of the global production followed by United States (12,902,000 tons) and India (11,979,700 tons) (FAO, 2013). The popularity of the tomato and its products continues to rise. It is a nutritious and delicious vegetable used in salads, soups and processed into stable products like ketchup, sauce, puree, marmalade, chutney and juice. They are extensively used in the canning industry. Nutritive value of the fruit is an important aspect of quality in tomato. Food value of tomato is very rich because of higher contents of vitamins A, B and C including calcium and carotene (Bose and Som, 1990). Tomato contains 94 g water, 0.5 g minerals, 0.8 g fibre, 0.9 g protein, 0.2 g fat and 3.6 g carbohydrate and other elements like 48 mg calcium, 0.4 mg iron, 356 mg carotene, 0.12 mg vitamin B-1, 0.06 mg vitamin B-2 and 27 mg vitamin C in each 100 g edible ripen tomato (BARI, 2010).

The soil and climatic condition of winter season of Bangladesh are congenial for tomato cultivation. Among the winter vegetable crops grown in Bangladesh, tomato ranks second in respect of production to potatoes and third in respect of area (BBS, 2015). The yield of tomato quite low as compared to other leading tomato producing countries of the world such as China, Egypt, USA, Turkey where per hectare yield was reported as 30.39, 34.00, 65.22 and 41.77 t ha^{-1}, respectively. The recent statistics shows that tomato was grown in 23886.639 ha of land and the total production was approximately 190 thousand tons in 2011-2012 (BBS, 2013). The average yield of tomato was 40.36 ton per acre (BBS, 2013). The yield of the tomato is very low compared to those of some advanced countries (Sharfuddin and Siddique, 1985).

Tomato production in Bangladesh is affected by many factors, among them insect pest attack is the major one (Brader*et al*., 1985). There are many insect pests attacking tomato have been reported which create havoc by causing both quantitative and qualitative loss to the crop. Some common tomato pests of are stink bugs, cutworms, tomato hornworms, tobacco hornworms, aphids, cabbage loopers, whiteflies, tomato fruit worms, flea beetles, red spider mite, slugs, and Colorado potato beetles. The tomato plants were attacked by different species of insect pests such as whitefly, aphid, tomato fruit borer and leaf miner in Bangladesh. Among them tomato fruit borer *Heliothis armigera* (Hub.) is one of the major pests of tomato and damage by this pest may be up to 85-93.7% (Haque, 1995).

In order to minimize plant damage caused by pests, at present farmers mainly depend on the use of synthetic pesticides (Wiratno and Soetopo, 1990). Nowadays, about 20 pesticides are recommended for controlling pests of tomato. However, the use of synthetic pesticides in most of the developing countries, including Bangladesh, is frequently associated with inappropriate training and unsafe application of the pesticides. The flawed use and disposal of pesticides poses not only a serious health risk to local workers and the people living near the treated areas, but also threatens non-target species, including potential natural enemies of the pests (Tobin, 1996). Therefore, it has become an important issue to find relatively easy alternative control strategies, which are as effective when compared to the synthetic pesticides, but safer to the farmers, consumers, and the environment and available at low price (Wiratno, *et al.* 2007).

One of the possible alternatives would be the use of pesticides of plant origin, also known as botanical pesticides. Botanical products have been used by man since ancient times, especially in cultures with a strong herbal tradition (Yang and Tang, 1988). They have been reported to be effective against i.e. nematodes (Park *et al.*2005; Sangwan *et al.* 2004), beetles (Rahman and Schmidt 1999), mites (Kim, *et al.* 2004).), ticks (Thorsell *et al.* 2006).) and fungi causing plant diseases (Vayias *et al.*2006). Parts of the plants which are used for the pesticides are roots or rhizomes (i.e. derris) (Kardinan, 1995), vetiver (Zhu *et al.*2001)and sweet flag (Schmidt and Streloke, 1994), flowers or buds (i.e. pyrethrum) (Athanassiou and Kavallieratos, 2005) and clove (Ho *et al.* 1994), seeds (i.e. neem) (Nathan, *et al.* 2006), castor bean (Niber, 1994). and yam bean (Kardinan, 1995), and leafs (i.e. patchouli) (Mardiningsih and Kardinan, 1995), betelvine (Wardhana *et al.* 2007) and tobacco (Opolot *et al.* 2006). Although the mechanisms of action of the botanical pesticides may differ greatly and are often not yet well understood, they have as advantage that they combine a wide range of toxic potencies hence reducing the chance of pests to develop resistances (Roger, 1997).

In addition to that, residues are hardly expected on the products or in the environment since botanical pesticides are generally considered to be non-persistent under field conditions as they are readily degraded by light, oxygen and micro-organisms into less toxic products (Philogène *et al.* 2005). However, since botanical pesticides are non-persistent, application of the pesticides has to be repeated more often compared to that of the synthetic pesticides. Bangladesh seems to be trying to bea potential position to develop and utilize botanical pesticides since the country has a rich biodiversity of plant species some of which have already been used as a pesticide.

The repeated use of high dose and increased spray frequency of pesticides on vegetables by smallholder tomato farmers has led to severe ecological consequences like destruction of natural enemy fauna, adverse effects on non-target organisms, increased pesticide residues in the harvested produce as well as selecting for insecticide resistance in important pest species (Martin *et al.*, 2002). Nowadays, the increased consumer request in developed countries for organic products which are free from synthetic pesticide residues stimulates the interest in the use of botanical pesticides in agricultural production by exporting tropical countries. These unsustainable pesticide use practices provide an opportunity to identify eco-friendly, safer, and sustainable methods of pest control especially with the increasing demand for vegetables in expanding. In Bangladesh, very few research works have been done mainly on use of botanical insecticides etc. Over the years, the entomologists are working to find ecologically sound and environmentally safe method for pest control (Bari and Sardar, 1998).

Hence, the proposed study will be undertaken to fulfill the following objectives:

- to identify major insect pests of tomato.
- to find out the effectiveness of different eco-friendly approaches on the insect pests of tomato.

CHAPTER II
REVIEW OF LITERATURE

Tomato is one of the most important vegetable crops grown under field and greenhouse conditions, which received much attention to the researchers throughout the world. Whitefly (*Bemisia tabaci*) and fruit borer (*Helicoverpa armigera*) are the major insect pest of different vegetables including tomato, which causes significant damage to crop every year. The incidence of these pests occurs sporadically or in epidemic throughout Bangladesh and affecting adversely the quality and yield of the crop. It causes great yield reduction, which is considered as an important obstacle for economic production of these crops. Substantial works have been done globally on these pest regarding their origin and distribution, host range, life cycle, nature of damage, rate of infestation yield loss, seasonal abundance and management. but published literature on this pest especially on its infestation status and management are scanty in Bangladesh. Literatures cited below under the following headings and sub-headings reveal some information about the present study.

2.1 Taxonomic position of Whitefly

Phylum: Arthropoda
Class: Insecta
Order:Homoptera
Suborder: Sternorrhyncha
Superfamily: Aleyrodoidea
Family: Aleyrodidae
Sub family:Aleurodicinae
Genus: *Bemisia*
Species: *B. tabaci*

Origin and Distribution of Whitefly

Bemisia tabaci was first described as a pest of tobacco in Greece in 1889. Outbreaks in cotton occurred in the late 1920 and early 1930 in India and subsequently in Sudan and Iran from the 1950 and 1961 in EL Salvador (Hirano *et al.* 1993). *B. tabaci* is widespread in the tropics and subtropics and seems to be on the move, having been recorded in many areas outside the previously known range of distribution. The whitefly has been reported as a green house pest in several temperate countries in Europe, e. g., Denmark, Finland, France, Norway, Sweden and Switzerland. Besides in green houses, the species has been reported on outdoor plants in France and Canada (Basu 1995). *B. tabaci* has a global presence. However, certain areas within Europe are still *Bemisia* free, e.g. Finland, Sweden, Republic of Ireland and the UK (Cuthbertson and Vänninen 2015).

Host Range: *B. tabaci* is highly polyphagous and has been recorded on a very wide range of cultivated and wild plants. Greathead (1986) updated the information reported by Mound and Hasley (1978) and listed 506 species of plants belonging to 74 families. It may be pointed out that 50% of the total number of host plants belonging to only 5 families, namely, Leguminosae, Compositae, Malvaceae, Solanaceae and Euphorbiaceae. A survey of the literature from the early 1900s suggests that the number of host plants colonized by *B tabaci* has increased over time, probably as agricultural practices have shifted to irrigated monoculture and as different species have been cultivated during the century . Current records indicate that *B. tabaci* can successfully colonize a multitude of host-plant species worldwide (Cock, 1986). Early documentation cited at least 155 plant species as hosts in Egypt alone (Azab *et al.*, 1970), whereas by 1986, a worldwide detailed survey yielded an estimate of 420 host plant species (Brown *et al*. 1995) .

The recently introduced B-biotypc has the broadest host range among whiteflies in the genus Benasta; some estimales range up to 500 species (Brown *et al.* 1995). Basu (1995) reported that *Benasia tabaci* is a highly polyphagous pest and it has been recorded on more than 500 species of plants including numerous field crops, ornamentals and weeds. Bloch and wool (1995) similarly reported that hosts of *B. tabaci* include vegetables, Cotton, and other agricultural crops and ornamental plants. According to Panwar (1995), the host plants of *Bemisia tabaci* include cotton, tomato, tobacco, sweet potato, cassava, cabbage, cauliflower, melon, brinjal, okra and many wild and cultivated plants.

In a study on host range, it was observed that more than 100 species and varieties belonging to 16 families, 7 species of Solanaceac and 8 in other families became systemically infected following inoculation by *Bemisia tabaci*. In the field, the virus was found from tomato at all growth stages and in all seasons, also from naturally infected

Datura stramoniunt, tobacco, 3 wild *Lycopersicon* spp. and from breeding lines of tomato (Ioannou *et al.* 1987).

In an experiment conducted in Mexico during 1990-1995 it was observed that a total of 58 wild and 14 cultivated plant species were found to host *Bemisia tabaci* at some of its life cycle. The most important species of wild species were Leguminosae, Euphorbiaceae, Asteraceae, Convulvulalaceac, and Malvaccac (Aviles Bacza 1995).

Seasonal Abundance of Whitefly

Maximum pest population (7.99/3 leaves) was build up at temperature ranged from 26ºC to 35ºC, relative humidity ranges from 84 and 67 per cent, zero rainfall, wind velocity 6.30 km/hr, total sunshine hours (9.4 hrs/week), evaporation (52.20 mm) and dewfall (0.708 mm). The highest incidence of whitefly population was recorded in SPCH 22 followed by SVPR 3 and MCU 7 (Selvaraj and Ramesh). Whitefly population was build up showed a significant and positive correlation with maximum and minimum temperature whereas, it was significant and negative association with evening relative humidity. The determination of effects of different weather factors on population of whiteflies in cotton was essential for effective pest management. Kaur *et al.* (2009) who reported the peak population of whiteflies was observed when the maximum temperature and minimum temperature range of less than 36ºC and more than 26 ºC, respectively and the number of sunshine hours variably more than 8 hrs. Similarly, Prasad *et al.* (2008); Reddy and Rao (1989) who reported that a maximum and minimum temperature range of 29ºC to 32ºC and 18ºC to 22ºC respectively, was highly favourable for the population build up of whiteflies. Selvaraj et al. (2010); Dhaka and Pareek (2008); Arif *et al.* (2006); Gupta et al. (1998); Rao and Chari (1993), Rote and Puri et al. (1991); Singh and Butter (1985) who reported significant positive association between maximum temperature and the population.

