# MANAGEMENT OF MAJOR INSECT PESTS OF MAIZE IN RABI SEASON

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# MANAGEMENT OF MAJOR INSECT PESTS OF MAIZE IN RABI SEASON

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## CERTIFICATE

This is to certify that the thesis entitled, '**Management of Major Insect Pests of Maize in Rabi Season'** submitted to the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment 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 **Md. Noyon Ali,** Registration number: 19-10128 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: JUNE, 2021
Dhaka, Bangladesh


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Dedicated

To

My Beloved Parents

# ABBREVIATIONS

| Elaborated Form | | Abbreviated Form |
|---|---|---|
| And others (Co-workers) | = | *et al.* |
| Gram | = | G |
| Coefficient of Variation | = | CV |
| Degree centigrade | = | $^oC$ |
| Example | = | viz. |
| Least significant difference | = | LSD |
| Million tons | = | Mt |
| Non-significant | = | NS |
| Per Hectare | = | $ha^{-1}$ |
| Percentage | = | % |
| Nitrogen | = | N |
| Phosphorus | = | P |
| Potassium | = | K |
| Randomized Complete Block Design | = | RCBD |
| Standard Week | = | SW |
| Sher-e-Bangla Agricultural University | = | SAU |
| Standard Error | = | SE |
| that is | = | i.e. |
| Tons | = | T |

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**The Author**

**JUNE, 2021**

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# MANAGEMENT OF MAJOR INSECT PESTS OF MAIZE IN RABI SEASON

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## ABSTRACT

The study was conducted in the research field of Sher-e-Bangla Agricultural University, Dhaka in order to study the major insect pests of maize and their management. There were seven treatments and three replications used in a randomized complete block design (RCBD). The treatments were $T_1$ (Success @ 0.5 ml/L of water at 7 days interval); $T_2$ (Matrine @ 1 ml/L of water at 7 days interval); $T_3$ (Virtaco @ 0.2 g/L of water at 7 days interval); $T_4$ (Neem oil @ 5 ml/L of water with detergent at 7 days interval); $T_5$ (Emamectin Benzoate @ 1 ml/L of water at 7 days interval); $T_6$ (Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water at 7 days interval); and $T_7$ (untreated control). Treatment $T_6$ showed the lowest fall armyworm infestation 0.11 larvae per plot during 3 days after spray, 0.17 larvae per plot during 7 days after spray. Similarly, Treatment $T_6$ showed the lowest aphid infestation 14.54 aphids per piot during 3 days after spray, 9.06 aphids per plot during 7 days after spray. Lowest plant infestation (1.91% per plot) of stem borer was obatained from treatment $T_6$. in case of % dead heart, Fortenza+Sunfezin showed the lowest infestation i.e. 1.60%. The lowest number of insects was observed in treatment $T_6$ and produced the maximum yield. Seed treatment with Fortenza+Sunfezin was the most effective insecticide against pest complex of maize.

# CHAPTER I

# INTRUDUCTION

Maize (*Zea mays L.)*, called 'corn' in some regions of the world including North America, is a grass of tropical origin that has become the major grain crop in the world in terms of total production, with recent worldwide production of around 1000 million tons per year. Most of the maize grain produced is used as animal feed, but in some less-developed regions, maize is a staple food. The amazing ability of maize to be genetically adapted to a wide range of conditions and to produce very large yields of grain rich in starch and with some protein and fat has led to its success as a world crop (Rizzo *et al*. 2021).

Maize is the second most important cereal crop in Bangladesh after rice. Maize was initially grown on a small scale by a few tribal communities as a rainfed food crop in Bangladesh. During the 1990s and 2000s it expanded greatly as a high input and very high yield cash crop grown during the winter Rabi season, mainly to provide poultry feed and fish feed. In Bangladesh, maize is grown mainly during the winter (Rabi) season. Most of the available research, extension advice and farmer experience relates to maize produced during that season. However, the cultivation of maize in the summer (Kharif- I) season, commonly after potato, tobacco or mustard, is gaining popularity.

Maize is a good source of food and fodder, and also used in manufacturing corn oil, corn flakes, corn syrup etc. It could be a good source of protein, carbohydrate and lipids for the malnourished population (Alam *et al.* 2019). Corn oil, valued for its bland flavour and light colour, is used primarily for food.  It is favoured as a salad oil and frying oil because it contains little cholesterol. Corn oil can be converted into margarine by hydrogenation, a process in which the oil is combined with hydrogen at high temperature and pressure in the presence of a catalyst.

Every year huge amount of maize is utilized in Bangladesh of which only 42% is produced by the country and remaining imported from other country (BBS 2016).

Several factors are responsible for hindering the production of maize in Bangladesh. Among them insect pests are major production limiting factor. Among the major insect pests infesting maize in Bangladesh Fall armyworm *Spodoptera frugiperda*, Corn Aphid *Ropalosiphum maidis*, Stem borer *Chilo partellus* are notable ones. The fall armyworm (FAW) (*Spodoptera frugiperda*) is one of the devastating insect pest belonging to the family Noctuidae and falls in the Lepidoptera order. It is a polyphagous pest (Baudron *et al*. 2019) causing damage to economically important cultivated cereal crops such as maize, rice, sorghum, cotton and various vegetable crops and eventually impacts on food security. The FAW feeds on leaves, stem and reproductive parts of plant species (Tefera *et al*. 2019). It is native to tropical and subtropical regions of the America.

*Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae), the spotted stem borer, is possibly the most serious pest of maize and sorghum in eastern and southern Africa (Silva *et al.* 2015) and a serious pest of maize and sorghum in Asia. It has also been noted to be a pest of sugarcane (Assefa *et al*. 2018), rice (Harris 1990) and pearl millet (Harris 1990). The species originates from Asia (Harris 1990), though its known distribution there appears poorly understood, with relatively few point location records available.

Corn aphids can invade crops at any time between the seedling stage and grain fill. Early infestations can cause reduced tillering, stunting and early leaf senescence. Later infestations on leaf sheaths and flag leaves between booting and the milky dough stages can also result in yield losses. In some cases, aphid colonies infest the seed heads and congregate in large numbers. After grain fill, aphid feeding has minimum or no impact on yield. Secretion of honeydew can cause secondary fungal growth, which inhibits photosynthesis and can decrease plant growth. Corn aphids cause indirect damage by spreading plant viruses. Aphids spread viruses between plants by feeding and probing when they move between plants and paddocks. The ability to transmit particular viruses differs with each aphid species and viruses may be transmitted in a persistent or non-persistent manner. This influences the likelihood of plant infection.

There are various methods for controlling these insect pests including physical, chemical, cultural, and biological methods. However, Chemical pesticides are being used enormously despite their adverse effects (Jasmine *et al*. 2008). Farmers are using chemical pesticides in the higher rate and in a haphazard way for the management of the insect pests without considering about pesticide residue, pest resistance, the resurgence of pest, destruction of beneficial insects and environmental pollution, detrimental effects on the fertility of the soil and human health (Abang *et al.* 2013). Also, the old and traditional insecticides have become ineffective for the management of major insect pests of maize and are unfit for sustainable maize production, thus substitution of the hazardous chemical pesticide must be done.

Keeping above-mentioned information in view, the present study was undertaken to achieve the following objectives-

i. To investigate the efficacy of some promising novel insecticides against major insect pests of maize.
ii. To determine the yield and yield attributes of maize influenced by different chemical treatments.

# CHAPTER II

# REVIEW OF LITURATURE

## 2.1. Maize, *Zea mays*

Corn, (*Zea mays*), also called Indian corn or maize, is a cereal plant of the grass family (Poaceae) and its edible grain. The domesticated crop originated in the America and is one of the most widely distributed of the world's food crops. Corn is used as livestock feed, as human food, as biofuel, and as raw material in industry.

### 2.1.1. Domestication and history

Corn was first domesticated by native peoples in southern Mexico about 10,000 years ago. Modern corn is believed to have been derived from the Balsas teosinte (*Zea mays parviglumis*), a wild grass. Its culture had spread as far north as southern Maine by the time of European settlement of North America, and Native Americans taught European colonists to grow the indigenous grains. Since its introduction into Europe by Christopher Columbus and other explorers and colonizers, corn has spread to all areas of the world suitable to its cultivation. It is grown from 58° N latitude in Canada and Russia to 40° S latitude in South America, with a corn crop maturing somewhere in the world nearly every month of the year. It is the most important crop in the United States and is a staple food in many places.

### 2.1.2. Physical description

The corn plant is a tall annual grass with a stout, erect, solid stem. The large narrow leaves have wavy margins and are spaced alternately on opposite sides of the stem. Staminate (male) flowers are borne on the tassel terminating the main axis of the stem. The pistillate (female) inflorescences, which mature to become the edible ears, are spikes with a thickened axis, bearing paired spikelets in longitudinal rows.each row of paired spikelets normally produces two rows of grain. Varieties of yellow and white corn are the most popular as food, though there are varieties with red, blue, pink, and black kernels, often banded, spotted, or striped. Each ear is enclosed by modified leaves called shucks or husks.

#### 2.1.3. Health benefits of maize

Corn is the third largest plant-based food source in the world. Despite its importance as a major food in many parts of the world, corn is inferior to other cereals in nutritional value. Its protein is of poor quality, and it is deficient in niacin. Diets in which it predominates often result in pellagra (niacin-deficiency disease). Corn is high in dietary fibre and rich in antioxidants. Unlike many other cereal grains, corn flour is gluten-free and cannot be used alone to make rising breads. It is widely used, however, in Latin American cuisine to make masa, a kind of dough used in such staple foods as tortillas, arepas, and tamales. In the United States and many other places, sweet corn is boiled or roasted on the cob, creamed, converted into hominy (hulled kernels) or meal, and cooked in corn puddings, mush, polenta, griddle cakes, cornbread, and scrapple. It is also used for popcorn, confections, and various manufactured breakfast cereal preparations. Corn oil, valued for its bland flavour and light colour, is used primarily for food. It is favoured as a salad oil and frying oil because it contains little cholesterol. Corn oil can be converted into margarine by hydrogenation, a process in which the oil is combined with hydrogen at high temperature and pressure in the presence of a catalyst. Corn is also fermented into a number of alcoholic beverages, notably bourbon and other corn whiskeys.

### 2.2. Major insect pests of Maize

#### 2.2.1. Fall armyworm, *Spodoptera frugiperda*

The fall armyworm (FAW) (*Spodoptera frugiperda*) is one of the devastating insect pest belonging to the family Noctuidae and falls in the Lepidoptera order. It is a polyphagous pest (Baudron *et al.* 2019) causing damage to economically important cultivated cereal crops such as maize, rice, sorghum, cotton and various vegetable crops and eventually impacts on food security. The FAW feeds on leaves, stem and reproductive parts of plant species (Tefera *et al.* 2019). It is native to tropical and subtropical regions of the America. FAW, which was first found in America, is one of the common pests of maize in South and North America. In Africa, it was first reported in 2016 (Sisay *et al.* 2018) and has become one of the major invasive pests reaching over 30 countries across tropical and southern Africa including Madagascar, Seychelles and Cabo Verde at the end of 2017 which later reached over 44 countries (Sisay *et al.* 2019). There are 353 plants reported as a host for this pest (Kansiime *et al.* 2019).

#### 2.2.1.2. Taxonomy of the insect

Two strains of fall armyworm such as rice strain and corn strain are found (Nagoshi *et al.* 2007). Rice strain feeds on rice and other pasture grasses whereas the corn strain feeds on maize, cotton and sorghum (CABI 2020). These strains are morphologically similar but can be differentiated at the molecular level. The fall armyworm invaded in Africa has a greater diversity than that found in America which contains both the strains (CABI 2020, Jacobs *et al.* 2018).Detail classification of fall armyworm (*S. frugiperda*)

| | |
|---|---|
| Domain: | Eukaryota |
| Kingdom: | Metazoa |
| Phylum: | Arthropoda |
| Subphylum: | Uniramia |
| Class: | Insecta |
| Order: | Lepidoptera |
| Family: | Noctuidae |
| Genus: | *Spodoptera* |
| Species: | *S. frugiperda* |

#### 2.2.1.3. Distribution of the insect

An adult fall armyworm does have a capacity to fly over longer distances. The distance covered by one generation is estimated 300 miles. This fast migration rate may be due to the movement of air in weather fronts (Sparks 1979). Fall armyworm is the major insect pests of tropical regions of the Americas and a native to tropical and subtropical regions of the Americas. In late 2016, it was reported for the first time in West Africa and rapidly spread throughout Sub- Saharan Africa (SSA) and later confirmed in forty four African countries (Sisay *et al.* 2019). The report suggests that the entry of both the strains of FAW from Americas to Africa was through commercial aircrafts, cargo containers or aeroplane holds and which later spread through the dispersal of wind. Fall armyworm has been reported in many Asian countries. In Indian continent, it was first reported in 2018 in Karnataka. Later, it spread in different places like Bihar, Chhattisgarh, Gujrat, Maharashtra, Odisha, West Bengal etc (CABI 2020). The insect pest has existed in Asian countries like China, Japan, Bangladesh, Cambodia, Indonesia, Myanmar, Korea, Thailand, Srilanka and Vietnam (FAO 2019). Fall armyworm is yet to be recorded in some continent but the threat of its spreading is very high in a short time. In Nepal, it was first recorded in Nawalparasi district on 9th May 2019 (Bhusal and Bhattarai 2019) and declaration of the invasion of FAW was made in the 19th meeting of Nepal Plant Protection Organization (NPPO) of Nepal (GoN 2019). This pest has now been observed in fifteen districts of Nepal (Bajracharya and Bhatt 2019).

#### 2.2.1.4. Economic importance of FAW

The larval stage of the fall armyworm is the most devastating in nature and detrimental to crops. In infected maize plants, the larvae of FAW can be observed on the different plant parts viz., young leaves, leaf whorls, tassels and cob depending on the growth stages of the plant (Goergen *et al.* 2016). To determine the loss due to FAW, many variables needs to be considered. In general, crop infestation due to the pest depends on the number of pest, time of infestation, natural enemies and pathogens of the pest available at that time and health (nutritional and moisture) status of the plant. Baudron *et al.* (2019) reported that when there is 26.4% to 55.9 % of pest incidence in maize then there is yield reduction of 11.57%. Chimweta *et al.* (2019) revealed that the 25-50% damage of leaf, silk and tassel results in 58% of yield reduction while 55-100 % of severity at the period of mid to late whorl stage caused up to 73% of yield loss (CABI 2020). Kumela (2019) reported 12.5 to 30% loss in country's economy in Malawi.

There was a yield loss of 3.2 million tonnes in Tanzania, 13.91 million tonnes in Uganda and 30.54 million tons in Ethopia during the reporting period of maize (Kiprop 2017). In Kenya, FAW affected 250,000 ha of agricultural land that accounts 11 percent of the country's total maize cultivated area (Kiprop 2017). Similarly, production loss of maize estimated by FAW in Ghana and Zambia were 45% and 40%, respectively. In Africa, losses from FAW in twelve countries including Ghana and Zambia were estimated at 8.5 to 21 million tonnes worth about 250- 630 million US dollars if no control measures were applied.

A total of 170,000 ha of maize crops was estimated to be affected by FAW in India spreading in 10 states of the country (Sangomla and Kukreti 2019). In China, Yunnan province is mostly affected area by this pest where 80,000 hectare of land has been found to be affected by this pest damaging the crops like maize, sorghum, sugarcane and ginger crops (Gu and Woo 2019). The total area of 11,1992.17 ha has been affected in China and 98.6 % of the total area is covered with maize (FAO 2019). Likewise, more than 10,000 ha of maize was affected in four provinces of Cambodia (Cambodia News 2019). FAW was detected in 8 regions, 22 districts and 71 administrative regions with the infestation rate of 0.5 to 32 % in Bangladesh. Similarly, almost 10,000 ha of land in Indonesia, 16,200 ha of land in Myanmar and 46,000 ha of land in Vietnam was reported to be infested by this worm. In Thailand, yield loss predicted by FAW was reported to be 25 to 40% that results in 130 million to 260 million dollar loss (FAO, 2019). Beshir *et al*. (2019) reported that the deadly pest having voracious appetite for the crops like maize and others can hugely affect the Nepalese farmers and economy. Since Nepalese climatic condition is suitable for the establishment of the populations of this pest, the potential crop loss up to 100 % is predicted in maize if this pest is not managed properly.

#### 2.2.1.5. Favorable environment for the pest

Fall armyworm is affected by the climatic factors and changes in the climate may affect its distribution in various geographical regions. It has been reported that growth, abundance, survival, mortality, number of generations and other characteristics of the pest population are highly affected by environmental condition (Ramirez-cabral *et al.* 2017).The pest overwintering mechanism governs the greater invasion of FAW. It thrives in cool, wet weather and severe outbreaks after heavy rainfall and humid weather (Westbrook and Sparks 1986). A warm and humid growing season with heavy rainfall is favorable for the survival and reproduction of the pest. The development of the pests ceases below the temperature of $10^0$ C (Assefa and Ayalew 2019). For the efficient reproduction, tropical and subtropical areas are favored where more than ten generations of the fall armyworm per year are reported compared to just two generations in temperate areas (Assefa and Ayalew 2019). A warm temperature accelerates the development of insects with probability of increasing the multiple generations of fall armyworm (Westbrook and Sparks 1986).

The varied temperatures at the different stages are required to complete the life cycle of fall armyworm. The minimum threshold temperature required is $10.9^0$

C with sandy clay or clay sand soils which is suitable for pupation and adult emergence (CABI 2020). Eggs hatch within two to four days at temperatures of 21-27° C (Assefa and Ayalew 2019). The optimum temperature required for the development of larvae is $28^0$ C whereas pupation requires a bit lower temperature than for larval development with threshold temperature of $14.6^0$ C. The wings of the pest are deformed at temperature above $30^0$ C (CABI 2020).

#### 2.2.1.6. Symptoms of pest damage in maize

Symptoms of FAW infestation in maize starts after the eggs are hatched. The typical symptoms caused by FAW are the papery windows of variable sizes and ragged edges with oblong to round appearance on the leaves leading to become loose and detach from the plants. At the severe stage, extensive defoliation can be observed with the excessive faecal material left over on the plant due to voracious feeding nature of larval instars. Eventually, growth and development of crops are stopped that results in no cob or tassel formation (Reddy 2019). The windows pane of translucent patches are observed at 1st and 2nd instar infestation while larger elongated holes are visible at 3rd to 6th instars. At the end, the faecal of the FAW looks as sawdust-like materials in the maize funnel or on the leaves.The leaf damage assessment of the crop can be done as follows as presented in the Table 2 (Sisay *et al.2019).*

#### 2.2.1.7. Life Cycle of the insect

The life cycle of the insect can be classified into four stages. The fall armyworm can be identified either by using morphological characters or through characteristic injury symptoms on susceptible crops or molecular characterizations (FAO 2019).

**Egg**: The egg of fall armyworm is dome-shaped with a flattened base with 0.4 mm in diameter and 0.3 mm in length (Prasanna *et al.* 2018). Bajracharya and Bhat (2019) reported that eggs of the fall armyworm are creamy white in color with reticulate ribs covered with abdominal hairs. The female lays 100 to 200 eggs at a time in mass (Prasanna *et al.* 2018) on the upper, lower sides of the leaf, the stalk and the funnel of the maize plant.

**Larvae**: The newly hatched caterpillars at first and second instar are green in colour which turns into brown to black colour at the third to sixth instars (CABI 2018b). The mature larva has a white inverted "Y" shaped mark on the front and its epidermis is rough or granular in texture (Prasanna *et al.* 2018) with four dark raised spots in the form of square. The newly hatched larvae is observed to be burrowing in nature.

Capinera (2000) reported that the 1– 6 instar have head capsule with 0.35, 0.45, 0.75, 1.3, 2.0, and 2.6 mm wide, and body lengths are about 1.7, 3.5, 6.4, 10.0, 17.2, and 34.2 mm, respectively.

**Pupa**: Pupae are oval in shape, reddish brown in colour and form a cocoon of 20- 30 mm in length which are usually found at the depth of 2-8 cm in soil. According to Silva *et al.* (2017), pupae are usually 15 mm long and are found in the soil in cocoons (20–30 mm across).

**Adult**: The adults of FAW are nocturnal in behaviour. The adult moths vary in colour and wingspan (32 to 40 mm). The male moths have shaded grey and brown forewing with triangular white spots at the tip and near the centre of the wing (Assef and Ayalew 2019) which is absent in female moth. The moths are migratory in nature and can fly over long distance through travel (CABI 2020).

#### 2.2.1.8. Management of Fall Armyworm

The detection of fall armyworm is utmost important before the pets causes economic damage. Figueroa (2002) reported that it is recommended to use the control measures in the maize, only when the 5% of seedlings are cut or 20% of whorls of small plants (during the first 30 days) are infested with fall armyworm. Assefa and Ayalew (2019) revealed that larval stage of fall armyworm is the effective time for the proper management of the pest with timing (morning, afternoon or evening) when the management activity is done and is indispensable.

##### 2.2.1.8.1.Botanical Method

Different locally available resources and botanical methods are used to control fall armyworm in the world through local botanical extract, soil, sand, wood ash, lime, oils and soaps (Hruska 1997). Sparks *et al.* (1979) reported that plant oils obtained from *Corymbia citriodora*, *Eucalyptus urograndis* and *Eucalyptus urograndis* had positive effects for protecting maize plants from FAW larvae. The neem seed powder has been reported to be effective in killing over 70% of larvae of FAW in the laboratory. A significant mortality of larvae of FAW has been reported from the use of aqueous seed extract obtained from *Carica papaya* which is similar to the mortality caused by Malathion (Figueroa-Brito *et al.* 2002). Similarly, the plant oils obtained from the turmeric, clove, palmarosa and neem have significant effects in controlling first and second instar of FAW larvae (Barbosa *et al.(*2018), Jirnmci (2013) and Schmutterer (1985) reported that various botanicals extracts obtained from plants such as *Azadirachta indica*, *Millettia ferruginea*, *Croton macrostachyus*, *Phytolacca docendra*, *Jatropha curcas*, *Nicotiana tabacum* and *Chrysanthemum cinerariifolium* have been successfully used to control the FAW. The seed cake extract of *Azadirachta indica* (Silva *et al.* 2015) and ethanolic extracts of *Argemone ochroleuca* (Martinez *et al.* 2017) cause high mortality of FAW larva due to reduction of food intake by larvae resulting slower growth. As the botanical pesticides have lesser effect on the non-target organisms and have an ability to add in growth promotion some of the pesticidal plants, they are found effective with reduce in use of synthetic insecticides (Rioba *et al.* 2020, Mkindi *et al.* 2020, Abudulai *et al.* 2001). *Ageratum conyzoides* (Rioba and Stevenson 2017, Lima *et al.* 2010), *Chenopodium ambrosioides* has been evaluated for their efficacy against fall armyworm (Rioba *et al.* 2020, Sisay *et al.* 2019). *Cymbopogon citratus*, *Malva sylvestris*, *Ruta graveolens*, *Petiveria alliacea, Zingiber officinale, Bacharis genistelloides, Artemisia verlotiorum (*Tagliari *et at.* 2010), extracts of castor plant, *Carica papaya* (Figueoroa *et al.* 2002) and *Moringa* (Rioba *et al.* 2020) has been reported to have insecticidal properties against fall armyworm. The larval mortality was found highest 66 % from both *Nicotiana tobacum* and *Lippia javanica* in contact toxicity test and in a feeding bioassay *L. javanica* and *N. tabacum* reported the highest larval mortality of 62 % and 60 percent respectively at the concentration of 10 % w/v. At the same time while evaluating the feeding differences, *Cymbopogon citratus* and *Azadirachta indica* were found to be the most potential feeding deterrents with 36 % and 20 % respectively (Phambala *et al.* 2020).