In a study in Sudan Kranz *et al.* (1977) found a sharp increase in whitefly population in September and October which was directly correlated with higher relative humidity (80-90%) and increasing temperature (36-38ºC). These conditions favour the development of the juvenile stages by shortening the duration of each stage. They indicated that the population decreases due to high mortality rate at eggs and free juvenile stages in March, April and May when the temperature is high (43-45ºC) and RH is low (8-17).On the other hand, Gerling *et al.* (1986) observed that the extreme RH, both high and low, was unfavorable for the survival of immature stages. Thus in Sudan, Horowitz (1986) found significant drop of whitefly population levels at heavy rainy condition.

Gerling *et al.* (1986) found that the lower and upper developmental thresholds of temperature are 11 and 33ºC, respectively. Rates of development are maximal at 28 ºC. At that temperature, development from egg to adult takes 20 days. Avidov (1956) considered low humidity as the major mortality factor in Israel, leading to cessation of oviposition and adult mortality. Low humidity of 20% or less during hot weather has been reported to be highly detrimental to the immature stages of whitefly (Gameel 1978; Avidov 1956). In Sudan heavy rains were usually followed by a drop in population levels (Gameel 1978; Khalifa and El-Khidir 1964). Ohnesorge *et al*. (1981) found that the oviposition was impaired by rain.

Nature of Damage: According to Butani and Jotwani (1984) the white, tiny, scale like insects may be seen darting about near the plants or crowding in between the veins on ventral of leaves, sucking the sap from the infested parts. The pest is active during the dry season and its activity decreases with the on set of rains. As a result of their feeding the affected parts become yellowish, the leaves wrinkle and curl downwards and are ultimately shed. Besides the feeding damage, these insects also excrete honeydew which favors the development of sooty mould. In case of severe infestation, this black coating is so heavy that it interferes with the photosynthetic activity of the plant resulting in its poor and abnormal growth. The whitefly also acts as a vector, transmitting the leaf curl virus disease, causing severe loss. Sastry and Singh (1973) estimated 20-75% loss in tomato yield due to tomato leaf curl virus disease in India.

Bemisia tabaci continues to be an economically important pest of greenhouse and field crops throughout equatorial areas of the world (De Barro 1995). Both nymph and adult cause direct damage to the plants by sucking from the phloem and by secreting honeydew. This weakens the plants by sap extraction and allows black shooty mold fungus to develop on honeydew. However, direct damage due to feeding would not appear to have been a matter of much concern. The main damage caused by *Bemisiatabaci* to the tomato is indirect-by transmitting virus diseases in plants (Cohen and Berlinger 1986). This is one of the most important limiting factors for tomato production in wormer climates. Schuster *et al.* (1990) reported a new disorder of fruit on tomatoes in Florida. The disorder termed irregular ripening, was associated with field populations of the *Bemisia* abaci and is characterized by incomplete ripening of longitudinal sections of the fruit. An increase in internal white tissue was also associated with whitefly populations. In field-cage studies, fruit on uninfected tomato plants exhibited slight or no irregular ripening, whereas fruit from infested plants did the same.

Stansly and Schuster (1990) reported that damage in tomato resulted from irregular ripening and transmission of tomato mottle geminivirus. Crop damage in tomato due to this pest was estimated to more than 500 million dollars in the United States in 1991 (Perring *et al.* 1993).

Whiteflies suck phloem sap and large populations can cause leaves to yellow, appear dry, or to fall off of plants. Due to the excretion of honeydew plant leaves can become sticky and covered with a black sooty mould. The honeydew attracts ants, which interfere with the activities of natural enemies that may control whiteflies and other pests. Feeding by the immature whiteflies can cause plant distortion, silvering of leaves and possibly serious losses in some vegetable crops. This devastating global insect pest caused damage directly by sucking the plant sap from phloem, indirectly by excreting honeydews that produce sooty mould, and by spreading 111 plant virus diseases. Among the plant viruses, Tomato Yellow Leaf curl Virus (TYLCV) is most important (Mughra *et al.* 2008).

Life History

Egg: Eggs are pear shaped and 0.2 mm long. They are laid indiscriminately almost always on the undersurface of the young leaves (Hirano *et al.* 1993). The female can lay 119 eggs in captivity (Hussain and Trehan 1933) and 300 eggs on egg plant under field conditions (Avidov 1956). Initially the eggs are translucent, creamy white and turn into pale brown before hatching. The incubation period varies widely mainly due to varying environmental conditions especially temperature. Under outdoor condition the incubation period has been reported to be range between 3-5 days in summer and 7-33 days during winter (Azab *et al.* 1971; Hussain and Trehan 1933).The first instar nymphs (crawlers) move a very short distance over the leaf surface. Once settled, they remain sessile until they reach the adult stage, except for brief periods during molts (Hirano *et al.* 1993).

Nymphal and pupal Stages

The first instar nymphs are pale, translucent white, oval, with a convex dorsum and flat central side. They measure 0.267± 0.007 mm in length and 0.144±0.010 mm in width (Lopez- Avila, 1986). The second instar nymphs are quite distinct from first instar for its size. These nymphs are 0.365± 0.026 mm long and 0.218± 0.012 mm wide at the broadest part of the thorasic region. The body of the third instar nymph is more elongated than the earlier instars, measuring 0.489± 0.022 mm in length and 0.295± 0.018 mm in breadth. The fourth instar nymphs have elliptical body measuring 0.662± 0.023 mm long and 0.440 ± 0.003 mm broad. This fourth instar (the so- called "pupae") has red eye spots, which become eyes at the adult stage, are characteristic of this instar (Hirano *et al.* 1993).10

Two distinctive characters of the pupa are the eyes and the caudal furrow. Dorsal surface of the elliptical body is convex and the thoracic and abdominal segments are pronounced. Mound (1963) showed that the pupae from which females emerge are larger than those producing males. Duration of these stages varies and has generally been correlated with temperature or seasonal factor. Under constant conditions of 25ºC, RH 75% and light: dark 16:8 hours, the fourth instar nymph lasted 3.4 days on bean, 2.1 days on cotton and 2.0 days on tomato .The duration of pupal stage were 4.4 days on bean, 2.4 days on tomato and 1.7 days on cotton (Lopez-Avila 1986). The total duration of the immature stages of *B. tabaci* varies widely and is correlated with climate and host- plant conditions. The shortest duration of 11 days during summer (Pruthi and Samuel 1942) and the longest of 107 days during winter (Hussain and Trehan 1933) were observed in India.

Adults: Adults are soft and pale yellow, change to white within a few hours due to deposition of wax on the body and wings. Byre and Houck (1990) revealed sexual dimorphism in wing forms: the fore and hind wings of females were larger than those of males. The mean wing expanses of females and males are 2.13 mm and 1.81mm, respectively (Byrne *et al* 1991). Adult longevity of males on tobacco was 4 days in summer and 7days in winter, corresponding female lifespan was 8 and 12 days, respectively in India (Pruthi and Samuel 1942).

The maximum adult emergence occurs before 0800 and 1200 hours (Musuna 1985; Butler *et al.* 1983; Azab *et al.* 1971; Husain and Trehan 1933). *Bemisia tabaci* is arrhenotokus and is known to lay unfertilized eggs which give rise to males only (Sharaf Batta 1985; Mound 1983; Hussain and Trehan 1933; Azab *et al.* 1971). Unmated females produce male offsprings while mated females produce both males and females. Monsef and Kashkooli (1978) recorded 10-11 generations per year on cotton in Iran. Husain and Trehan (1933) and Pruthi and Samuel (1942) found 12 overlapping generations in India on cotton.

Virus Diseases Transmitted by *B. tabaci* on Tomato

Among the six or seven classes of whitefly-borne viruses in tomato, geminivirus group is by far the most important both in terms of number of diseases and their economic importance in various parts of the world (Brown and Bird 1992; Byrne *et al*. 1990; Duffus 1987; Bock 1982). The brief description of some geminivirus diseases of tomato are given below:

Tomato Leaf Curl Virus (TLCV): This is the most important disease of tomato in India (Chenulu and Giri 1985) and perhaps in many tropical countries (Thanapase *et al.* 1983; Yassin 1978). They described that the main symptoms are vein clearing, stunting and marked reduction in leaf size with mild or severe mosaic pattern or chlorosis with marginal curling of leaves. Severely affected plants show complete yellowing of interveinal areas and puckering of leaves. Losses in tomato yield depend on severity and the stage of the crop at the time of infection. Early infection may result in losses of over 90%.

Tomato yellow leaf curl virus (TYLCV): TYLCV was first reported in Israel in 1939-40 associated with outbreaks of *Bemisia tabaci*. The causal agent was described in 1964 and named *Tomato yellow leaf curl virus* (TYLCV) (Cohen and Harpaz 1964). *Tomato* *yellow leaf curl virus* (TYLCV) has been a major constraint to tomato production in the Near East since 1966. It is the best characterized virus causing yellowing and leaf curl disease of tomato (Green and Kallool 1994). Czosnek and Laterrot (1997) published world wide survey report on TYLCV. They pointed out that the name TYLCV has been given to several whitefly transmitted geminiviruses affecting tomato cultures in many tropical and subtropical regions. Their result based on DNA and protein sequence revealed that tomato geminiviruses fall into three main clusters representing viruses from 1) The Mediterranean / the Middle East / the African region, 2) India/ the Far East and Australia and 3) The Americas. They also pointed out that TYLCV diseases increased considerably between 1990 and 1996. Early diagnosis of TYLCV is essentially based on symptom observation, although symptoms vary greatly as a function of soil, growth conditions and climate.

Fruit Borer

Taxonomic position of Fruit Borer

Tomato fruit borer, *Helicoverpa armigera* (Hub.) is a polyphagous insect, belonging to the family Noctuidae of the order Lepidoptera. There are several genera under this family, and the genus *Helicoverpa* contains more number of species, including *Helicoverpa armigera,* which is the serious pest of tomato (Mishra *et al.* 1996).

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Superfamily: Noctuoidea
Family: Noctuidae
Genus: *Helicoverpa*
Species: *H. armigera*

Origin and Distribution of Fruit Borer

Tomato fruit borer is a versatile and widely distributed polyphagous insect. Besides Bangladesh, this pest occurs in Southern Europe, probably the whole of Africa, the middle East, India, Central and South East Asia to Japan, the Philippines, Indonesia, New Guinea, the eastern part of Australia, New Zealand and a number of pacific islands except desert and very humid region (Singh 1972).

Host Range of tomato fruit borer

A wide range of host tomato fruit borer are cotton, tobacco, maize, sorghum, pennisetum, sunflower, various legumes, citrus, okra and other horticultural crops. Wild plants considered important include species of Euphorbiaceae, Amaranthaceae, Malvaceae, Solanaceae, Compositae, Portulaceceae and Convolvulaceae, but many other plant families are also reported to be the hosts of this insect pest (Jiirgen *et al.* 1977).

Tomato fruit borer, *Helicoverpa armigera* Hubner is a cosmopolitan, polyphagous pest, distributed widely in Indian subcontinent (Sing andNarang, 1990, Fenemore, 1990). Apart from tomato, *H. armigera* is reported to infest cotton, maize, chickpea, pigeon-pea, sorghum, sunflower, soyabean and groundnut (Fitt, 1989). Larvae affect almost all the aerial parts of the tomato plant from the early growth till to the fruit maturation stage (Lal and Lal, 1996, Tripathy *et al.* 1999). Loss incurred to growing tomato crop is insurmountable and may extend up to 51.20 per cent in Punjab (Sing andNarang, 1990); 40-50 per cent in Bangalore (Khaderkhan *et al*. 1997) and 32.52 per cent in Madhya Pradesh (Ganguly *et al.* 1998). Severe infestation causes necrosis to the leaf chlorophillus tissue, suppresses tomato flowers to bloom and makes the mature fruit unfit to consume (Jallow *et al.* 2001). In Jalpaiguri, Bengal considerable losses to tomato due to this pest have been reported (Chaudhuri 2000).

Life history of tomato fruit borer

Egg

Eggs are 0.4-0.5 mm in diameter, nearly spherical with flattened base, glistering yellowish- white in colour, changing to dark brown prior to hatching (Singh and Singh, 1975).

Larva

The fully grown larva is about 40 mm in length, general colour varies from almost black, brown or green to pale yellow or pink and is characterized by having a dark band along the back to each side of which there is a pale band. The larval period varies from 15.35 days (Singh and Singh 1975).

Pupa

The light brown pupa, living in the soil, is seldom seen unless special sampling techniques are used (Nachiappan and Subramanium 1974).

Adult

Stout bodied moth has a wing span of 40 mm. General colour varies from dull yellow or olive grey to brown with little distinctive marking. The moths become sexually mature and mate about four days after emergence from the pupae having fed from the nectars of plants. The moth is only active at night and lays eggs singly on the plant. On hatching, the larva normally eats some or all of its egg shell before feeding on the plant. The larva passes through six instars and the larval period varies from 15-35 days (Ewing *et al.* 1947). Damage by the pest was found to be independent of all these characters except ascorbic acid content, which was positively correlated with damage.

Resistant cultivar against fruit borer

Gajendra *et al*. (1998) screened twenty four tomato cultivars against of tomato fruit borer, *H. armigera* during the spring in Madhya Pradesh. Cultivars Pusa early dwarf, Akra Vikas and Pusa Gourva with highly hairy peduncles were less susceptible to the pest damage than those with less hairs on the peduncles. Negative correlation between ascorbic acid content of the fruit and fruit damage by the pest was observed. Sivaprakasam (1996) observed the leaf trichome (number/$mm^{2)}$, petioles, internodal stems and calyx on 9 tomato genotypes. Results suggested that the low fruit borer damage in Paiyur-1 and X-44 might be due to the presence of long calyx, trichomes, physically preventing feeding by *H. armigera* larvae, rather than to trichome number/mm^2. Paiyur-1 had lowest number of trichomes on all plants parts studied, but the largest calyx area per fruit (3.4 cm^2). Rath and Nath (1995) conducted field screening of 112 tomato genotypes at Uttar Pradesh, India, during the Kharif season against *H. armigera*. Leaf trichome density, sepal length, number of branches, fruit diameter and P^H of ripe fruit showed a significant and positive impact on infestation level. The increased fruit number in a plant enhanced numbers of *H. armigera*. The percentages of plant infestation were negatively correlated with fruit pericarp, thickness and the percentages of fruit damage were negatively correlated with fruit per plant but positively correlated with trichome density. Information on genetic variability, and genetic advance is derived from data on number of fruits/plant, fruit weight, fruit borer (*Heliothis armigera*) incidence, wilt (*Fusarium oxysporum f. sp Lyopersics*) incidence and yield of 16 tomato varieties grown at Ghumsar, Udayagiri was observed by Mishra and Mishra (1995). The cultivars BT 6-2, BT 10, BT 17, T 30 and T 32, exhibiting resistance to both wilt and fruit borer, could be utilized as donors in future multiple resistance breeding programmes.

Money-Maker and Royesta were evaluated to screen out the suitable resistant/susceptible genotypes against the fruit borer in Pakistan (Sajjad *et al*., 2011). The results imparted that the percentage of fruit infestation and larval population per plant on tested genotypes of tomato varied significantly. Lower values of host plant susceptibility indices (HPSI) were recorded on resistant genotypes. Sahil, Pakit and Nova Mecb could be used as a source of resistance for developing tomato genotypes resistant to tomato fruit borer.

Khanam *et al*. (2003) conducted an experiment on the screening of thirty tomato varieties/lines to tomato fruit borer, *Helicoverpa armigera* (Hub.) infestation in relation to their morphological characters and conducted in different laboratories of BAU and BINA, Mymensingh during Rabi season, November, 1999 to March 2000. The tomato fruit borer infestation varied significantly among the varieties/lines and also with the age of the tomato plants. Among the varieties/lines, V-29 and V-282 were found moderately resistant and susceptible, respectively. Plant height, stem diameter, total number of branches/plant, total number of leaves/plant, 2^{nd} leaf area, total leaf chlorophyll, number of leaf hair and number of fruits/plant of V-29 line were 81.74 cm, 1.45 cm, 14, 453, 19.58 sq. cm, 1.13 mg/g, 12 and 48, respectively. Again the aforementioned characters for V-282 line were 80.74 cm, 1.18 cm, 9.396, 21.57 sq.cm, 1.24 mg/g, 17 and 30, respectively.

Karabhantanal and Kulkarni (2002) reported that the tritrophic interactions were assessed under net cage conditions among tomato cultivars L-15, PKM-1, Arka Vikas, Arka

Sourabh, Arka Ashish on *Helicoverpa armigera* and egg hyperparasitoids (*Trichogramma chilonis* and *Trichogramma pretiosum*). Significantly lower oviposition by *H. armigera* was observed on local genotypes, L-15 and PKM-1, while the oviposition was higher on IIHR genotypes, Arka Sourabh, Arka Vikas and Arka Ashish. Irripective of *T. pretiosum* recorded higher hyperparasitism than *T. chilonis*. Further, it was observed that as the trichome density increased there was an increase in oviposition by *H. armigera* and a decrease in hyperparasitism by *Trichogramma* species.

Saha *et al*. (2001) reported that an investigation was conducted in Uttar Pradesh, India to determine the effect of intercropping. Tomato fruit borer (*Helicoverpa armigera*) heavily infested sole tomato plots compared to all intercrop treatments. The borer population was also found on sole lentil plots but was less than that on sole tomato plots. The fruit borer population was, more or less, similar in all intercropped plots even in the sole lentil plot. Their populations were higher on sole lentil but were less than tomato.

Rath and Nath (2001) reported that tomato genotypes were assessed for fruit damage by fruit borer *Helicoverpa armigera* in a field experiment conducted in Varanasi, Uttar Pradesh, India, during 1991 (112 genotypes) and 1992 (27 genotypes, along with wild type *Lycopersicon pimpinellifolium*). The genotypes were categorized according to percent fruit damage by the pest. Five genotypes, HT-64, Hybrid No.37, PTH-104, PTH-103, recorded the lowest level of per cent fruit damage (< 10) in both years. The wild genotype showed less than 10% fruit damage during 1992. H-86-82, ZLE-006, Parm-mitra and HS-173 recorded the highest fruit damage of more than 40% during 1991. During 1992, the highest fruit damage of more than 30% were recorded from Shrestha, Kalyanieunush, PTH-102, PTH 101, HS-173 and XLE-006.

Saha *et al*. (2000) reported that intercrops of tomato cv. Pusa Ruby were infested with different species of insect pests of tomato fruit borer, *Helicoverpa armigera*, showed significant differences in infestation levels in various intercrop situations in Varanasi, Uttar Pradesh, India, during Rabi season of 1996-97. However, there was a general downward trend in infestation level of different pests in intercrop combinations compared to their numbers in sole crops as preferred host. The intercrops were thus, found to be more suitable for natural suppression of pest populations.

Seasonal abundance

Parihar and Singh (1986) reported that the larval population of *Heliothis armigera [Helicoverpa armigera]* on tomato and losses caused by this pest were studied in the Meerut district of Uttar Pradesh, India, In 1983-84 and 1984-85. The larval population was low until the first week of February in both years and increased rapidly thereafter, reaching a peak in the last week of March. In the last week of April, the population declined to 4 larvae/10 plants. Percent fruit infestation was low up to the end of February, while in the 2nd week of April 50.08 and 33.04% of fruits were infested in 1984 and 1985, respectively. By the 2nd week of May, 1.441% of fruits were infested in 1984 and 2.84% in 1985. It was recommended that control measures should be applied at the time of flowering, which is also the time of mass oviposition.

Patel and Koshiya (1997) worked on seasonal abundance of *Heliothis armigera* during Kharif season, the pest started its activity in groundnut from first week of July. There after, the pest moves to cotton crop from last week of July and started to build up its population during the month of August to mid-September. Simultaneously the pest infestation was also noticed in sunflower and pearl millet during this period but the population was very low in sunflower. However, in pearl millet, it was at peak during September. In Rabi season, post activity was observed in chickpea during November to February. However, its population was at peak during December. In summer season, the pest started its activity on groundnut in February and was active up to June. The seasonal history of tomato fruit borer, *Heliothis armigera* varies considerably due to different climatic conditions throughout the year. A Study revealed that the population of *Heliothis armigera* began to increase from the mid-January and peaked during the last weed of February. The population of this pest was positively correlated with average temperature, mean relative humidity and total rainfall. Parihar and Singh (1986) in India showed that, the larval population of *Heliothis armigera* on tomato was low until the first week of February and increased rapidly there after, reaching to 4 larvae/ 10 plants, percent fruit infestation was low up to the end of February, while in the second week of April 50.08% and 33.04% of fruits were infested in 1984 and 1985, respectively.

Nature of damage of tomato fruit borer (TFB)

Hussain and Bilal Ahmed (2006) conducted an experiment during two years where fruit damage due to TFB was highest (19.59%) in Noorbagh of district Srinagar and lowest (1.61%) in Awneera of district Pulwama. Whereas, on an overall mean basis district Anantnag recorded lowest (1.85%) and district Srinagar recorded highest (17.36%) fruit damage. However, hybrids were generally more damaged than local varieties. The effect of marigold which act as a trap crop along with various combinations of tomato showed that 3:1 combination recorded lowest fruit damage and larval population but trapped more larvae on trap crop. Thus, the yield was higher than other treatments. However, tomato equivalent yield was 2455714 kg/ha in 2003 and 28399.99 kg/ha in 2004.

Aphid

There are six species of aphids that damage crops. These species include *Rhopalosiphum padi, Schizaphis graminurn, Sitobion avenae, Metopoliphiurn dirhodum, R. Maidis* and *Diuraphis noxia.* Two of those species are commonly known as Russian Aphid (*Diuraphis noxia*) and Bird Cherry-Oat Aphid (*Rhopalosiphum padi*) which are considered notorious for their direct and indirect losses.

Aphid is known to be a sporadic insect causing significant yield losses by spreading out from its origin. The centre of origin for aphid is considered to be the central Asian mountains of Caucasus and Tian Shan. The species could now be found in South Africa, Western United States, Central and Southern Europe and Middle East. The economic impact of aphid includes direct and indirect losses that have been estimated to be $893 million in Western United States during 1987 to 1993 (Morrison and Peairs, 1998) whereas 37% yield losses in winter have been reported in Canadian Prairies. Direct losses have also been assessed as an increased input cost due to insecticides and indirect losses include reduced yield due to aphid infestation.