#### 2.2.1.8.2. Chemical Method

The appropriate time for the chemical application is utmost important for the management of the fall armyworm. An individual should have knowledge on the life cycle and timing when to apply the pesticide i.e. there is no effectiveness in spraying when the larvae are deeply embedded inside the whorls and ears of maize and in the day time because larvae only come out to feed on plants during night dawn or dusk (Day *et al.* 2017). Various chemicals have been recommended to control the fall armyworm. The insecticides of different groups such as Methomyl, pyrethroids, Cyfluthrin and organophosphate insecticide, methyl parathion can be used for the control of fall armyworm (Tumma and Chandrika 2018). The seed treatment with chlorantraniliprole and cyantraniliprole was found to be effective and reduced the need for foliar sprays against fall armyworm in soya (Thrash *et al.* 2013). Van Huis (1981) reported that when chlorpyrifos was mixed with the saw dust and used as a treatment, 20% control of the fall armyworm was found. Chemicals like chlorpyrifos, carbosulfan, emamectin benzoate, cartap hydrochloride and beta cypermethrin have been widely used for the control of the fall armyworm in Africa. Among them, emamectin benzoate, cartap hydrochloride and beta cypermethrin are also recommended to use for vegetables (IRAC South Africa 2018). Cruz *et al.* (2012) and Bhusal & Bhattarai (2019) reported that over 90% of larval mortality through the use of Spinosad and new insecticide Chlorantraniliprole, flubendiamide, and spinetoram was found to perform better than traditional insecticide lambda-cyhalothrin and novaluron (Hardke *et al.* 2015).

### 2.2.2.Maize stem borer, *Chilo partellus*

*Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae), the spotted stem borer, is possibly the most serious pest of maize and sorghum in eastern and southern Africa (e.g. Sylvain *et al. 2015,* Getu *et al.* 2001, Guofa *et al.* 2001, Bate *et al.* 1991, Van den Berg *et al.* 1991 and Harris 1990) and a serious pest of maize and sorghum in Asia (Ahad *et al.* 2008, Ashfaq and Farooq-Ahmad 2002, Harris 1990, Dang and Doharey 1971, Carl 1962). It has also been noted to be a pest of sugarcane (Assefa *et al.* 2010, Harris 1990, Carl 1962), rice (Harris 1990) and pearl millet (Harris 1990). The species originates from Asia (Harris 1990, Kfir 1988), though its known distribution there appears poorly understood, with relatively few point location records available. Its distribution in Asia now includes Afghanistan, Bangladesh, Cambodia, India, Indonesia, Iran, Laos, Nepal, Pakistan, Sri Lanka, Thailand, Vietnam and Yemen (Harris 1990, Rajabalee 1990, CABI Invasive Species Compendium datasheet 12859). In Africa, *C. partellus* was first reported in Malawi in 1930 (Tams 1932).

#### 2.2.2.1. Distribution of *Chilo partellus*

Based on the work of Du Plessis and Lea (1943), it was known that more than one generation of moths occurred every season and that early infestations of a given season were derived from late infestations of the preceding season. In 1973/74 the Highveld Region of the department of Agriculture initiated a project at Potchef stroom in which maize was planted at fortnightly intervals starting in mid-September of each year for a total of 16 plantings per season for each of three seasons. Each planting was regularly sampled and the occurrence of each developmental stage of the insect, numbers of individuals and position in the plant were recorded. It was also realised that infestation patterns might vary with locality in view of the rainfall and temperature gradient that exists from East to West in the greater production area. In order to address this, light traps were operated for three years (1973/74 to 1975/76) at Bethal, Vereeniging, Delareyville and Bethlehem and for 12 years (1973/74 to 1984/85) at Potchefstroom. Daily moth captures were kept separately by collaborators and stem borer moth numbers were recorded. Results from these studies had immediate application in practice. Results revealed that there were three seasonal moth flights which varied geographically in both magnitude and duration from East to West (Van Rensburg *et al.* 1985), that moths gave preference to plants four weeks after emergence for oviposition (Van Rensburg *et al.* 1987a; Van Rensburg *et al.* 1989), and that moth numbers vary according to rainfall patterns (Van Rensburg *et al.* 1987b). These results explained the variance in infestation patterns with planting date, between localities and seasons and served to advance the efficacy of chemical control measures. The ecological study also provided information on levels of natural larval mortality, the importance of the braconid wasp Cotesia sesamiae

(Cameron) as principle natural enemy (Van Rensburg *et al.* 1988a) the comparative abundance of the spotted stem borer, Chilo partellus (Swinhoe) (Van Rensburg *et al.* 1988e) and on alternative hosts of B. fusca (Van Rensburg & Van den Berg 1990). Knowledge of moth activity on individual farms would contribute to improved chemical control, but it was not possible to deploy light traps commercially since the use of light traps require specialised knowledge to distinguish stem borer moths from those of other nocturnal species. In an attempt to assist producers in identifying potentially hazardous on-farm flight levels, a pheromone trapping system was developed (Revington *et al.* 1984). The system was, however, shown to be unreliable during periods of pronounced moth activity due to poor competition of the synthetic pheromone with the natural product (Van Rensburg 1992).

#### 2.2.2.2. Extent of damage caused by *Chilo partellus*

In order to determine an economic threshold level for chemical control it was necessary to establish the relationship between infestation levels and yield loss, which necessitated the development of an artificial infestation method of plants. In field trials conducted over several years it was established that the above relationship was not linear due to intra-specific competition among larvae (Van Rensburg *et al.* 1988b). Furthermore, stem borer injuriousness was not only dependent on infestation levels but also on plant developmental stage at the time of infestation (Van Rensburg *et al.* 1988b), the plant parts affected (Van Rensburg *et al.* 1988c) and plant population and cultivar effects (Van Rensburg *et al.* 1988d). It was shown that plants could tolerate considerable leaf feeding damage without grain yield being affected. It was damage to a single internode would have a significant effect on yield, that severe ear damage was invariably caused by late infestations, that larval dispersal and survival were enhanced by increased plant populations and that longer growing season hybrids suffered more severe yield losses under similar infestation conditions than those of shorter duration.

An economic threshold level of 10% plants with visible damage was introduced to the industry (Van Rensburg *et al.* 1988b), despite the realization that the economics of chemical control would, to a large extent, depend as much on choice of insecticide and cultivar as on levels and times of infestation. The threshold was a compromise, but tests conducted at various localities showed that it enhanced the correct timing of insecticide applications (Van Rensburg 1990) and in years to follow it undoubtedly served to avoid many unjustified insecticide applications. During the 1980s the insecticide market for stem borer control (including both maize and grain sorghum) was estimated to be about R30 million, but in practice amounted to between R12 and R16 million, at least to some extent due to the use of the threshold. A later effort was made to base the threshold on the number of egg batches recorded on plants between three and five weeks after emergence, since the egg-laying pattern in relation to plant age remained constant in different plantings. A sequential sampling method for egg surveys (based on the negative binomial distribution) was developed in which the number of samples to be taken was determined by the intensity of infestation (Van Rensburg & Pringle 1989). The method saved time and effort required for sampling while allowing for more timely application of insecticides. The method, however, met with limited practical application. A considerable research effort on both B. fusca and *C. partellus* in grain sorghum (not related here), which in part also contributed to improved stem borer control in maize (Van den Berg and Van Rensburg 1996, Bate and Van Rensburg 1992, Van Rensburg and Van den Berg 1992a, 1992b; Van Rensburg *et al.* 1991, Van den Berg and Van Rensburg 1991). Research on habitat management through the use of trap crops and repellent plants contributed to stem borer control in small farming systems (Van den Berg *et al.* 2001). Investigations were also made by the ARC-Plant Protection Research Institute into the diversity of the local parasitoid complex. This was aimed at improved biological control, but none of the indigenous parasitoids was able to keep infestations below economic injury levels.

#### 2.2.2.3. Biology of *Chilo partellus*

A good knowledge on the biology of *Chilo partellus* is a prerequisite for understanding how this species interacts with plants. Most of the information produced for *Chilo partellus* during the last century, which forms the basis of the knowledge of the biology and ecology of this pest, stemmed from South Africa However, since the majority of the studies in South Africa addressed *Chilo partellus* at high altitudes and in commercial farming systems, some aspects regarding its biology and interactions with the environment may differ from those in other agroecological zones. Furthermore, most of the following information on *Chilo partellus* biology and reproduction was obtained on maize plants.

The female lays many eggs in batches of 30-50, inserted between the sheath and the stem. Incubation lasts about 1 week. After hatching, the larvae feed on the young blades of the leaf whorl and then, suspended from silk strands, spread to neighboring plants. They penetrate the stems by boring through the whorl base.

Generally, they destroy the growing points and tunnel downward. After passing through six to eight stages (30-45 days), they chew an outlet for the adult and pupate in the tunnel. Pupation lasts 10-20 days. Up to four generations are produced per year. At the end of the rainy season, larvae of the last generation enter diapause in maize and sorghum stubble or in wild grasses. They pupate a few months later, just before the start of the following rainy season. In the mid and high elevation an area of eastern and southern Africa, *Chilo partellus* is often the most important stem borer of maize. Yield losses have been estimated to be about 12% for every 10% of plants infested (Harris and Nwanze 1992). In Sub-Saharan African countries, which include Ghana, *Chilo partellus* is considered the most important pest of maize, yield loss as high as 40% has been attributed to *Chilo partellus* infestations (www.maizedoctor.com 2010). In Zaire for instance, *B. fusca* occasionally caused yield losses of 8-9% in early-planted maize, and 22-25% in lateplanted maize. In Cameroon, Cardwell *et al.* (1997) reported grain loss at 4.6g per borer in lowland fields and 8.7g per borer in highland fields.

**Eggs**

*Chilo partellus* females oviposit a highly variable number (from 100 up to 800) of round and flattened eggs in batches. The batches are laid behind the vertical edges of leaf sheaths of pre-tasseling plants and also, but rarely, underneath the outer husk leaves of ears. Van Rensburg and colleagues recorded eggs on 12- to 16- week old plants, but only when these were planted very late in the season. It appears that the position at which the eggs are found correlates with the developmental stage of the plant, and with the increasing plant age, egg batches are increasingly found higher up on the plant. Van Ransburg and colleagues noted that leaf sheaths fitted more loosely around stems as plants get older, and that females preferred the sheaths of youngest unfolded leaves for oviposition. Although it is rare to find more than one *Chilo partellus* egg batch per plant, van Rensburg and colleagues reported cases of between 2 to 4 egg batches per plant (Felix 2008). They however attributed this to extremely high population pressure at late planting dates.

**Larvae**

Larvae hatch after about one week and they migrate first to the whorl where they feed on young and tender leaves deep inside the whorl. In contrast to stem borer species from the *Sesamia* and *Chilo* genera, young *Chilo partellus* larvae do not consume any leaf tissue outside of the whorls of plants. Larvae can remain in the whorls of especially older plants (6–8 weeks old) up to the 4th instars (Kruger 2012). From the 3rd instar onwards, larvae migrate to the lower parts of the plant where they penetrate into the stem. Some larvae do however migrate away from natal plants with approximately 4% of larvae leaving the natal plant immediately after hatching (Van Rensburg 1997).

The larval stage lasts between 31 and 50 days and consists of 7–8 instars with a minimum of 6. More recently, continuous observations of larvae on an artificial diet indicated that, under optimum environmental conditions (25 °C and 50%– 60% R.H.), thelarval stage consisted of 5 stages and was completed during approximately 35 days (Usua 19670). Additional instars were observed when the conditions were suboptimal or when larvae went into diapause. Although, it is well known that *Chilo partellus* undergoes a facultative diapause consisting mostly of a larval quiescence, several issues around this survival mechanism remain unclear. Although Okuda showed that water contact is a significant factor terminating diapauses.The mechanisms explaining diapause physiology in *Chilo partellus* have not been fully elucidated.

**Adults**

The mean sex ratio of *Chilo partellus* is 1:1.1 (male:female). The adults emerge about 13–14 days after pupation and they emerge mostly between sunset and midnight (Ratnadass 2001). Most males emerge before onset of the scoto phase, while most females do so one hour later. The average life span of moths ranges between 8 and 10 days.