Climatic conditions and temperature in particular, play a significant role in population dynamics of the aphids. A warmer temperature can potentially accelerate the aphid's growth both in terms of number and size, yet, the extreme temperatures can possibly reduce the survival and spread of aphids. Aphid is known to be present in its three different morphological types: immature wingless females, mature wingless females and mature winged females. Winged mature females or adults spread the population and infection to the surrounding host plants whereas the wingless types or apterous cause damage by curling and sucking the young leaves. Heavily infested plants may typically look prostrated and/or stunted with yellow or whitish streaks on leaves. These streaks, basically, are formed due to the saliva injected by the aphid (Morrison and Peairs, 1998). The most obvious symptoms due to heavy infestations can cause reduced leaf area, loss in dry weight index, and poor cholorophyll concentration. Plant growth losses could be attributed mainly due to reduced photosynthetic activity to plants aphid infestation. The photochemical activities of the plants were reportedly inhibited by the aphid feeding from leaves and disruption in electron transport chain. Spikes can have bleached appearance with their awns tightly held in curled flag leaf. Yield losses can greatly vary due to infestation at different growth stages, duration of infestation and climatic conditions (wind patterns and temperature). A number of biotypes for aphid have been reported to be present throughout the cereal production areas of the world. These biotypes are classified due to significant genetic differences among them.

A number of strategies have been deployed to mitigate aphid infestation. Among these strategies, the host plant resistance has been the most effective and economic method to induce antixenosis, antibiosis and/or tolerance against aphid. Its host plant resistance is well known to be qualitative in nature, and about nine resistance genes have been documented so far. A number of alternate methods to control this pest has been suggested and practiced that include cultural, biological and chemical control methods. Cultural control strategies involving eradication of volunteer and alternate host plants are generally recommended. Another strategy is grazing the volunteer plants which significantly reduce the aphid infestation (Walker and Peairs, 1998). Adjusting planting dates to de-synchronize the insect population dynamics and favourable environmental conditions of any particular area can also be helpful in controling aphid. The enhanced fertigation of infested field, and biological control of aphid is also possible with 29 different species of insects and 6 fungus species of the predator insects, 4 different species of wasps have become adopted to United States. Besides these cultural practices, chemical control method is also widely practiced with equivocal cost efficiency.

Life cycle

Most aphids reproduce sexually throughout most or all of the year with adult females giving birth to live offspring often as many as 12 per day without mating. Young aphids are called nymphs. They molt, shedding their skin about four times before becoming adults. There is no pupal stage. Some species produce sexual forms that mate and produce eggs in fall or winter, providing a more hardy stage to survive harsh weather and the absence of foliage on deciduous plants. In some cases, aphids lay these eggs on an alternative host, usually a perennial plant, for winter survival. When the weather is warm, many species of aphids can develop from newborn nymph to reproducing adult in seven to eight days. Because each adult aphid can produce up to 80 offspring in a matter of a week, aphid populations can increase with great speed (Flint, 1998).

Nature of damage

Low to moderate numbers of leaf-feeding aphids aren't usually damaging in gardens or on trees. However, large populations can turn leaves yellow and stunt shoots; aphids can also produce large quantities of a sticky exudates known as honeydew, which often turns black with the growth of a sooty mold fungus. Some aphid species inject a toxin into plants, which causes leaves to curl and further distorts growth. A few species cause gall formations (Cannon, 2008).

Squash, cucumber, pumpkin, melon, bean, potato, lettuce, beet, chard, and bok choy are crops that often have aphid-transmitted viruses associated with them. The viruses mottle, yellow, or curl leaves and stunt plant growth. Although losses can be great, they are difficult to prevent by controlling aphids, because infection occurs even when aphid numbers are very low; it takes only a few minutes for the aphid to transmit the virus, while it takes a much longer time to kill the aphid with an insecticide.

2.4 Botanicals

Several biologically active compounds have been isolated from different parts of neem tree. Several vilasinin derivatives, salanins, salanols, salasnolactomes, vepaol, isovepaol, epoxyazadirachdone, gedunin, 7-deacetylgedunin have been isolated from neem kernels. Azadirachtin is the most potent growth regulator and antifeedant (Butterworth and Morgan, 1968; Warthen *et al.*, 1978).

The triterpenoid azadirachtin (C35H44O16) was first isolated from the seeds of the tropical neem tree by Butterworth and Morgan (1968). Its definite structural formula, which resembles somewhat that of ecdysone, was finally explained in 1985.

Azadirachtin is a limonoid alleliochemical (Butterworth and Morgan, 1968; Broughton *et al.*, 1986) present in the fruits and other tissues of the tropical neem tree (*Azadirachta indica*). The fruit is the most important aspect of neem that affects insects in various ways. The leaves, which may also be used for pest control, may reach a length of 30 cm.

Mode of action of neem

Settling Behavior

Crude neem extracts deters settling and reduces feeding in *M. persicae* (Griffiths *et al*., 1978 and 1989).

Oviposition Behavior

The females of some lepidopterous insects are repelled by neem products on treated plant parts or other substrates and will not lay eggs on them under laboratory conditions.

Feeding Behavior

Azadirachtin is a potent insect antifeedant. Antifeedancy is the result of effects on deterrent and other chemoreceptors. The antifeedant effects of azadirachtin have been reported for many species of insects. Reduction of feeding was also observed after topical application or injection of neem derivatives, including AZA and alcoholic neem seed kernel extract. This means that the reduction of food intake by insects is not only gustatory which means that sensory organs of the mouth parts but also non-gustatory regulate it. These two phagodeterrent/antifeedant effects were called primary and secondary (Schmutterer, 1985).

Metamorphosis

Azadirachtin has different influence on the metamorphosis of the insects resulting in various morphogenetic defects as well as mortality, depending on the concentration applied.

The IGR effect of neem derivatives such as methanolic neem leaf extract and azadirachtin in nymphs and larvae of insects was first observed in 1972 in Heteroptera (Leuschner, 1972) and Lepidoptera. Molting, if it occurred, was incomplete and resulted in the death of the tested insects.

Botanicals possess an array of properties including insecticidal activity and insect growth regulatory activity against many insect pests and mites (Rajasekaran and Kumaraswami, 1985; Prakash and Rao, 1987; Prakash *et al*., 1988;Prakash *et al*., 1990). Low mammalian toxicity, no reported development of resistance to their production so far, less hazardous to non-target organisms, no pest resurgence problem, no adverse effect on plant growth, negligible application risks, low cost and easy availability are the advantages of plant products over synthetic chemicals (Bhaskaran and Narayansamy, 1995).

Ahmed (1984) enlisted 2121 plant species, possessing pest control property which include neem, sweetflag, cashew, custard apple, sugar apple, derris, lantana, tayanin, indian privet, agave, crow plant etc. 1005 species of plants having biological properties against insect pests including 384 species as antifeedants, 297 as repellents, 97 as attractants and 31 as growth inhibitors.

About 413 different species/sub-species of insect pest have been listed by Schmutterer (1995) found to be susceptible to neem products. The listed species/sub-species belong to different insect orders most of them were Lepidoptera (136) and Coleopteran (79).

Management by botanicals

The use of neem based insecticides as a source of biologically active substances for pest control is increasing worldwide, and have recently gained popularity as components of integrated pest management (Banken and Stark, 1997).

Maximum reduction in bollworm infestation (65.7%) was observed in garlic treated plot. Garlic extract and Neen Seed Kernel Extract both at 10 per cent were found to be superior. Lowest bollworm incidence was observed with NSKE (10.3%), datura and neem oil emulsion (Anon., 1987).

Sardhana and Krishnakumar (1989) studied the efficacy of neem oil, karanj oil (both at 0.5, 1.0 and 2.0%) and garlic oil (0.25, 0.5 and 1.0%) in comparison with monocrotophos (0.05%). Among the oils, neem oil and karanj oil offered effective control against okra fruit borers.

It was concluded that weekly application of neem oil at two per cent concentration was effective in controlling fruit borer in okra and was safe to natural enemies. Weekly application of neem (*Azadirachta indica*) oil at 2% was effective for controlling *E. vittella* on okra (Sardana and Krishnakumar, 1989). They observed that the plots having lower fruit damage and increased yields in treated plots monocrotophos at 0.05% and can therefore, be recommended for the use in an integrated control scheme for the rest.
The most probable effect of neem in Lepidopterans is the disruption of the larval-pupal molt (i.e. pupation), which has been frequently reported (Schmutterer *et al.*, 1983; Koul and Isman, 1991).

Repellent activity of neem against oviposition by Lepidopterous pests has also been reported for *Spodoptera litura* (Joshi and Sitaramaiah, 1979), *Cnaphalocrocis medinalis* (Saxena *et al.*, 1981) and *E. vittella* (Sojitra and Patel, 1992). Extracts of neem and bakain caused maximum adverse effects on fecundity and hatching.

Numerous plant species have been reported to possess pest control properties but only a few seem to be ideally suited to practical utilization. Among these, neem (*Azadirachta indica* A.) and bakain (*Melia azedarach* L.) are the most promising plants from the entomological perspective (Schmutterer, 1990 and 1995).

Neem based formulations have already been recommended in the management of bollworms including *E. vittella* in cotton (Gupta and Sharma, 1997; Anon., 1997).

Neem oil produced non-toxic effects after spray and acted as antifeedant, growth inhibitor and oviposition deterrent against insects pests of okra and cotton (Ahmed *et al.*, 1995).

Patil (2000) conducted an experiment with 20 indigenous plant extracts to evaluate the antifeedant property against insect pest. *Apis indica* exhibited maximum of 10-51 percent antifeedant followed by *A. calamus* (15.69%) and *A. squamosa* (17.31%) against third instar larvae of *Earias vittella.*

Morale *et al.* (2000) studied the effect of plant product against *E. vittella* of cotton under laboratory condition and revealed that neem oil 1%, karanj oil 1%, cotton seed oil 1%, neem seed extract (NSE aqueous) 5% and NSE (methanolic) 1% were significantly affected the larval period, larval mortality and fecundity of *E. vittella.*

Lakshmanan (2001) reported effectiveness of neem extract alone or in combination with other plant extracts in managing lepidopteran pests viz., *E. vittella*, *Chilo partellus* Swinhoe, *Helicoverpa armigera* and *Spodoptera litura*.

Antifeedant effect of neem in combination with sweetflag and pongam extracts on okra shoot and fruit borer was studied by the Rao *et al.* (2002) which gave 43.12 to 80.00 percent mortality protection over control.

Mudathir and Basedow (2004) found that different preparations of neem significantly reduced okra shoot and fruit borer infestation in okra.

Singh *et al.* (2005) tested the efficacy of two botanicals and insecticides and reported that NSKE @ 1.5% was found superior after fenvalerate with respect to yield. NSKE (1.5%), NSKE (1%), karanj seed kernel extract (KSKE) (1.5%) and NSKE (1%) were superior by recording 58.27, 47.32, 44.25 and 41.5 q/ha yield, respectively as against 29.17 q/ha in untreated control.

Mochiah *et al.* (2011) conducted a study to evaluate the efficacies of some botanical products on insect populations associated with two vegetables; Eggplant and Okra. Two field experiments were conducted on-station at the CSIR-Crops Research Institute, Kwadaso, Kumasi, and on-farm at Eatwell farm at AgonaMampong all in the Ashanti region of Ghana from December 2009 to March 2010 and September to December 2010, respectively. Seven botanical treatments were applied viz; Ecogold (10 ml/l of water);

Alata soap (5 g/l of water); Garlic (30 g/litre of water); Neem oil (3 ml/l of water); Papaya leaves (92 g/l of water); Wood ash (10 g/plant stand) and control (no botanical). The experimental set up was a Randomized Complete Block design (RCBD) with three replications. Parameters studied included insect pest numbers and their natural enemies, number of days to 50% flowering, plants height at flowering (cm), number of fruits per plant, fruit damage, and mean weight of fruits (g). Major insect pest recorded on the two vegetables included aphids (*Aphis gossypii*), flea beetles (*Podagrica* spp), white flies (*Bemisia tabaci*), fruit borers (Earias sp), cotton strainers (*Dysdercus superstitiosus* (F.)), variegated grasshoppers (*Zonocerus variegatus* L.), *Urentius hysterricellus* (Richter) and shoot and fruit borers (*Leucinodes orbonalis* Gn). The natural enemies of pests of the two vegetables identified were the ladybird beetles, (*Cheilomenes* sp) and predatory spiders (Araneae). There were significant percentage reductions in pests for all the botanicals applied ($P < 0.05$) on both the eggplant and okra plants compared to the control. Generally, plants to which the botanicals were applied produced the highest mean weight of fruits, translating into mean percentage increases in fruit weight ranging between 21 and 59% on both the eggplant and okra plants compared to the control in both growing periods. It is concluded that botanicals such as Ecogold, Alata soap, exotic garlic, neem oil, papaya leaves and wood ash could be effectively considered as pest management options to reduce insect pest populations and increase eggplant and okra productivity.

Botanical pesticides are naturally occurring chemicals extracted from plants, and have long been touted as attractive alternatives to synthetic chemical insecticides for pest management because they pose little threat to the environment or to human 16 health (Isman, 2006).

Botanical pesticides possess an array of properties including toxicity to the pest, repellency, antifeedance and insect growth regulatory activities against pests of agricultural importance (Prakash and Rao, 1996). According to Prakash and Rao (1996), there are four major types of botanical products used for insect control (neem, pyrethrum, rotenone, and essential oils).

Azadirachtin is a botanical insecticide obtained from seeds of the neem tree, *Azadirachta indica* Juss (Meliaceae) (Schmutterer, 2002). It is strong anti-feedent, repellent and growth regulator of a wide variety of phytophagous insects (Mitchell *et al*., 2004). The main advantages of neem are reduced human toxicity (Raizada *et al*., 2001), fast and complete degradation in the environment, low risk for resistance and selective properties reported for some non-target organisms (Walter, 1999). Currently, several neem-based products are registered as pesticides in Kenya (Knapp and Kashenge, 2003). These products have already proven to be effective against several insect pests like diamondback moth, *Plutella xylostella*, aphids, *Brevicoryne brassicae* L., *Myzus persicae* (Kalt) and *Lipaphis erysimi* (Sulz) in cabbage, *Brassica oleracea* var capitata, and *Lyriomyza* spp. on tomatoes and cut flowers (Knapp and Kashenge, 2003; Waiganjo *et al*., 2011).

Neem can be used as a component in several IPM strategies. There is evidence on the synergistic effect of neem with microbial pesticides such as Nucleopolyhedrovirus (NPV) in the control of the African bollworm attacking tomato fruits (Senthilkumar *et al.*, 2008). Pyrethrum plant from the genus Chrysanthemum is grown in Kenya and the active ingredients consists of a mixture of pyrethrins and cinerin obtained from the dried 17 flowers of the pyrethrum daisy (*Tanacetum cinerariaefolium*; Asteraceae) (Rajapakse and Ratnasekera, 2008).

The insecticidal action of the pyrethrins is characterized by a rapid knockdown effect, particularly in flying insects, and hyperactivity and convulsions in most insects (Isman, 2006). According to Isman (2006), natural pyrethrins are unstable in light compared with the synthetic derivatives (pyrethroids), a fact that has greatly limited their use outdoors. A recent study indicated that the half-lives of pyrethrins on field-grown tomato and bell pepper fruits were two hours or less (Antonious, 2004).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to evaluate ecofriendly pest management of tomatoduring the period from November 2018 to April 2019. A brief description of the experimental site, climatic conditions, soil characteristics, experimental design, treatments, cultural operations, data collection and analysis of different parameters were used for conducting this experiment are presented under the following headings:

3.1 Location of the experimental field

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2016 to March 2017. The location of the experimental site was at 23^0 $46^{'}$ N latitude and 90^0 $22^{'}$E longitudes with an elevation of 8.24 meter from sea level (Khan, 1997).

3.2 Climate condition during the experiment

The experimental area is characterized by subtropical rainfall during the month of April to September and scattered rainfall during the rest of the year. Information regarding average monthly temperature as recorded by Bangladesh Meteorological Department (climate division) during the period of study has been presented in Appendix I.

3.3 Soil of the experimental field

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) (UNDP and FAO, 1988) with pH 5.8-6.5, ECE-25.28. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka.

3.4 Experimental materials

BARI Tomato-14 tomato variety were used for this study and the treatments were used as follows

i. Untreated control (T_1)
ii. Neem oil suspension spray (T_2)
iii. Garlic oil (T_3)
iv. Black seed oil (T_4)
v. Marigold intercropping (T_5)
vi. Netting at seedling stage (T_6)
vii. Tobacco leaf powder extract spray (T_7)

3.5 Experimental design and layout

The experiment consisted of seven different ecofriendly treatment and was laid out in Randomized Complete Block Design (RCBD) with three replications. Experimental plot was sub-divided into three blocks where two pits were in each plots. Thus, there were 30 (3 × 10) unit plot in the experiment. The size of each plot was 3.50 m × 2.0 m.

3.6 Cultivation procedure

3.6.1 Seedling raising

The land selected for nursery bed was well drained and was of sandy loam type soil. The area was well prepared and converted into loose friable and dried mass to obtain fine till. All weeds and dead roots were removed and the soil was mixed with well rotten cow dung at the rate of 5 kg/bed. The size of each seed bed was 2 x 1 m raised above the ground level maintaining a spacing of 50 cm between the beds. One seed beds were prepared for raising the seedlings. Ten grams of seeds were covered with light soil. Miral 3-GN was applied in each seed bed as precautionary measures against ants and worms. Complete germination of the seeds took place with 6 days after seed sowing. Necessary shading was made by bamboo mat (chatai) from scorching sunshine or rain. Weeding, mulching and irrigation were done as and when required. No chemical fertilizer was used in the seed bed.

3.6.2 Land preparation

The land for growing the crop was opened with a tractor on 15 October, 2016. Thereafter, it was gradually ploughed and cross ploughed several times with power tiller. Each plugging was followed by laddering to break the clods and to level the soil. During land preparation, weeds and other stubbles of the previous crop were collected and removed from the land. These operations were done to bring the land under a good tilt conditions. Irrigation channels were prepared around the plots four days before transplanting the seedlings.

3.6.3 Manures and fertilizers and its methods of application

Fertilizer	**Quantity**	**Application method**
Cow dung	10 t /ha	Basal dose
Urea	69 kg/ha	20, 35 and 50 DAT
TSP	60 kg/ha	Basal dose
MOP	60 kg/ha	Basal dose

The half of cow dung, TSP and MP and one third of urea were applied as basal dose during land preparation. The remaining cowdung, TSP and MP were applied in the pit 15 days before seed sowing. The rest of urea was top dressed after each flush of flowering and fruiting in three equal splits.

3.7 Seedlings transplanting

Healthy and uniform sized 25 days old seedlings were taken separately from the seed bed and were transplanted in the experimental field on 01 December, 2016 maintaining a spacing of 70 and 70 cm between the rows and plants, respectively. The seed beds were watered before uprooting the seedlings so as to minimize damage to the roots. This operation was carried out during late hours in the evening. The seedlings were watered after transplanting. Shading was provided by pieces of banana leaf sheath for three days to protect the seedling from the direct sun. Seedlings were also grown around the experimental area to do gap filling and to check the border effect.

Plate 1. The experimental plot during the study period

Plate 2. The picture ofexperiment during the study period

3.8 Intercultural operations

After transplanting the seedlings, various kinds of intercultural operations were accomplished for better growth and development of the plants.

3.8.1 Gap filling

When the seedlings were established, the soil around the base of each seedlings was pulverized. A few gap filling was done by healthy plants from the border whenever it was required.

3.8.2 Weeding and mulching

Weeding and mulching were accomplished as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the crust. It also helped in soil moisture conservation.

3.8.3 Staking and pruning practices

When the plants were well established, staking was given to each plant by Bamboo sticks to keep them erect. Within a few days of staking, as the plants grew up, the plants were pruned uniformly having single main stem per plant.

3.8.4 Irrigation

Four irrigations were given throughout the growing period by watering can. The first irrigation was given 15 days after planting followed by next three 15 days interval each irrigation. Mulching was also done after each irrigation at appropriate time by breaking the soil crust.

3.9 Harvesting

Fruits were harvested at 4 days intervals during maturing and ripening stage. The maturity of the crop was determined on the basis of red coloring of fruits. Harvesting was started from 23February 2019 and completed by 16 March, 2019

3.10 Data collection

Data on the following parameters were recorded from the sample during the course of experiment. Five plants were selected randomly from each plot in such a way that the border effect was avoided for the highest precision.

3.10.1Number of white fly plant^{-1}

The number of white fly per plant were counted manually at vegetative, flowering and reproductive stage from randomly selected tagged plants. The average of five plants were computed and expressed in average number of white fly per plant.

3.10.2Number of aphid plant^{-1}

The number of aphid per plant was manually counted at vegetative, flowering and reproductive stage from randomly selected tagged plants. The average of five plants were computed and expressed in average number of aphid per plant.

3.10.3Number of fruit borer plant^{-1}

The number of fruit borer per plant was manually counted at vegetative, flowering and reproductive stage from randomly selected tagged plants. The average of five plants were computed and expressed in average number of fruit borer per plant.

3.10.4Number of leaf miner plant^{-1}

The number of leaf miner per plant was manually counted at vegetative, flowering and reproductive stage from randomly selected tagged plants. The average of five plants were computed and expressed in average number of leaf minerper plant.

3.7.5 Number of fresh ripe fruit

Total number of ripe fruits was counted from selected plants and their average was taken as the number of ripe fruits per plant. Harvesting was done by five times at 90, 94, 98, 102 and 106 DAT.

3.7.6 Weight of individual fruit (g)

Among the five harvest of marketable fruits during the period from first to final harvests, first and last harvests were omitted and five intermediate harvests were taken for individual fruit weight by the following formula:

Weight of individual fruit (g) =

$$\frac{\text{Total weigh of marketable fruits from four harvest of sample plant}}{\text{Total number of marketable fruit from four harvests of sample plant}}$$

3.7.7 Weight of fruit per plant (kg)

It was measured by the following formula

Weight of fruit per plant (kg) = Number of fresh ripe fruit per plant × weight of individual fruit.

3.7.8 Weight of fruit per plot (kg)

It was measured by the following formula

Weight of fruit per plant (kg) = Number of fresh ripe fruit per plant × weight of individual fruit × number of plant per plot.

3.7.9 Yield t ha^{-1}

A pan scale balance was used to take the weight of fruits per plant and convert into ton per hectare.

3.8 Statistical Analysis

The data obtained from experiment on various parameters were statistically analyzed in MSTAT-C computer program (Russel 1986). The mean values for all the parameters were calculated and the analysis of variance for the characters was accomplished and means were separated by Duncan's Multiple Range Test (DMRT) test at 5% levels of probability (Gomez and Gomez 1984).

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2018 to march, 2019 to evaluate the ecofriendly pest management of tomato. The results on different parameters have been interpreted, discussed and presented under the following sub-headings:

4.1 Common insect pest of tomato found in the field

Under the present study, the insect pests oftomato found in the experiment field are presented in Table 1.