#### 2.2.2.4. Management of *Chilo partellus*

Dressing maize seeds with carbosulfan (Marshal 35 ST) did not protect maize from the attack of maize stalk borer (Tsedeke and Elias 1998). Similar investigations carried on the protection ability of carbosulfan (Marshal) at different rates (0, 0.9, 1.8, and 2.7 kg/qt of maize) at eight locations indicated that the insecticide did not protect maize from stem borers, leafhoppers and aphids (EARO 1996/97). On the other hand, chemical screening of thirteen insecticides was carried out at Awassa and Areka. Compared with the untreated check, the lowest cob infestation at both locations was observed on Ethiosulfan 35%, Diazinon 60%, Ethiosulfan 5%, Thionex 25%, Actellic E.C., Decitab and Cypermethrin G sprayed plots. At Awassa, the highest yield (98.4 q/ha) was obtained from plots treated with Cypermethrin G (EARO 1998/99). Screening of insecticides conducted by the Crop Protection Division of the Awassa College of Agriculture showed effective control of B. fuscawith Carbaryl, Decis tablet, Cypermthrin G, Bulldock G, Chloropyrifos G, Diazinon G, Endosulfan EC, Endosulfan D, Lamdacyhloahterin Sachet (Ferdu Azerefegne and Yibrah Beyene).

A preliminary field test in 1993/94 showed that application of extracts of fruits of chinaberry (Melia azedarachL.), Endod (Phytolacca dodecandra L.) and pepper tree (Schinus molle L.) significantly reduced the levels of leaf infestation and dead heart injury due to larvae of the maize stalk borer, Busseola fusca (Fuller), and resulted in increases in crop yield (Assefa and Ferdu 1999). Extracts of both leaves and fruits of chinaberry (either fresh or dried) were effective in reducing the number of larvae (Table 3). All the rates (2, 10 and 20 kg/ha for fresh leaves; 1, 2 and 10kg/ha for dried leaves; 10, 20 and 30 kg/ha for fresh fruits, and 2, 10 and 20 kg/ha for dried leaves) used significantly reduced the number of larvae relative to the untreated controls. Fresh leaves and fruits of endod were also effective against *B. fusca*. Fruits of pepper tree were superior to leaves. Fresh leaves of this plant did not reduce the number of larvae. Two applications of any of the three botanicals were not sufficient to provide complete protection of maize against second generation larvae. This suggests that these botanicals have only brief persistence, and more than two applications of the extracts would be necessary to reduce pest numbers (Assefa and Ferdu 1999). Neem berries (*A. indica*), pyrethrum flowers (Chrysanthemum spp), garlic bulbs and abasoyo-hot pepper pods were tested against 2nd and 3rd instar of maize stalk borer larvae under laboratory conditions. Applications of extracts of neem berries (seed) and pyrethrum flowers at 8% concentration resulted in 90 and 100% mortality to I to II instar of *B.fusca* within three days, respectively (EARO 1998/99).

### 2.2.3.Corn leaf aphid, *Rhopalosiphum maidis* F

The first recorded observation of the corn leaf with maize as host dates back to Fitch (1856). Forbes (1893) identified this species has been different from the corn root aphid. The scientific name of the insect was recorded as *aphis maidis* F and remained for about hundred years. in 1975 one scientist stated that Webstar change the genus to *Rhopalosiphum* in 1887.The adult forms of the corn aphid can be found as a winged female (alate), wingless female (aptarae) and extremely rarely as a male. The wingless adult is oval, soft bodied, 2.5 mm long and usually pale bluish green with black antennae, legs and cornicles. Cornicles have a dark area around the base. The head is marked with two longitudinal dark bands and the abdomen with the row of black spots on each side. The nymphs are similar to the wingless adult but smaller and without wings. Males was only found under for culture conditions. In general they are smaller than the female although their size varies with the condition of their culture.

#### 2.2.3.1. Biology and life cycle of corn aphid

Aphids are a group of soft-bodied bugs commonly found in a wide range of crops and pastures. Identification of crop aphids is very important when making control decisions. Distinguishing between aphids can sometimes be challenging. It can be easier in the non-winged form but is more difficult with winged aphids.

Corn aphids are light green to dark green, with two darker patches at the base of each cornicle (siphuncle). Adults grow up to 2 mm long, have an oblong-shaped body and antennae that extend to about a third of the body length. The legs and antennae are typically darker in colour. Corn aphids can be found all year round, often persisting on a range of volunteer grasses and self-sown cereals during summer and early autumn. Winged aphids fly into crops from grass weeds, pasture grasses or other cereal crops, and colonies of aphids start to build up within the crop.

Aphids can reproduce both asexually and sexually, however, in Australia, the sexual phase is often lost. Aphids reproduce asexually whereby females give birth to live young. Temperatures during autumn and spring are optimal for aphid survival and reproduction. During these times, the aphid populations may undergo several generations. Populations peak in late winter and early spring; development rates are particularly favoured when daily maximum temperatures reach 20-25°C. Nymphs are similar to adults but smaller in size and always wingless, whereas adults may be winged or wingless.

Young wingless aphid nymphs develop through several growth stages, moulting at each stage into a larger individual. Plants can become sticky with honey-dew excreted by the aphids. When plants become unsuitable or overcrowding occurs, the population produces winged aphids (alates), which can migrate to other plants or crops.

**2.2.3.2. Nature of damage by corn aphid**

**2.2.3.2.1. Direct feeding damage**

Corn aphids can invade crops at any time between seedling stage and grain fill. Early infestations can cause reduced tillering, stunting and early leaf senescence. Later infestations on leaf sheaths and flag leaves between booting and the milky dough stages can also result in yield losses. In some cases, aphid colonies infest the seed heads and congregate in large numbers. After grain fill, aphid feeding has minimal or no impact on yield. Secretion of honeydew can cause secondary fungal growth, which inhibits photosynthesis and can decrease plant growth. Visual symptoms of corn aphid attack are often not obvious until close inspection of leaf whorls and sheaths, where dark-coloured masses of aphids may be seen.

#### 2.2.3.2.2. Indirect damage (virus transmission)

Corn aphids cause indirect damage by spreading plant viruses. Aphids spread viruses between plants by feeding and probing when they move between plants and paddocks. The ability to transmit particular viruses differs with each aphid species and viruses may be transmitted in a persistent or non-persistent manner. This influences the likelihood of plant infection.

Corn aphids can transmit viruses that contribute to yield losses in crops, including barley yellow dwarf virus (BYDV), cauliflower mosaic (CaMV) and turnip mosaic viruses (TuMV). These viruses are not seed-borne. CaMV and TuMV are non-persistent viruses being retained in the aphid mouthparts for less than 4 hours. BYDV infects wheat, barley, oats and grasses. BYDV is a persistent virus. Once an aphid acquires the virus after feeding from the phloem of an infected plant it will continue to transmit the virus to any plant it feeds on for its entire life.

Virus infections are more common in high rainfall cropping zones where virus infected, self-sown cereals and grasses are present, along with large numbers of aphids during the early growth stages of new season crops. BYDV infection decreases grain yield and also causes shrivelled grain. If crops are infected early, BYDV can result in significant losses. In susceptible cereal varieties, where the entire crop is infected by BYDV soon after sowing, yields of wheat, barley and oats can fall by up to 80 %. If the crop is infected late, yield may be reduced by only 10 to 20%.

# CHAPTER III

# MATERIALS AND METHODS

The study was carried out in the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka- 1207 during November 2020 to April 2021 i.e. in the Rabi season with a view to assessing the efficacy of some novel insecticides against major insect pests of maize. The materials and methods used for conducting the experiment presented in this chapter under the following headings-

## 3.1.Description of experimental site

The study was conducted during the period from November 2020 to April 2021. Field work was conducted in the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The experimental site is situated at $23.074^0$/N latitude and $90.0035^0$/E longitude with an altitude of 8.2 meter from the sea level. In terms of climate, the experimental site is under the subtropical climate and its climatic conditions are characterized by low temperature and scanty rainfall during the winter i.e. Rabi season. Soil of the experimental site belongs to “The Modhupur Tract”, AEZ-28. However, the experimental site was flat having a provision of available irrigation and an ample drainage system.

## 3.2. Planting materials

In order to conduct the current experiment, BARI Hybrid Maize-1 was used as planting materials. Seeds were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. BARI Hybrid Maize-1 was developed by crossing between three inbred lines collected from Thailand. The ear is large, heavy, height of ear 100-105 cm, plant height 190-210 cm. The grains are yellow, large and presence of deep anthocyanin in 1st leaf sheath. Crop du ration is 140-150 days and

100-110 days in kharif season. Anthocyanin color in first leaf sheath and light anthocyanin color in second leaf sheath.

### 3.3. Treatments of the experiment

There are seven treatments including control used in this experiment.
The name of the treatments and respective doses are given in Table 1.

**Table 1. Treatments of the experiment**

| **Treatment Number** | **Common Name** | **Trade Name** | **Dose (at 7 days interval)** |
|---|---|---|---|
| $T_1$ | Success(Spinosad ) | Success 25 EC | 0.5 ml//L of water |
| $T_2$ | Matrine | Matrine 5% SC | 1.0 ml/L of water |
| $T_3$ | Virtaco(Chlorantraniliprole + Thiamethoxam,) | Virtaco 40 WG | 0.2 g/L of water |
| $T_4$ | Neem oil | Neem oil | 5.0 ml/L of water with detergent |
| $T_5$ | Emamectin benzoate | Emamectin Benzoate 5 SG | 1.0 ml/L of water |
| $T_6$ | Seed treatment with Fortenza +Sunfezin | Fortenza (Cyantraniliprole)+Sunfezin 40WP | 0.2 g/L of water |
| $T_7$ | Control | | |

### 3.4. Experimental design and layout

The experimental field was designed in a single factor randomized complete block design (RCBD) with three replications. The experimental site was divided into three blocks allocating the replications to assemble homogeneous soil conditions. Every block was divided into seven-unit plots as treatments. Raised bunds were used as identifiers for treatment demarcation. However, the total numbers of experimental plots were 7X3=21. Each plot size was 3.6 m × 1.6 m. Subsequently,

**Field Layout:**

0.5 m and 0.5 m distance were maintained between two blocks and two plots respectively.

| | | |
|---|---|---|
| $R_1T_4$ | $R_2T_1$ | $R_3T_7$ |
| $R_1T_3$ | $R_2T_2$ | $R_3T_5$ |
| $R_1T_6$ | $R_2T_4$ | $R_3T_3$ |
| $R_1T_1$ | $R_2T_5$ | $R_3T_2$ |
| $R_1T_7$ | $R_2T_6$ | $R_3T_4$ |
| $R_1T_5$ | $R_2T_3$ | $R_3T_6$ |
| $R_1T_2$ | $R_2T_7$ | $R_3T_1$ |

### 3.5.Land preparation and seed sowing

Under normal soil preparation, four to five ploughings, followed by laddering was done for sowing. Deep tillage gives the highest yields but it involves more energy and expenditure and also damages soil physical properties if repeated over time. The incorporation of crop residues in combination with deep tillage was also done for a further rising of yields over conventional practice. Seed were treated with Fortenza. The spacing maintained line to line 50 cm and plant to plant 25 cm. To ensure maximum germination, seeds were sown at a depth of 3 to 5 cm.

### 3.6. Manure and fertilizer

To get high yields, Maize need to be fertilized. There were two groups of crop nutrients: organic manures and chemical fertilizers. Well decomposed cow dung was applied at the time of final land preparation. As suggested by the Bangladesh Agricultural Research Institute, fertilizers N, P, K in the form of Urea, TSP, MoP and S, Zn, and B in the form of gypsum, zinc sulphate and borax were applied (Mondal *et al.* 2011).

**Table 2. Fertilizer and manure used in the experiment**

| Name of Fertilizer and manure | Total Amount (Kg/ha.) | Last plough (Kg/ha.) | 30-35 DAT | 60-65 DAT |
|---|---|---|---|---|
| Cow dung/ FYM | 10,000-12,000 | 10,000-12,000 | - | - |
| Urea | 600 | 200 | 200 | 200 |
| TSP | 250 | 250 | - | - |
| MoP | 250 | 250 | - | - |
| Gypsum | 200 | 200 | - | - |
| Boric Acid | 8 | 9 | - | - |
| Zinc Sulphate | 10 | 10 | - | - |

## 3.7. Intercultural operation

### 3.7.1. Weeding

Weed control is essential to ensure a good harvest in summer maize since competition from weeds can be high. The critical period for weed competition with maize lies between 20 to 30 days after crop emergence, during the early stages of vegetative growth. Accordingly, a first weeding was done when the seedlings were about 2-weeks old. An additional 2-3 weedings was required depending on the degree of weed infestation during the life cycle of the crop under local field conditions. Weeding was normally done using hand implements.

### 3.7.2. Earthing-up

Earthing-up of plants is especially important with maize cultivation. Earthing-up means placing soil near the base of the plant after it has been collected from the space between the rows. This operation helps to provide anchorage of the lower whorls of adventitious roots above the soil which then begin to function as absorbing roots. It also helps to brace the plants against lodging during heavy rainfall and windstorms. Earthing-up was done early in the development of the crop (often in combination with weeding) and it may need to be repeated.

### 3.7.3. Irrigation

Maize is very responsive to irrigation but needs well drained soils and timely drainage when excess water is present. Thus appropriate and timely water management is very important to ensure high crop yields and high water productivity. During the winter, maize is a long duration crop (130-150 days) and largely dependent on irrigation after utilizing residual soil moisture. Generally, four irrigations given at the seedling (25-30 days after sowing (DAS)), vegetative (45-50 DAS), silking (65-75 DAS) and grain filling stage (95-105 DAS).

### 3.8. Harvesting

Harvesting was done when 90% of  fruits dried outer cover. The mature crops were harvested and separated it plot wise. Then the corns were dried in sunshine.

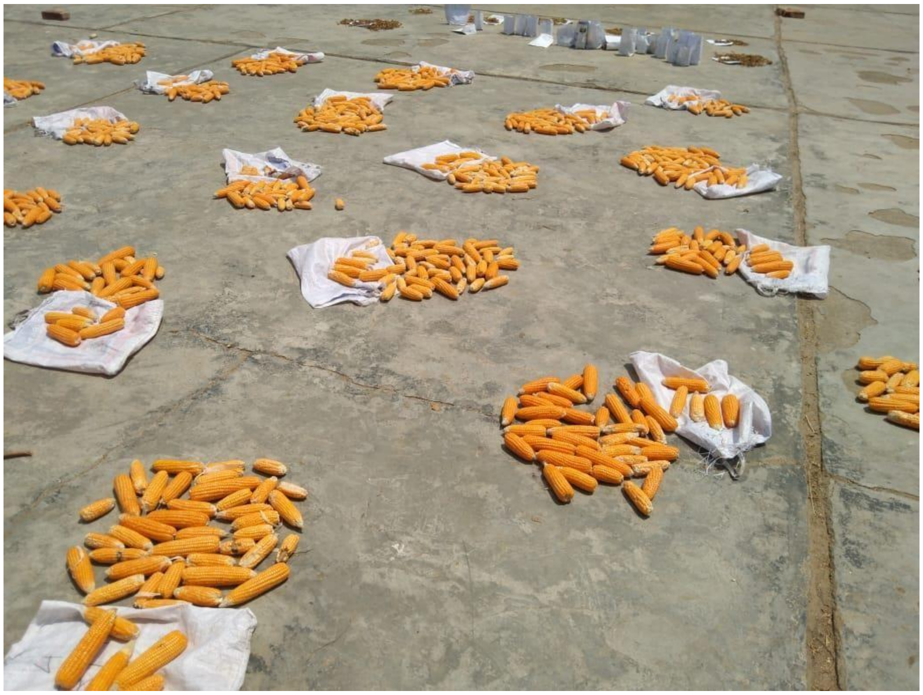

Figure 1. Harvested maize cob from experimental plots

### 3.9. Data collection

### 3.9.1. Data recording on the infestation of fall armyworm (FAW)

Each of the insecticide applications at seven days interval. The numbers of larvae were counted in the treated plants and untreated control plants. The percent reduction of fall armyworm infestation and other insect's population for each treatment was calculated by the formula

$$\% \text{ Reduction} = \frac{Pr - Po}{Po} \times 100$$

(Where, Pr = count
in respective
treatment and
Po = count in
control treatment)

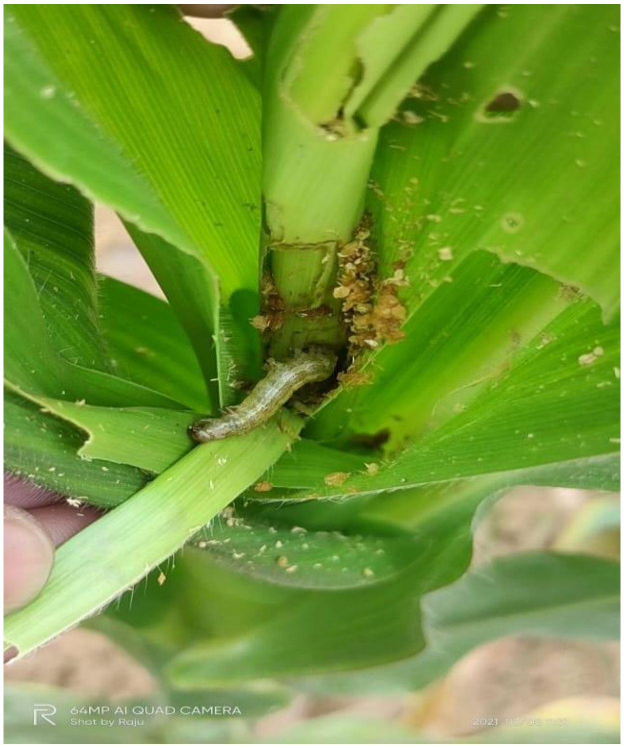


Figure 2. Fall armyworm infesting maize plant

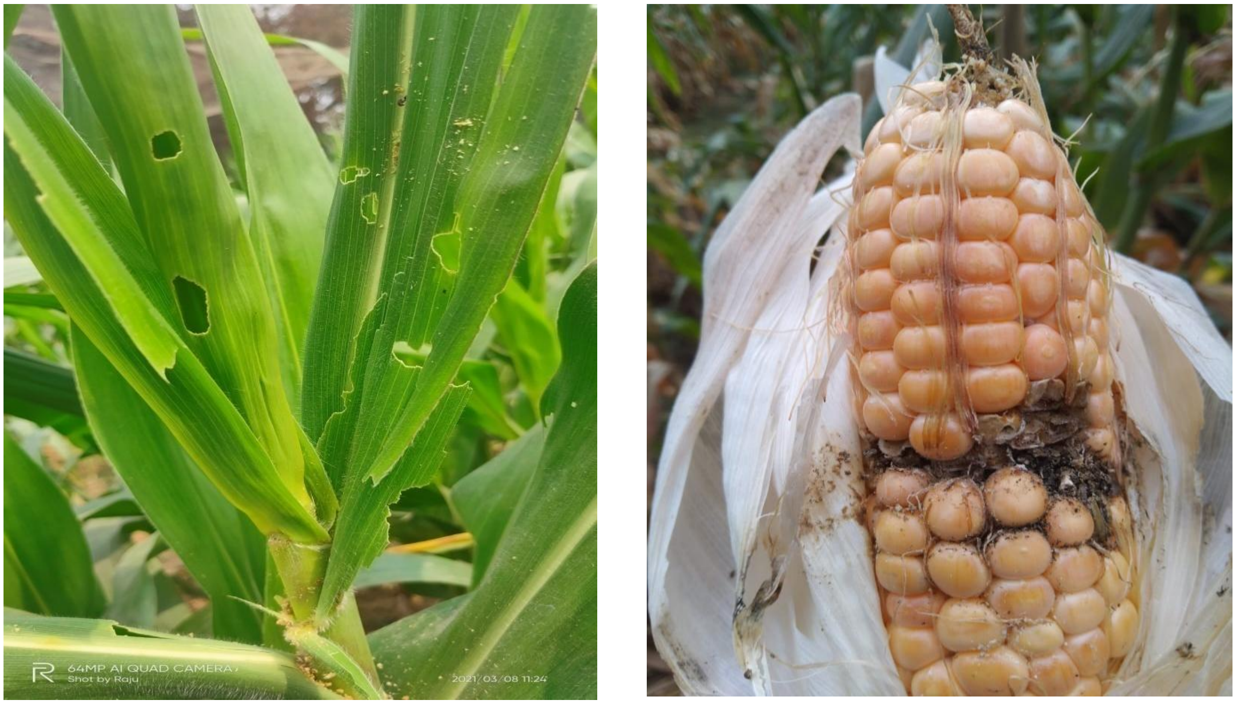


**Figure 3: Infested leaf and infested corn at the experimental plot**

### 3.9.2. Data recording on the infestation of corn aphid

The population of adult and nymph of aphid were recorded randomly from five leaves of each plant in the experiment as per plots at seven days interval of the insecticide applications, the numbers of aphids were counted in the treated plants and untreated control plants Upper and lower surface of maize leaves were carefully observed to count the number of aphids.

### 3.9.3. Data recording on the infestation of stem borer

Observations on the number of infested plants and dead heart from randomly selected plants in each plot were recorded after each spray. The data thus obtained were merged together to obtain cumulative plant infestation/dead heart caused by maize stem borer. Based on these observations, mean percent plant infestation as well as dead heart were computed.

### 3.10. Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance for different treatments. The analysis of variance was performed by using the STAT-10 Program. The significance of the difference among the treatment combinations was estimated by Tukey's HSD Test at 5% level of probability.

# CHAPTER IV

# RESULTS AND DISCUSSION

Seven treatments including control were applied on three major insect pests of maize and the obtained data were compiled followed by analysis. The results are discussed below:

## 4.1. Infestation of fall armyworm in Maize

### 4.1.1. Effect of treatments on fall armyworm infestation 3 days after spray

Infestation of fall armyworm varied significantly among the treatments and ranged from 0.11 to 2.36 larvae per plot at 3 days after spray. The highest infestation was recorded in (control) $T_7$ (2.36) followed by $T_2$ (1.94), $T_3$ (0.56), $T_4$ (0.34), $T_1$ (0.23) and $T_5$ (0.17) respectively. Treatment $T_6$ showed the lowest infestation (0.11). On the other hand, in case of % decrease over control, it was found that the treatment $T_6$ decreased the highest infestation % which were 95.33 followed by $T_5$ (92.79), $T_1$ (90.25), $T_4$ (85.59) and $T_3$ (76.27) respectively. The lowest % decrease was estimated from $T_2$, i.e. 17.79 (Table 3).

From the above findings, we can see that the treatment $T_6$, (Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water at 7 days interval); worked best to decrease the % infestation over control in the 3 days after spray. $T_5$ (Emamectin Benzoate @ 1.0 ml/L of water at 7 days interval); and $T_1$ (Success @ 0.5 ml/L of water at 7 days interval); also performed remarkably in this stage and gave very close result to the Treatment $T_6$. But, the treatment $T_2$, i.e. (Matrine @ 1.0 ml/L of water at 7 days interval) yielded the worst datum in case of decreasing the % infestation. Thus, the performance can be summarized as below: $T_6 > T_5 > T_1 > T_4 > T_3 > T_2$ or,

Fortenza+Sunfezin >Emamectin Benzoate>Success>Neem oil>Virtaco>Matrine

**Table 3. Effect of treatments on fall armyworm infestation 3 days after spray**

| Treatment Serial | Treatment name | No. fall armyworm larvae per plot | Decrease over control (%) |
|---|---|---|---|
| $T_1$ | Success @ 0.5 ml/L of water | 0.23 de | 90.25 |
| $T_2$ | Matrine @ 1.0 ml/L of water | 1.94 b | 17.79 |
| $T_3$ | Virtaco @ 0.2 g/L of water | 0.56 c | 76.27 |
| $T_4$ | Neem oil @ 5.0 ml/L of water with detergent | 0.34 d | 85.59 |
| $T_5$ | Emamectin Benzoate @ 1.0 ml/L of water | 0.17 de | 92.79 |
| $T_6$ | Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water | 0.11 e | 95.33 |
| $T_7$ | Control | 2.36 a | - |
| | LSD(0.05) | 0.21 | - |
| | CV (%) | 9.11 | - |

Means followed by the same letters in a column do not differ at 5% level of significance by Tukey's HSD.