Table 4.1 List of insect pest of tomato with stages of insect, site of infestation and nature of damage

Sl. No.	Common name of insect	Scientific name	Site of infesta tion	Nature of damage
1.	White fly	*Bemisia tabaci*	leaf	Both Adults and nymph feed by sucking sap from the foliage.
2.	Aphid	*Myzus persicae*	Leaf, shoot	Both Adults and nymph feed by sucking sap from the tender leaves and shoots.
3.	Fruit borer	*Helicoverpa armigera*	Fruit	The larvae of which feed on a wide range of plants, including many important cultivated crops.
4.	Leaf miner	*Liriomyza tnifolies*	Leaf	The larvae feed on the cells within tomato leaves and create silvery lines across the infested leaves.

4.2 Number of whitefly plant^{-1} and control percentage at different growing stage

There was a significant difference observed on number of whitefly plant^{-1} due to different treatments at vegetative stage. The highest number of white fly per plant (25.45) was found from T_1 (Untreated control), whereas the lowest number of white fly per plant were observed (3.13) in treatment T_2 (Neem oil suspension spray)(Table 4.2). On the other hand, the highest control percentage ofwhite fly per plant (87.89) was found from T_2 (Neem oil suspension spray)and the lowest control percentage of white fly per plant (0.000) was found from treatment T_1 (Untreated control) (Table 4.2).

At the flowering stage, there was a significant difference observed on number of whitefly plant^{-1} due to different treatments. The highest number of white fly per plant (27.66) was found from T_1 (Untreated control), whereas the lowest number of white fly per plant were observed (3.01) in treatment T_2 (Neem oil suspension spray)(Table 4.2). On the other hand, the highest control percentage of white fly per plant (89.31) was found from treatment T_2 (Neem oil suspension spray) and the lowest control percentage of white fly per plant (0.00) was found from treatment T_1 (Untreated control) (Table 4.2).

Significant difference observed on number of whitefly plant^{-1} due to different treatments At the reproductive stage. The highest number of white fly per plant (22.96) was found from T_1 (Untreated control), whereas the lowest number of white fly per plant were observed (2.49) in treatment T_2 (Neem oil suspension spray)(Table 4.2). On the other hand, the highest control percentage of white fly per plant (89.31) was found from treatment T_2 (Neem oil suspension spray)and the lowest control percentage of white fly per plant (00) was found from treatment T_1 (Untreated control) (Table 4.2).

From the results it was found that the number of whitefly per plant was higher in vegetative stage. At ripening stage this counted number followed a decreasing trend. Botanical control was more effective than other control measures. The systemic action and quick knockdown properties of chemicals might have helped in reducing whitefly population in the entire cultivation period. At early flowering stage of tomato similar results were also obtained by Alam *et al.* (1994) but he found this result by chemical control. Similarly, Haq (2006) examined the efficacy of different neem products (botanical pesticides) against sucking pest complex (Thrip, Aphid, Jassid, and Whitefly) on okra crop and concluded that thrips, jassid and whitefly population was remarkably controlled with the application of different neem products.

Increasing trend of temperature increased the activity of whitefly and increased infestation. Rainfall and humidity also enhanced the activity of whitefly which also reduced the yield. Gerling *et al.* (1986) found that the lower and upper developmental thresholds of temperature are 11 and 33ºC, respectively. Rates of development are maximal at 28ºC. Avidov (1956) considered low humidity as the major mortality factor in Israel, leading to cessation of oviposition and adult whitefly mortality. Low humidity of 20% or less during hot weather has been reported to be highly detrimental to the immature stages of whitefly (Gameel 1978; Avidov 1956).

Table 4.2 Effect of different treatments on number of whitefly plant^{-1}and control percentage at different growing stage

Treatments	Vegetative stage	Control %	Flowering stage	Control %	Fruiting stage	Control %
T_1	25.45a	-	27.66a	-	22.96a	-
T_2	3.13g	87.89	3.01g	89.31	2.49g	89.31
T_3	13.37c	47.57	13.03c	53.00	10.81c	53.03
T_4	15.46b	39.33	15.03b	45.74	12.47b	45.77
T_5	11.34d	55.54	11.02d	60.26	9.15d	60.29
T_6	5.46f	78.70	5.52f	80.16	4.59f	80.17
T_7	9.55e	62.60	9.49e	65.89	7.86e	65.91
LS	**		**		**	
$LSD_{(0.05)}$	0.507		1.235		1.123	
CV (%)	2.39		4.57		3.59	

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of probability.

T_1=Untreated control, T_2=Neem oil suspension spray, T_3=Garlic oil, T_4=Black seed oil, T_5=Marigold intercropping, T_6= Netting at seedling stage, T_7=Tobacco leaf powder extract spray.

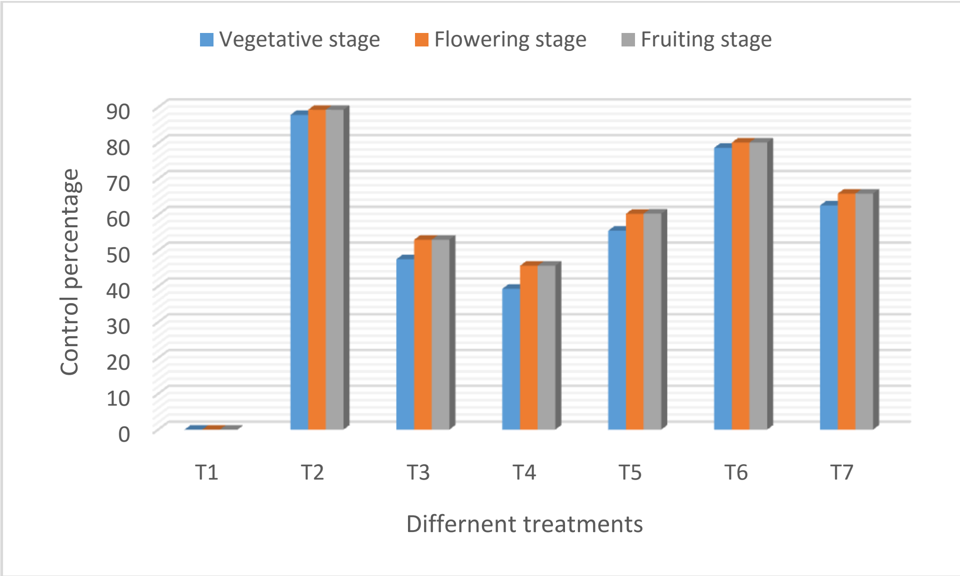

Figure 4.1 Effect of different treatments on control percentage of white fly at different growing stage

T_1= Untreated control, T_2= Neem oil suspension spray, T_3= Garlic oil, T_4= Black seed oil, T_5= Marigold intercropping, T_6= Netting at seedling stage, T_7=Tobacco leaf powder extract spray.

4.3 Number of aphid plant^{-1} and control percentage at different growing stage

Significant difference observed on number of aphid plant^{-1} due to different treatments at vegetative stage. The highest number of aphid per plant (20.16) was found from T_1 (Untreated control), whereas the lowest number of aphid per plant were observed (1.20) in treatment T_2 (Neem oil suspension spray)(Table 4.3). On the other hand, the highest control percentage of aphid per plant (94.23) was found from treatment T_2 (Neem oil suspension spray)and the lowest control percentage of aphid per plant (0.00) was found from treatment T_1 (Untreated control) (Table 4.3).

At the flowering stage, there was a significant difference observed on number of aphid plant^{-1} due to different treatments. The highest number of aphid per plant (20.97) was found from T_1 (Untreated control), whereas the lowest number of aphid per plant were observed (1.20) in treatment T_2 (Neem oil suspension spray)(Table 4.3). The highest control percentage of aphid per plant (94.41) was found from treatment T_2 (Neem oil suspension spray)and the lowest control percentage of aphid per plant (00) was found from treatment T_1 (Untreated control) (Table 4.3).

There was a significant difference observed on number of aphid plant^{-1} due to different treatments at the reproductive stage,. The highest number of aphid per plant (19.44) was found from T_1 (Untreated control), whereas the lowest number of aphid per plant were observed (1.01) in treatment T_2 (Neem oil suspension spray)(Table 4.3). On the other hand, the highest control percentage of aphid per plant (94.98) was found from treatment T_2 (Neem oil suspension spray)and the lowest control percentage of aphid per plant (00) was found from treatment T_1 (Untreated control) (Table 4.3).

The results are further supported by Lowery and Isman (1994) who reported 50% mortality of aphids by spraying neem based biopesticide; while Kumar and Singh (2001) reported that neem seed kernel extract was effective in controlling insect pests with highest cost:benefit ratio. Similarly, Singh and Kumar (2003) determined the efficacy of neem (*Azadirachta indica)* based pesticides against sucking complex and neem kernel extract was the most effective in controlling the aphid and jassid. Binage *et al.* (2004) found that 5% neem seed extract showed the lowest infestation of aphids and maximum crop yield. Tiwari and Srivastava (2005) examined the efficacy of some plant extracts, i.e. neem, eucalyptus, bougainvillea, mint, dhatura, lantana, ramphal, sitaphal, mehandi, tulsi and ginger against crop pests in the laboratory and reported that all extracts exhibited significant antifungal activity. Similarly, Haq (2006) examined the efficacy of different neem products (botanical pesticides) against sucking complex (Thrip, Aphid, Jassid, and Whitefly) on okra crop and concluded that thrips, jassid and whitefly population was remarkably controlled with the application of different neem products.

Table 4.3 Effect of different treatments on number of aphid plant^{-1} and control percentage at different growing stage

Treatments	Vegetative stage	Control %	Flowering stage	Control %	Fruiting stage	Control %
T_1	20.16a	-	20.79a	-	19.44a	-
T_2	1.20f	94.23	1.20f	94.41	1.01f	94.98
T_3	5.46d	73.06	5.62d	73.09	5.13d	73.76
T_4	6.76c	66.58	6.96c	66.63	6.23c	68.07
T_5	7.36b	63.65	7.44b	64.32	6.92b	64.51
T_6	7.45b	63.15	7.36b	64.76	6.84b	64.94
T_7	3.24e	84.11	3.13e	85.13	2.12e	89.25
LS	**		**		**	
LSD $_{(0.05)}$	0.422		0.443		0.414	
CV (%)	3.22		3.29		3.43	

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of probability.

T_1= Untreated control, T_2= Neem oil suspension spray , T_3= Garlic oil, T_4= Black seed oil, T_5= Marigold intercropping, T_6= Netting at seedling stage, T_7=Tobacco leaf powder extract spray .