### 4.1.2.Effect of treatments on fall armyworm infestation 7 days after spray

On 7 days after spray, it was noticed that the infestation of fall armyworm ranged between 0.17 to 2.67 larvae per plot. In addition, the obtained data from different treatment varied significantly too. However, the treatment $T_7$ (control) showed the highest infestation (2.67 armyworm larvae per plot) as expected. The second highest infestation (2.33) was found on the treatment $T_2$. The rest of the treatments i.e. $T_3$, $T_4$, $T_1$, and $T_5$ showed the % infestation as 0.75, 0.53, 0.33 and 0.24 respectively. $T_6$ raised the lowest infestation i.e. 0.17 per plot. In contrast with this, the highest % decrease over control was observed on treatment $T_6$ (93.63) followed by $T_5$ (93.63), $T_1$ (93.63), $T_4$ (93.63) and $T_3$ (93.63) respectively. The lowest% decrease over control was performed by treatment $T_2$ i.e. 12.73 (Table 4).Therefore, it may be suggested that the $T_6$ (Seed treatment with

Fortenza+Sunfezin @ 0.2 g/L of water at 7 days interval) performed the best in decreasing the infestation over control followed by $T_5$ (Emamectin Benzoate @ 1.0 ml/L of water at 7 days interval), $T_1$ (Success @ 0.5 ml/L of water at 7 days interval) and $T_4$ (Neem oil @ 5.0 ml/L of water with detergent at 7 days interval). Although, the treatment $T_2$, i.e. (Matrine @ 1.0 ml/L of water at 7 days interval) showed the lowest performance on 7 days after spray. So, on the basis of these findings, we can draw a performance summery as: $T_6 > T_5 > T_1 > T_4 > T_3 > T_2$ or,

Fortenza+Sunfezin > Emamectin Benzoate >Success>Neem oil>Virtaco>Matrine

**Table 4. Effect of treatments on fall armyworm infestation 7 days after spray**

| Treatment Serial | Treatment name | No. fall armyworm larvae per plot | Decrease over control (%) |
|---|---|---|---|
| $T_1$ | Success @ 0.5 ml/L of water | 0.33 c | 87.64 |
| $T_2$ | Matrine @ 1.0 ml/L of water | 2.33 a | 12.73 |
| $T_3$ | Virtaco @ 0.2 g/L of water | 0.75 b | 71.91 |
| $T_4$ | Neem oil @ 5.0 ml/L of water with detergent | 0.53 bc | 80.14 |
| $T_5$ | Emamectin Benzoate @ 1.0 ml/L of water | 0.24 c | 91.01 |
| $T_6$ | Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water | 0.17 c | 93.63 |
| $T_7$ | Control | 2.67 a | - |
| | LSD(0.05) | 0.42 | - |
| | CV (%) | 14.56 | - |

Means followed by the same letters in a column do not differ at 5% level of significance by Tukey's HSD.

In 2019, Gitierrez-Moreno *et al*. revealed that farmers have resorted to 2 to 3 sprays of different insecticides without the knowledge of their efficacy in the year of fall armyworm introduction. They also said that multiple sprays of insecticides may lead to the quick development of resistance as has occurred in other areas. Therefore, the

Central Insecticide Board and Registration Committee recommended the use of chlorantraniliprole 18.5 SC, thiamethoxam 12.6% + lambda cyhalothrin 9.5 % ZC, and spinetoram 11.7 SC for fall armyworm management in 2019.

## 4.2.Infestation of corn aphid in Maize

### 4.2.1.Infestation of corn aphid in Maize 3 days after spray

Infestation of corn aphid in maize varied significantly among the treatments and ranged from 14.54 to 96.01 aphids per plot at 3 days after spray. The highest infestation was recorded in (control) $T_7$ (96.01) followed by $T_2$ (74.86), $T_3$ (57.73), $T_4$ (45.69), $T_1$ (36.44) and $T_5$ (26.06) respectively. Treatment $T_6$ showed the lowest infestation (14.54). On the other hand, in case of % decrease over control, it was found that the treatment $T_6$ decreased the highest infestation % which were 84.85 followed by $T_5$ (72.85), $T_1$ (62.04), $T_4$ (52.51) and $T_3$ (39.87) respectively. The lowest % decreased infestation was estimated from $T_2$, i.e. 22.02 (Table 5).From the above findings, we can see that the treatment $T_6$, (Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water at 7 days interval) worked best to decrease the % infestation over control in the first 3 days after spray. $T_5$ (Emamectin Benzoate @ 1.0 ml/L of water at 7 days interval) and $T_1$ (Success @ 0.5 ml/L of water at 7 days interval) also performed remarkably in this stage and gave very close result to $T_6$. But, the treatment $T_2$, i.e.( Matrine @ 1.0 ml/L of water at 7 days interval) yielded the worst datum in case of decreasing the % infestation. Thus, the performance can be summarized as below: $T_6 > T_5 > T_1 > T_4 > T_3 > T_2$ or,

Fortenza+Sunfezin > Emamectin Benzoate >Success>Neem oil>Virtaco>Matrine

**Table 5. Infestation of corn aphid in Maize 3 days after spray**

| Treatment Serial | Treatment name | No. aphid per plot | Decrease over control (%) |
|---|---|---|---|
| $T_1$ | Success @ 0.5 ml/L of water | 36.44 de | 62.04 |
| $T_2$ | Matrine @ 1.0 ml/L of water | 74.86 b | 22.02 |
| $T_3$ | Virtaco @ 0.2 g/L of water | 57.73 c | 39.87 |
| $T_4$ | Neem oil @ 5.0 ml/L of water with detergent | 45.59 cd | 52.51 |
| $T_5$ | Emamectin Benzoate @ 1.0 ml/L of water | 26.06 ef | 72.85 |
| $T_6$ | Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water | 14.54 f | 84.85 |
| $T_7$ | Control | 96.01 a | - |
| | LSD(0.05) | 12.83 | - |
| | CV (%) | 8.96 | - |

Means followed by the same letters in a column do not differ at 5% level of significance by Tukey's HSD.

### 4.2.2. Infestation of corn aphid in Maize 7 days after spray

On 7 days after spray, it was noticed that the infestation of corn aphid ranged between 9.06 to 79.52 aphids per plot. In addition, the obtained data from different treatment varied significantly too. However, the treatment $T_7$ (control) showed the highest infestation (79.52 aphid per plot) as expected. The second highest infestation (59.60) was found on the $T_2$ treatment. The rest of the treatments i.e. $T_3$, $T_4$, $T_1$, and $T_5$ raised the % infestation as 42.99, 33.93, 29.26, and 17.18 aphid per plot respectively. $T_6$ showed the lowest infestation i.e. 9.06.

In contrast with this, the highest % decrease over control was observed on treatment $T_6$ (88.61) followed by $T_5$ (78.39), $T_1$ (63.21), $T_4$ (57.33) and $T_3$ (45.93) respectively. The lowest% decrease over control was found in treatment T2 i.e. 25.05 (Table 6). Therefore, it may be suggested that the $T_6$ (Seed treatment with

Fortenza+Sunfezin @ 0.2 g/L of water at 7 days interval) performed the best in decreasing the infestation over control followed by $T_5$ (Emamectin Benzoate @ 1.0 ml/L of water at 7 days interval), $T_1$ (Success @ 0.5 ml/L of water at 7 days interval) and $T_4$ (Neem oi l@ 5.0 ml/L of water with detergent at 7 days interval). Although, the treatment $T_2$, i.e.( Matrine @ 1.0 ml/L of water at 7 days interval) showed the lowest performance on 7 days after first spray. So, on the basis of these findings, we can draw a performance summery as: $T_6 > T_5 > T_1 > T_4 > T_3 > T_2$ or,

Fortenza+Sunfezin > Emamectin Benzoate >Success>Neem oil>Virtaco>Matrine

**Table 6. Infestation of corn aphid in Maize 7 days after spray**

| Treatment Serial | Treatment name | No. aphid per Plot | Decrease over control (%) |
|---|---|---|---|
| $T_1$ | Success @ 0.5 ml/L of water | 29.26 d | 63.21 |
| $T_2$ | Matrine @ 1.0 ml/L of water | 59.60 b | 25.05 |
| $T_3$ | Virtaco @ 0.2 g/L of water | 42.99 c | 45.93 |
| $T_4$ | Neem oil @ 5.0 ml/L of water with detergent | 33.93 cd | 57.33 |
| $T_5$ | Emamectin Benzoate @ 1.0 ml/L of water | 17.18 e | 78.39 |
| $T_6$ | Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water | 9.06 e | 88.61 |
| $T_7$ | Control | 79.52 a | - |
| | LSD(0.05) | 11.32 | - |
| | CV (%) | 10.32 | - |

Means followed by the same letters in a column do not differ at 5% level of significance by Tukey's HSD.

In 2017, Ahmed *et al.* observed the performance of seven insecticides on the reduction of percent plants infestation of maize by maize aphid, plant height, cob length without husk, number of grain per cob, 100 grain weight and grain yield. It was found that the application of insecticides showed significant ($P \leq 0.01$ and $P \leq 0.05$) on different mentioned parameters compared to control. In the study, the lowest (18.53%) plant infestation was obtained in Imidacloprid 20SL@ 0.3ml/L which was followed by 26.49%, 35.24%, 44.16%, 49.47%, 56.12% and 61.40% in Imidachlorprid 25% + Thiram 20% @ 0.4 g/L, Chloropyriphos 50% + Cypermethrin 5% @ 1.2 ml/L, Abamactin 1.8 EC @ 2.0ml/L, Carbofuran 5G@ 20g/L, Spinosad @ 0.4 ml/L and emamectin benzoate 5 SG @ 1G/L, respectively, whereas the highest (94.55%) plant infestation was found in control. With a view of the overall insecticidal effect on maize aphid, in case of percent reduction of infested plants over control, the highest (80.40%) percent reduction of plant infestation was recorded in Imidachlorprid 20SL@ 0.3ml/L which was followed by Imidachlorprid 25% + Thiram 20% @ 0.4 g/L (71.98%), Chloropyriphos 50% + Cypermethrin 5% @ 1.2 ml/L (62.73%), Abamactin 1.8EC @ 2.0ml/L (53.29%), Carbofuran 5G @ 20 g/L (47.68%) and Spinosad @ 0.4 ml/L (40.65%), respectively, whereas the lowest (35.06%) percent reduction of plant infestation was obtained in Imidachlorprid 25% + Thiram 20% @ 0.4 g/L. This result was also in conformity with the findings of David *et al.* (2009). On the other hand, the plant height differed significantly among the treatments. The plant height was recorded in the range of 212.24 to 190.25 cm. Among the different tested insecticides, the maximum (212.24 cm) plant height was observed from treatment Emamectin benzoate 5 SG@ 1g/L and the minimum (190.25cm) was found in untreated control. The results of the present study are also similar to the study of Kumar *et al.* (2019). Alam *et al.* (2018) and Ahmed *et al.* (2017). They reported that plant height was directly increased with the increase of reduction of plant infestation during production of maize and other crops. As the results showed, there were significant ($P \leq 0.05$) differences among the length of cob without husk of different insecticides at 5% level of probability. The highest (22.26 cm) cob length without husk was obtained from Imidachlorprid 20SL@ 0.3 ml/L which was followed by Imidachlorprid 25% + Thiram 20% @ 0.4 g/L (19.54cm), chloropyriphos 50% + cypermethrin 5% @ 1.2 ML/L (18.63cm), Abamactin 1.8EC @ 2.0 ml/L (16.10 cm), Carbofuran 5G @ 20 g/L (15.98cm), Spinosad @ 0.4 ml/L

(14.69 cm) and emamectin benzoate 5 SG@ 1G/L (14.02cm), respectively, whereas the lowest height (13.17cm) without husk was found in untreated control. Similar result was found by Gaikwad *et al.* (2014) and Ahmed *et al.* (2017). However, Alama *et al.* conducted an experiment in 2017-18. The results showed that, the selected insecticides had significant ($P \leq 0.01$) effect on the reduction of plant infestation compared to untreated control.

In case of control condition, plant infestations were gradually increased to 90.80%, 93.32% and 96.79% after 2nd, 5th and7th days of observations, respectively. But this infestation level significantly reduced when maize plants were treated with different new generation insecticides. Among the different insecticides, Imidagold 20SL@ 0.5 ml/L showed the best efficacy which reduced plant infestation at the level of 42.22% at 2DAS. This result was statistically at par with the dose of 0.3 ml/L of Imidagold 20SL where the level of plant infestation was 42.81%.

**4.3.1.Incidence of stem borer (% plant infestation) in maize**

The incidence of stem borer in maize was estimated in the term of % plant infestation. The % plant infestation varied significantly among the treatments and ranged from 1.91 to 55.39. The highest plant infestation except control was observed in treatment $T_2$ (27.21) followed by $T_3$ (17.53),and $T_4$ (11.59) and $T_1$ (7.08). $T_5$ (3.81) performed very close to the lowest plant infestation yielding treatment $T_6$ which was 1.91. On the contrary, in case of % decrease over control, it was found that the $T_6$ treatment decreased the plant infestation % highest which were 96.55 followed by $T_5$ (93.12), $T_1$ (87.21), $T_4$ (79.07) and $T_3$ (68.35) respectively. The lowest % decrease was estimated from $T_2$, i.e. 50.87 (Table 7).

From the above findings, we can see that the treatment $T_6$, (Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water at 7 days interval) worked the best to decrease the % infestation over control. $T_5$ (Emamectin Benzoate @ 1.0 ml/L of water at 7 days interval) and $T_1$ (Success @ 0.5 ml/L of water at 7 days interval) also performed remarkably in this stage and gave very close result to $T_6$. But, the treatment $T_2$, i.e. (Matrine @ 1.0 ml/L of water at 7 days interval) yielded the worst datum in case of decreasing the % plant infestation. Thus, the performance can be summarized as below: $T_6 > T_5 > T_1 > T_4 > T_3 > T_2$ or,

Fortenza+Sunfezin > Emamectin Benzoate >Success>Neem oil>Virtaco>Matrine

**Table 7. Incidence of stem borer (% plant infestation) in maize**

| Treatment Serial | Treatment name | % plant infestation | Decrease over control (%) |
|---|---|---|---|
| $T_1$ | Success @ 0.5 ml/L of water | 7.08 de | 87.21 |
| $T_2$ | Matrine @ 1.0 ml/L of water | 27.21 b | 50.87 |
| $T_3$ | Virtaco @ 0.2 g/L of water | 17.53 c | 68.35 |
| $T_4$ | Neem oil @ 5.0 ml/L of water with detergent | 11.59 cd | 79.07 |
| $T_5$ | Emamectin Benzoate @ 1.0 ml/L of water | 3.81 de | 93.12 |
| $T_6$ | Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water | 1.91 e | 96.55 |
| $T_7$ | Control | 55.39 a | - |
| | LSD(0.05) | 8.35 | - |
| | CV (%) | 16.45 | - |

Means followed by the same letters in a column do not differ at 5% level of significance by Tukey's HSD.

### 4.3.2.Incidence of stem borer (% dead heart) in maize

In case of % dead heart, it was noticed that the symptom ranged between 1.60 to 30.03%. In addition, the obtained data from different treatment varied significantly too. However, the treatment $T_7$ (control) showed the highest infestation (30.03%) as expected. The second highest infestation (15.30) was found on the treatment $T_2$. The rest of the treatments i.e. $T_3$, $T_4$, $T_1$, and $T_5$ raised the % infestation as 11.23, 7.48, 5.37, and 3.59 respectively. $T_6$ showed the lowest infestation i.e. 1.60%.

In contrast with this, the highest % decrease over control was observed on treatment

$T_6$ (94.67) followed by $T_5$ (88.04), $T_1$ (82.11), $T_4$ (75.09) and $T_3$ (62.60) respectively. The lowest % decrease over control was performed by treatment $T_2$ i.e. 49.05 (Table 8).

Therefore, it may be suggested that the $T_6$ (Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water at 7 days interval) performed the best in decreasing the infestation over control followed by $T_5$ (Emamectin Benzoate @ 1.0 ml/L of water at 7 days interval), $T_1$ (Success @ 0.5 ml/L of water at 7 days interval) and $T_4$ (Neem oil @ 5.0 ml/L of water with detergent at 7 days interval). Although, the treatment $T_2$, i.e. (Matrine @ 1.0 ml/L of water at 7 days interval) showed the lowest performance. So, on the basis of these findings, we can draw a performance summery as: $T_6 > T_5 > T_1 > T_4 > T_3 > T_2$ or,

Fortenza+Sunfezin > Emamectin Benzoate >Success>Neem oil>Virtaco>Matrine

**Table 8. Incidence of stem borer (%dead heart) in maize**

| Treatment Serial | Treatment name | % dead heart | Decrease over control (%) |
|---|---|---|---|
| $T_1$ | Success @ 0.5 ml/L of water | 5.37 de | 82.11 |
| $T_2$ | Matrine @ 1.0 ml/L of water | 15.30 b | 49.05 |
| $T_3$ | Virtaco @ 0.2 g/L of water | 11.23 c | 62.60 |
| $T_4$ | Neem oil @ 5.0 ml/L of water with detergent | 7.48 d | 75.09 |
| $T_5$ | Emamectin Benzoate @ 1.0 ml/L of water | 3.59 ef | 88.04 |
| $T_6$ | Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water | 1.60 f | 94.67 |
| $T_7$ | Control | 30.03 a | - |
| | LSD(0.05) | 3.54 | - |
| | CV (%) | 11.69 | - |

Means followed by the same letters in a column do not differ at 5% level of significance by Tukey's HSD.

### 4.4.Effect of treatments on yield and yield attributes

The effect of the treatments was estimated from two parameters of the harvested crops. The results are presented below:

#### 4.4.1.Effect on number of grains per cob

The number of grains per cob varied significantly among all the treatments and ranged from 315.37 to 414.32 grains/cob. The highest number of grains per cob was resulted from treatment $T_6$ which was 414.32. The second highest result was observed on treatment $T_5$ (385.54) followed by $T_1$ (365.21), $T_4$ (347.62) and $T_3$ (334.74). $T_2$ yielded the lowest number of grains per cob except control i.e. 332.19 and the control plot yielded 315.37 grains per cob. Similarly, the highest % increase over control was observed on treatment $T_6$ (31.4) followed by $T_5$ (22.22), $T_1$ (15.87), $T_4$ (10.15) and $T_3$ (6.03) respectively.

The lowest % increase over control was performed by the treatment $T_2$ i.e. 5.39 (Table 9). From the above findings, we can see that the treatment $T_6$ (Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water at 7 days interval) worked best to increase the number of grains per cob over control. $T_5$ (Emamectin Benzoate @ 1.0 ml/L of water at 7 days interval) and $T_1$ (Success @ 0.5 ml/L of water at 7 days interval) also performed remarkably in this stage and gave very close result to the $T_6$. But, the treatment $T_2$, i.e. (Matrine @ 1.0 ml/L of water at 7 days interval) yielded the worst datum in case of increasing the grain number. Thus, the performance can be summarized as below: $T_6 > T_5 > T_1 > T_4 > T_3 > T_2$ or,

Fortenza+Sunfezin > Emamectin Benzoate >Success>Neem oil>Virtaco>Matrine

**Table.9.Effect on number of grains per cob**

| Treatment Serial | Treatment name | grains/cob | Increase over control (%) |
|---|---|---|---|
| $T_1$ | Success @ 0.5 ml/L of water | 365.21 c | 15.87 |
| $T_2$ | Matrine @ 1.0 ml/L of water | 332.19 e | 5.39 |
| $T_3$ | Virtaco @ 0.2 g/L of water | 334.74 de | 6.03 |
| $T_4$ | Neem oil @ 5.0 ml/L of water with detergent | 347.62 cd | 10.15 |
| $T_5$ | Emamectin Benzoate @ 1.0 ml/L of water | 385.54 b | 22.22 |
| $T_6$ | Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water | 414.32 a | 31.4 |
| $T_7$ | Control | 315.37 f | - |
| | LSD(0.05) | 5.67 | - |
| | CV (%) | 10.91 | - |

Means followed by the same letters in a column do not differ at 5% level of significance by Tukey's HSD.

### 4.4.2.Effect on yield (ton/ha)

In case of yield, it was noticed that the harvested weight of grains ranged from 6.36 to 10.65 ton/ha. In addition, the obtained data from different treatment varied significantly too. However, the treatment $T_7$ (control) showed the lowest yield (6.36 ton/ha) as expected. The highest yield (10.65 ton/ha) was found on the $T_2$ treatment. The rest of the treatments i.e. $T_3$, $T_4$, T1, and $T_5$ raised the grains as 7.65, 8.43, 9.32, and 9.83 ton/ha respectively. $T_6$ showed the highest performance over control i.e. 10.65 ton/ha. In the same way, the highest % increase over control was observed on treatment $T_6$ (67.45) followed by $T_5$ (54.55), $T_1$ (46.54), $T_4$ (32.54) and $T_3$ (20.28) respectively. The lowest % increase over control was performed by the treatment $T_2$ i.e. 15.40 (Table 10).

Therefore, it may be suggested that the $T_6$ (Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water at 7 days interval) performed the best in increasing the grain yield over control followed by $T_5$ (Emamectin Benzoate @ 1.0 ml/L of water at 7 days interval), $T_1$ (Success @ 0.5 ml/L of water) and $T_4$ (Neem oil @ 5.0 ml/L of water with detergent at 7 days interval). Although, the treatment $T_2$, i.e. (Matrine @ 1.0 ml/L of water at 7 days interval) showed the lowest performance. So, on the basis of these findings, we can draw a performance summery as: $T_6 > T_5 > T_1 > T_4 > T_3 > T_2$ or,

Fortenza+Sunfezin > Emamectin Benzoate >Success>Neem oil>Virtaco>Matrine

Table 10. **Effect on yield(ton/ha)**

| Treatment Serial | Treatment name | Yield (ton/ha) | Increase over control (%) |
|---|---|---|---|
| $T_1$ | Success @ 0.5 ml/L of water | 9.32 c | 46.54 |
| $T_2$ | Matrine @ 1.0 ml/L of water | 7.34 e | 15.40 |
| $T_3$ | Virtaco @ 0.2 g/L of water | 7.65 e | 20.28 |
| $T_4$ | Neem oil @ 5.0 ml/L of water with detergent | 8.43 d | 32.54 |
| $T_5$ | Emamectin Benzoate @ 1.0 ml/L of water | 9.83 b | 54.55 |
| $T_6$ | Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water | 10.65 a | 67.45 |
| $T_7$ | Control | 6.36 f | - |
| | LSD(0.05) | 0.34 | - |
| | CV (%) | 7.61 | - |

Means followed by the same letters in a column do not differ at 5% level of significance by Tukey's HSD.

# CHAPTER V

# SUMMARY, CONCLUSION AND RECOMMENDATION

The present study was undertaken in order to investigate the efficacy of some promising pesticides to control the major insect pests of maize in Bangladesh. The study was done in the research field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. The treatments were $T_1$ (Success @ 0.5 ml/L of water at 7 days interval); $T_2$ (Matrine @ 1.0 ml/L of water at 7 days interval); $T_3$ (Virtaco @ 0.2 g/L of water at 7 days interval); $T_4$ (Neem oil @ 5.0 ml/L of water with detergent); $T_5$ (Emamectin Benzoate @ 1.0 ml/L of water at 7 days interval); $T_6$ (Seed treatment with Fortenza+Sunfezin @ 0.2 g/L of water at 7 days interval); and $T_7$ (untreated control).