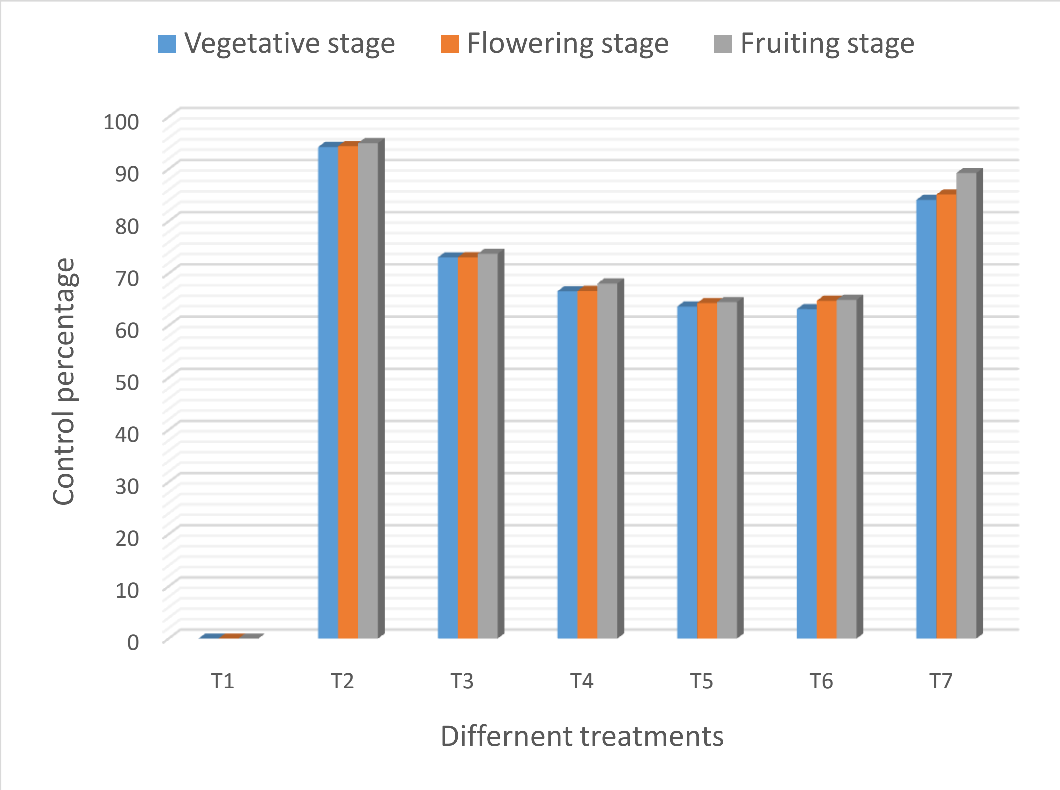

Figure 4.2 Effect of different treatments on control percentage of aphid at different growing stage

T_1= Untreated control, T_2= Neem oil suspension spray , T_3= Garlic oil, T_4= Black seed oil, T_5= Marigold intercropping, T_6= Netting at seedling stage, T_7=Tobacco leaf powder extract spray .

4.4Number of fruitborer plant^{-1} and control percentage at different growing stage

At the vegetative stage, there was a significant difference observed on number of fruit borer plant^{-1} due to different treatments. The highest number of fruit borerper plant (10.08) was found from T_1 (Untreated control), whereas the lowest number of fruit borerper plant were observed (1.02) in treatment T_2 (Neem oil suspension spray)(Table 4.4). The highest control percentage of fruit borerper plant (90.04) was found from treatment T_2 (Neem oil suspension spray)and the lowest control percentage of fruit borerper plant (00) was found from treatment T_1 (Untreated control) (Table 4.4).

Significant difference observed on number of fruit borer plant^{-1} due to different treatments at the flowering stage. The highest number of fruit borerper plant (16.93) was found from T_1 (Untreated control), whereas the lowest number of fruit borer per plant were observed (1.61) in treatment T_2 (Neem oil suspension spray)(Table 4.4). On the other hand, the highest control percentage of fruit borerper plant (90.65) was found from treatment T_2 (Neem oil suspension spray)and the lowest control percentage of fruit borerper plant (00) was found from treatment T_1 (Untreated control) (Table 4.4).

There was a significant difference observed on number of fruit borer plant^{-1}due to different treatments, at the reproductive stage. The highest number of fruit borerper plant (10.50) was found from T_1 (Untreated control), whereas the lowest number of fruit borerper plant were observed (0.90) in treatment T_2 (Neem oil suspension spray)(Table 4.4). On the other hand, the highest control percentage of fruit borerper plant (91.59) was found from treatment T_2 (Neem oil suspension spray)and the lowest control percentage of fruit borerper plant (00) was found from treatment T_1 (Untreated control) (Table 4.4).

Rahman *et al.* (2011). They reported the lowest percentage of fruit infestation by number (5.72%) and weight (9.69%) in total cropping season using Marshal @ 6.0 ml/2 litre of water at 7 days interval which was statistically similar (6.22% in number and 10.03% in weight) to that of neem leaf extract @ 0.5 kg/2 litre of water applied at 7 days interval. Bhushan *et al.* (2011) also reported that Neem seed kernel extract (NSKE 5%) was found most effective in reducing the larval population and pod damage in chickpea. Weekly spray application of the extract of neem seed kernel has also been reported effective against borers (Karim, 1994, Sivaprakasam, 1996; Saibllon *et al*., 1995 and Reddy *et al.*, 1996) attacking vegetable crops due to the presence of azadirachtin. It was demonstrated that azadirachtin was effective systemically and where insects ingest azadirachtin it had a toxic effect, interrupting growth and development. In subsequent work, azadirachtin and triterpenoids having antifeedant effects were isolated in smaller amounts from the neem seeds (Kraus 2002).

Table 4.4 Effect of different treatments on number of fruit borer plant^{-1} and control percentage at different growing stage

Treatments	Vegetative stage	Control %	Flowering stage	Control %	Fruiting stage	Control %
T_1	10.08a	-	16.93a	-	10.50a	-
T_2	1.02f	90.04	1.61f	90.65	0.90f	91.59
T_3	4.00c	60.46	6.11c	64.05	3.98b	62.24
T_4	3.13d	69.14	4.83d	71.63	3.02d	71.42
T_5	4.58b	54.70	7.64b	54.97	3.44c	67.41
T_6	4.72b	53.24	7.80b	54.05	3.48c	67.02
T_7	1.67e	83.58	2.59e	84.87	1.74e	83.56
LS	**		**		**	
LSD $_{(0.05)}$	0.202		0.353		0.215	
CV (%)	2.75		2.91		3.16	

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of probability.

T_1= Untreated control, T_2= Neem oil suspension spray, T_3= Garlic oil, T_4= Black seed oil, T_5= Marigold intercropping, T_6= Netting at seedling stage, T_7=Tobacco leaf powder extract spray.

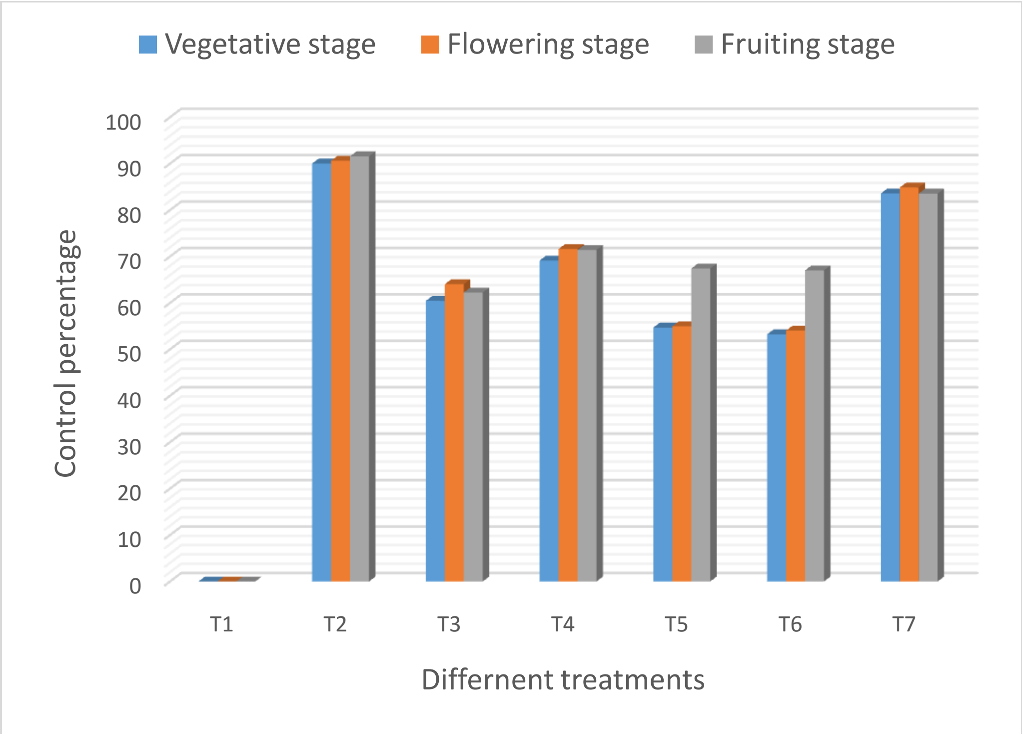

Figure 4.3 Effect of different treatments on control percentage of fruit borer at different growing stage

T_1= Untreated control, T_2= Neem oil suspension spray, T_3= Garlic oil, T_4= Black seed oil, T_5= Marigold intercropping, T_6= Netting at seedling stage, T_7=Tobacco leaf powder extract spray.

4.5 Number of leaf miner plant^{-1} and control percentage at different growing stage

At the vegetative stage, there was a significant difference observed on number of leaf miner plant^{-1} due to different treatments. The highest number of leaf minerper plant (5.04) was found from T_1 (Untreated control), whereas the lowest number of leaf minerper plant were observed (0.69) in treatment T_2 (Neem oil suspension spray)(Table 4.5). On the other hand, the highest control percentage of leaf minerper plant (93.52) was found from treatment T_2 (Neem oil suspension spray)and the lowest control percentage of leaf minerper plant (00) was found from treatment T_1 (Untreated control) (Table 4.5).

There was a significant difference observed on number of leaf minerplant^{-1} due to different treatments, at the flowering stage. The highest number of leaf minerper plant (4.66) was found from T_1 (Untreated control), whereas the lowest number of leaf minerper plant were observed (0.60) in treatment T_2 (Neem oil suspension spray)(Table 4.4). On the other hand, the highest control percentage of leaf minerper plant (87.27) was found from treatment T_2 (Neem oil suspension spray)and the lowest control percentage of leaf minerper plant (00) was found from treatment T_1 (Untreated control) (Table 4.5).

At the reproductive stage, there was a significant difference observed on number of whitefly plant^{-1} due to different treatments. The highest number of leaf minerper plant (4.21) was found from T_1 (Untreated control), whereas the lowest number of leaf minerper plant were observed (0.65) in treatment T_2 (Neem oil suspension spray)(Table 4.5). On the other hand, the highest control percentage of leaf minerper plant (84.69) was found from treatment T_2 (Neem oil suspension spray)and the lowest control percentage of leaf minerper plant (00) was found from treatment T_1 (Untreated control) (Table 4.5).

Table 4.5 Effect of different treatments on number of leaf miner plant^{-1} and control percentage at different growing stage

Treatments	Vegetative stage	Control %	Flowering stage	Control %	Fruiting stage	Control %
T_1	5.04a	-	4.66a	-	4.21a	-
T_2	0.69f	93.52	0.60f	87.27	0.65f	84.69
T_3	0.98d	80.68	0.95d	79.73	0.95d	77.54
T_4	1.16c	77.09	1.10c	76.50	1.12c	73.48
T_5	2.10b	58.37	1.81b	61.41	2.00b	52.49
T_6	2.02b	59.96	1.82b	60.98	2.04b	51.77
T_7	0.79e	84.46	0.82e	82.53	0.81e	80.87
LS	**		**		**	
$LSD_{(0.05)}$	0.106		0.099		0.087	
CV (%)	3.25		3.32		2.92	

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of probability.

T_1= Untreated control, T_2= Neem oil suspension spray , T_3= Garlic oil, T_4= Black seed oil, T_5= Marigold intercropping, T_6= Netting at seedling stage, T_7=Tobacco leaf powder extract spray .

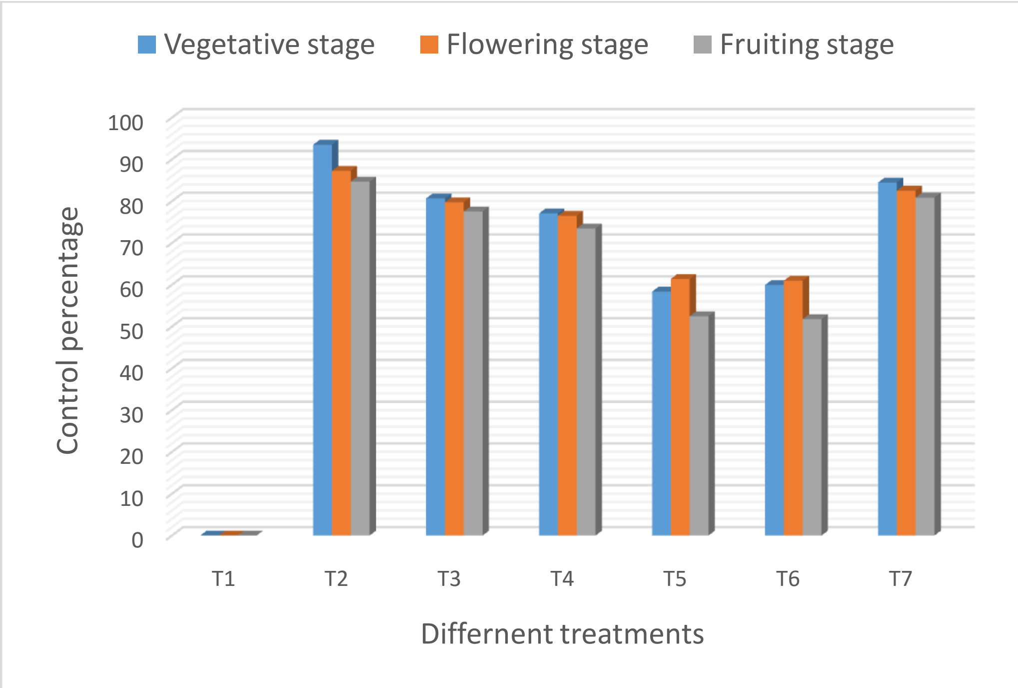

Figure 4.4 Effect of different treatments on control percentage of leaf miner at different growing stage

T_1= Untreated control, T_2= Neem oil suspension spray , T_3= Garlic oil, T_4= Black seed oil, T_5= Marigold intercropping, T_6= Netting at seedling stage, T_7= Tobacco leaf powder extract spray .

4.6Effect of different treatments on yield contributing and yield of tomato

4.6.1 Total number of fruit plant^{-1}

Total number of fruit plant^{-1} of tomato varied significantly due to different treatment (Table 4.6). The highest total number of fruit plant^{-1} (30.18) was obtained from T_2 (Neem oil suspension spray) and the lowest total number of fruit plant^{-1} (18.16) was obtained from T_1 (Untreated control) treatment.

Table 4.6 Effect of different treatments on yield contributing characters and yield of tomato

Treatments	Fruit plant^{-1} (no.)	Individual Fruit weight (g)	Fruit weight plant^{-1} (kg)	Fruit weight plot^{-1} (kg)	Yield (t ha^{-1})	Yield increased over control
T_1	18.16f	60.46f	1.09f	9.84f	24.60f	0.00
T_2	30.18a	81.59a	2.46a	22.11a	55.28a	55.49
T_3	24.08d	70.90d	1.70d	15.33d	38.33d	35.81
T_4	26.59c	74.01c	1.96c	17.67c	44.18c	44.31
T_5	21.27e	66.89e	1.42e	12.81e	32.03e	23.18
T_6	21.28e	65.47e	1.39e	12.54e	31.35e	21.52
T_7	28.19b	77.38b	2.17b	19.56b	48.90b	49.69
LSD ($_{0.05}$)	**	**	**	**	**	
LS	0.299	1.501	0.034	0.309	1.775	
CV (%)	2.69	2.40	5.10	3.11	4.36	

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of probability.

T_1= Untreated control, T_2= Neem oil suspension spray, T_3= Garlic oil, T_4= Black seed oil, T_5= Marigold intercropping, T_6= Netting at seedling stage, T_7=Tobacco leaf powder extract spray.

4.6.2Individual fruit weight

Individual fruit weight of tomato varied significantly due to different treatment (Table 4.6). The highest individual fruit weight (81.59 g) was obtained from T_2 (Neem oil suspension spray) and the lowest individual fruit weight (60.46 g) was obtained from T_1 (Untreated control) treatment.

4.6.3Fruit weight plant^{-1}

Fruit weight plant^{-1} of tomato varied significantly due to different treatment (Table 4.6). The highest fruit weight plant^{-1} (2.46 kg) was obtained from T_2 (Neem oil suspension spray) and the lowest fruit weight plant^{-1} (1.09 kg) was obtained from T_1 (Untreated control) treatment.

4.6.4Fruit weight plot^{-1}

Fruit weight plot^{-1} of tomato varied significantly due to different treatment (Table 4.61). The highest fruit weight plot^{-1} (22.11 kg) was obtained from T_2 (Neem oil suspension spray) and the lowest fruit weight plot^{-1} (9.84 kg) was obtained from T_1 (Untreated control) treatment.

4.6.5Yield

Yieldof tomato varied significantly due to different treatment (Table 4.6). The highest yield of tomato (55.28 t ha^{-1}) was obtained from T_2 (Neem oil suspension spray) which is 55.49% increased over control and the lowest yield of tomato (24.60 t ha^{-1}) was obtained from T_1 (Untreated control) treatment. Due to the lower insect infestation all the leaves were good shape and good physiological activities occurred and the variety gave the highest yield.

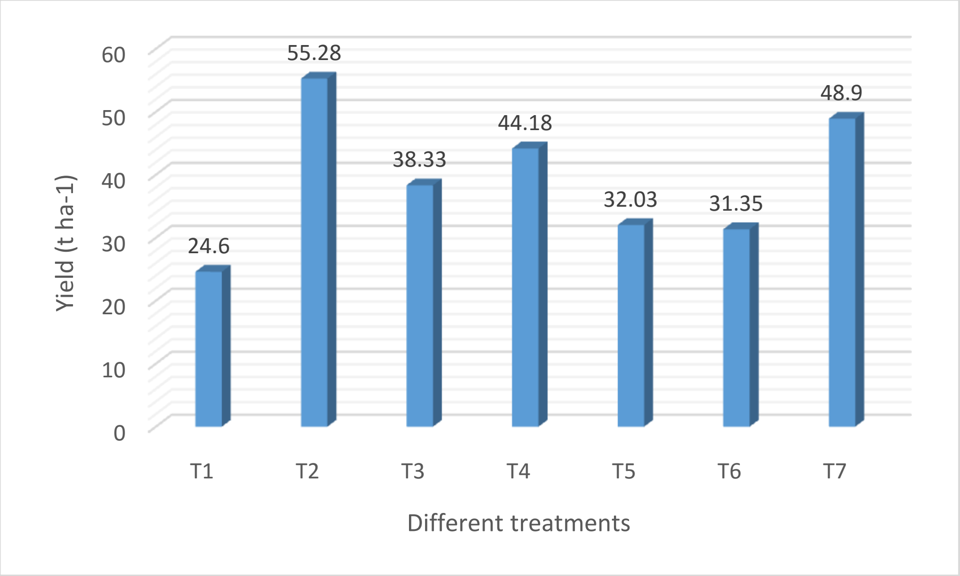

Figure 4.5 Effect of different treatments on yield of tomato

T_1= Untreated control, T_2= Neem oil suspension spray, T_3= Garlic oil, T_4= Black seed oil, T_5= Marigold intercropping, T_6= Netting at seedling stage, T_7=Tobacco leaf powder extract spray.

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from Novemver 2018 to April, 2019 to evaluate the ecofriendly pest management of tomato (BARI Tomato-14). The experiment consisted of seven different ecofriendly treatment and was laid out in Randomized Complete Block Design (RCBD) with three replications. The seven treatments were T_1= Untreated control, T_2= Neem oil suspension spray, T_3= Garlic oil, T_4= Black seed oil, T_5= Marigold intercropping, T_6= Netting at seedling stage, T_7=Tobacco leaf powder extract spray. Data on number of white fly, aphid, fruit borer and leaf miner per plant and their control percentage were at vegetative, flowering and reproductive stage were recorded. Number of fresh fruit, weight of individual fruit, weight of fruit per plant, weight of fruit per plot and yield of tomato were also collected. The data were statistically analyzed by MSTAT-C and means were separated by Duncan's Multiple Range Test (DMRT) test at 5% levels of probability.

Four insect pest were found in tomato cultivation white fly, aphid, fruit fly and leaf miner. At the vegetative, flowering and reproductive stage, there was a significant difference observed on number of whitefly plant^{-1} due to different treatments. The lowest number of white fly per plant (3.13, 3.01 and 2.49) and the highest control percentage of white fly (15.33, 89.31 and 89.31) were observed in treatment T_2 (Neem oil suspension spray) at three stage respectively.

The lowest number of aphid per plant were observed (1.20, 1.20 and 1.01) and the highest control percentage of aphid per plant (94.23, 94.41 and 94.98) was found from treatment T_2 (Neem oil suspension spray) at vegetative, flowering and reproductive stage.

At the vegetative, flowering and reproductive stage, the lowest number of fruit borer per plant were observed (1.02, 1.61 and 0.90) and the highest control percentage of fruit borer per plant (90.04, 90.65 and 91.59) was observed from treatment T_2 (Neem oil suspension spray).

The lowest number of leaf minerper plant were observed (0.69, 0.60 and 0.65) in treatment T_2 (Neem oil suspension spray) and the highest control percentage of leaf minerper plant (93.52, 87.27 and 84.69) was found from treatment T_2 (Neem oil suspension spray).

Nnumber of fruit plant-1, Individual fruit weight, Fruit weight plant-1, Fruit weight plot-1 and yieldof tomato varied significantly due to different treatment and the highest value were (30.18, 81.59 g, 2.46 kg, 22.11 kg 55.28 t ha^{-1}) was obtained from T_2 (Neem oil suspension spray) and the lowest were obtained from T_1 (Untreated control) treatment.

Conclusion

In a nutshell it can be concluded that

i) Treatment T_2 (Neem oil suspension spray) was suitable for among all the treatment used in this study controlling white fly, aphid, fruit borer and leaf miner per plant.

ii) Treatment T_2 (Neem oil suspension spray)gave better growth, yield contributing characters and yield of tomato than rest other treatments.

Recommendation

Due to some limitations only 7 treatment were included in this experiment. Further research should be conducted by taking more treatments for better production and better pest management of tomato.

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Appendix

Appendix I: Soil characteristics of experimental farm of Sher-e-Bangla Agricultural University are analyzed by soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Farm, SAU, Dhaka
AEZ	Modhupur tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	**N/A**

B. Physical and chemical properties of the initial soil

B. Physical and chemical properties of the initial soil **Characteristics**	**Value**
Practical size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
pH	5.56
Organic matter (%)	1.00
Total N (%)	0.06
Available P (μ gm/g soil)	42.64
Available K (me/100 g soil)	0.13

Source: SRDI

Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from October 2018 to March 2019

Month	Air temperature (^0C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
November,18	21.15	13.72	56	4
December,18	20.13	14.47	54	0
January,19	17.45	11.44	43	0
February,19	27.34	16.71	67	3
March,19	31.43	19.63	54	12
April, 19	36.44	22.51	63	18

Source: Bangladesh Metrological Department