Infestation of fall armyworm varied significantly among the treatments and ranged from 0.11 to 2.36 larvae per plot at 3 days after spray. The highest infestation was recorded in (control) $T_7$ (2.36) followed by $T_2$ (1.94), $T_3$ (0.56), $T_4$ (0.34), $T_1$ (0.23) and $T_5$ (0.17) respectively. Treatment $T_6$ showed the lowest infestation (0.11). On 7 days after spray, it was noticed that the infestation of fall armyworm ranged between 0.17 to 2.67 larvae per plot. In addition, the obtained data from different treatment varied significantly too. However, the treatment $T_7$ (control) showed the highest infestation (2.67 armyworm larvae per plot) as expected. $T_6$ raised the lowest infestation i.e. 0.17. In contrast with this, the highest % decrease over control was observed on treatment $T_6$ (93.63) followed by $T_5$ (93.63), $T_1$ (93.63), $T_4$ (93.63) and $T_3$ (93.63) respectively. The lowest % decrease over control was performed by treatment $T_2$ i.e. 12.73.

Infestation of corn aphid in maize varied significantly among the treatments and ranged from 14.54 to 96.01 aphids per plot at 3 days after spray. The highest infestation was recorded in control (96.01) followed by $T_2$ (74.86), $T_3$ (57.73), $T_4$

(45.69), $T_1$ (36.44) and $T_5$ (26.06) respectively whereas, treatment $T_6$ showed the lowest infestation (14.54).

On 7 days after spray, it was noticed that the infestation of corn aphid ranged between 9.06 to 79.52 aphids per plot. In addition, the obtained data from different treatment varied significantly too. However, the treatment $T_7$ (control) showed the highest infestation (79.52 aphid per plot) as expected whereas, $T_6$ showed the lowest infestation i.e. 9.06.

The incidence of stem borer in maize was estimated in the term of % plant infestation. The % plant infestation varied significantly among the treatments and ranged from 1.91 to 55.39. The highest plant infestation was recorded in (control) $T_7$ (55.39) followed by $T_2$ (27.21), $T_3$ (17.53), $T_4$ (11.59), $T_1$ (7.08) and $T_5$ (3.81) performed very close to the lowest plant infestation yielding treatment $T_6$ which is 1.91. In case of % dead heart, it was noticed that the symptom ranged between 1.60 to 30.03%. In addition, the obtained data from different treatment varied significantly too. However, the treatment $T_7$ (control) showed the highest infestation (30.03%) as expected. The second highest infestation (15.30) was found on the $T_2$ treatment. The rest of the treatments i.e. $T_3$, $T_4$, $T_1$, and $T_5$ raised the % infestation as 11.23, 7.48, 5.37, and 3.59 respectively. $T_6$ showed the lowest infestation i.e. 1.60%.

In case of yield attributes, the number of grains per cob varied significantly among all the treatments and ranged from 315.37 to 414.32 grains/cob. The highest number of grains per cob was resulted from the treatment $T_6$ which was 414.32. The second highest result was observed on treatment $T_5$ (385.54) followed by $T_1$ (365.21), $T_4$ (347.62) and $T_3$ (334.74). $T_2$ yielded the lowest number of grains per cob except control i.e. 332.19 and the control yielded 315.37 grains per cob.

In case of yield, it was noticed that the harvested weight of grains ranged from 6.36 to 10.65 ton/ha. In addition, the obtained data from different treatment varied significantly too. However, the treatment $T_7$ (control) showed the lowest yield (6.36 ton/ha) as expected. The highest yield (10.65 ton/ha) was found on the treatment $T_6$. The rest of the treatments i.e. $T_3$, $T_4$, $T_1$, and $T_5$ raised the grains as 7.65, 8.43, 9.32, and 9.83 ton/ha respectively. $T_6$ showed the highest performance over control i.e. 10.65 ton/ha.

Followings are the major findings of the experiment; besides, several concluding remarks and recommendations are given-

- ❖ Maize plants are mostly affected by Fall armyworm, Aphid and Stem borer. The degree of infestation varied throughout the growing period.
- ❖ The highest yield was obtained from the plot where the lowest number of insects was observed.
- ❖ Treatment $T_6$ was the most effective insecticide against pest complex of maize.
- ❖ However, more research and multilocation trial should be conducted to find out the best doses and time to apply the treatment $T_6$ for the best control of maize insect pests.

# CHAPTER VI

# REFERENCES

Abang, A., Kouame, C., Abang, M., Hanna, R. and Fotso Kuate, A. (2013). Vegetable grower's perception of pesticide use practices, cost, and health effects in the tropical region of Cameroon. *Intl. J. Agron. Plant Protect.* **1**: 75-76.

Abudulai, M., Shepard, B.M. and Mitchell, P.L. (2001). Parasitism and predation on eggs of *Leptoglossus phyllopus* (L.)(Hemiptera: Coreidae) in cowpea: impact of endosulfan sprays. *J. Agric. Urban Entomol*. **18**(2): 105-115.

Adugna, H. and Hofsvang, H. (2001). Survey of lepidopterous stem borer pests of sorghum, maize and millet in Erithrea. *Crop Protect*. **20**: 151-157.

Agarwal, S.B.D. and Sharma, C. (1954). Aldrin and dieldrin as outstanding agents in the control of *Microtermes obesi* Holmgr. On maize in Bihar. *Indian J. Entomol.* **16** (1): 78-79.

Akutse, K.S., Kimemia, J.W., Ekesi, S., Khamis, F.M., Ombura, O.L. and Subramanian, S. (2019). Ovicidal effects of entomopathogenic fungal isolates on the invasive Fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *J. Appl. Entomol.* **143**(6): 626-634.

Alam, M.J., Hoque, M., Mansura, A, Rony, M.N.H. and Haque, M.S. (2019). Sustainable management of corn borer, *Helicoverpa zea* of maize through using some chemicals and bio-rational insecticides. *J. Sci. Tech. Environ. Info.* **8**: 563-573.

Anonymous. (2014). Annual report 2013-2014. ICAR-Indian Institute of Maize Research, Pusa Campus, New Delhi.

Arnold, H.C. (1928). Top dressing of maize against stalk borer. *Rhodesia Agric.J.* **25**: 162 - 165.

Assefa, F. (2018). Status of Fall Armyworm (*Spodoptera frugiperda*), Biology and Control Measures on Maize Crop in Ethiopia: A Review. *Intl. J. Entomol. Res***. 6(**2): 75-85.

Assefa, F. and Ayalew, D. (2019). Status and control measures of fall armyworm (*Spodoptera frugiperda*) infestations in maize fields in Ethiopia: A review. *Cogent Food Agric.* **5**(1): 164-190.

Ayyar, T.V.R. (1940). Handbook of Economic Entomology for South India. *Madras Government Press*. pp. 520.

Bajracharya, A.R. and Bhat, B. (2019). The first record of Fall Armyworm *Spodoptera frugiperda* in Nepal. Khumaltar, Nepal, 2019 NARC http://narc.gov.np/the-first-record-of-fall-armyworm-spodoptera- frugiperdain-nepal. **2**(1): 70-73

Barbosa, M.S., Dias, B.B., Guerra, M.S. and Haralampidou da Costa Vieira, G., (2018). Applying plant oils to control fall armyworm (*Spodoptera frugiperda*) in corn. *Australian J. Crop Sci*. **12**(04): 557–62.

Baudron, F., Zaman-Allah, M.A., Chaipa, I., Chari, N. and Chinwada, P. (2019). Understanding the factors influencing fall armyworm (*Spodoptera frugiperda* JE Smith) damage in African smallholder maize fields and quantifying its impact on yield. A case study in Eastern Zimbabwe. *Crop Protect*. **120**: 141-150.

BBS (2016). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Bangladesh. pp.52

Belmain, S.R., Neal, G.E., and Ray, D.E. and Golob, P. (2001). Insecticidal and vertebrate toxicity associated with ethno botanicals used as post harvest protectants in Ghana. *Food Chem. Toxicol*. **39**: 287-291.

Ben-Yakir, D., Chen, M., Sinev S. and Seplyarsky V. (2012). *Chilo partellus* (Shinhoe) (Lepidoptera: Pyralidae) a new invasive species in Israel. *J. Entomol*. **137**: 398-400.

Beshir, A.R., Shrestha, H.K. and Pradhan, B. (2019). Destructive Pest Alert: Fall Army worm (FAW) is paving its way to Nepal. Retrived from: https://maize.org/destructive-pest-alert-fall armyworm-faw-is-paving-its- way-to nepal. **3**(2):80-85

Bessin, R. (2010). The common maize stalk borer in corn, University of Kentucky college of Agriculture, pp.1-2

Bhatnagar, S.P. (1970). Records of new Cetonides pests in Rajasthan State. Labdev. *J. Sci. Tech.* **8**-B (2): 119-120

Bhusal, K. and Bhattarai, K. (2019). A review on fall armyworm (*Spodoptera frugiperda*) and its possible management options in Nepal. *J. Entomol. Zool. Stud.* 7(4): 1289-1292.

Bhutani, D.K. (1961). Insect pests of maize and their control. *Indian Farm.* **11** (4):7-11.

Bindra, O.S. (1960). Termite damage in North Western Madhya Pradesh with results of experiments on their chemical control. *Indian J. Entomol.* **22**(4): 2

Blanco, C.A., Chiaravalle, W., Dalla-Rizza, M., Farias, J. R., García-Degano, M.F., Gastaminza, G. and Rodríguez, J. (2016). Current situation of pests targeted by Bt crops in Latin America. *Curr. Opin. Insect Sci.* **15**: 131-138.

Blanco, C.A., Portilla, M., Jurat-Fuentes, J.L., Sánchez, J.F., Viteri, D., Vega Aquino, P Terán-Vargas, A.P., Azuara-Domínguez, A., López Jr, J.D., Arias, R. and Zhu, Y.C. (2010). Susceptibility of isofamilies of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) to Cry1Ac and Cry1Fa proteins of *Bacillus thuringiensis*. *Southwestern Entomol*. **35**(3): 409-416.

Bonhof, M.J. (2000). The impact of predators on maize stem borers in coastal Kenya. PhD Thesis, Wagenigen University. pp. 181.

Bonhof, M.J., Huis, V., Kiros, F.G. and Dibogo, N. (2001). Farmer's perceptions of importance, control methods and Natural enemies of maize stem borers at the Kenya Coast. *Insect Sci. Applic*. **21**(1): 33-43.

Buschman, L.L. and Depew, L.J. (1990). Outbreaks of Banks grass mite (Acari: Tetranychidae) in grain sorghum following insecticide applications. *J. Econ. Entomol*. **83**: 1570–1574.

CABI. (2020). *Spodoptera frugiperda* (fall armyworm). Invasive Species Compendium. Retrived from: https://www.cabi.org/isc/datasheet/29810

Capinera, J.L. (2000). Fall armyworm, *Spodoptera frugiperda* (JE Smith)(Insecta: Lepidoptera: Noctuidae). University of Florida IFAS Extension.

Cate, J.H. Jr., Bottrell, D.G. and Teetes, G.L. (1973). Management of the greenbug on grain sorghum. 1. Testing foliar treatments of insecticides against greenbugs and corn leaf aphids. *J. Econ. Entomol*. **66**: 945-951.

Cave, R.D. (2000). Biology, ecology and use in pest management of *Telenomus remus*. *Biocont. News Inform*. **21**(1): 21N-26N.

Cave, R.D. and Acosta, N.M. (1999). *Telenomus remus* Nixon: un parasitoide en el control biológico del gusano cogollero, *Spodoptera frugiperda* (Smith).*Intr.J of pest managt*.pp.1-20

Chabi-Olaye, A., Nolte, C., Schulthess, F. and Borgemeister, C. (2005). Relationships of intercropped maize stem borer damage to maize yield and land-use efficiency in the humid forest of Cameroon. *Bull. Entomol. Res.* **95:** 417-427.

Chatterji, S. N., Young, W.R., Sharma, G.C., Sayi, I.V., Chahal, B.S., Khare, B.P., Rathore, Y.S., Panwar, V.P.S. and Siddiqui, K.H. (1969). Estimation of loss in yield of maize due to insect pests with special reference to borers. *Indian J. Entomol*. **31**(2): 109-115.

Chaudhary, R.N. and Sharma, V.K. (1975). Note on the comparative resistance of some elite maize germplasm to shootfly in spring. *Indian J. Agric. Sci.* **45**(11-12): 561.

Chimweta, M., Nyakudya, I.W., Jimu, L. and Bray Mashingaidze, A. (2019). Fall armyworm [*Spodoptera frugiperda* (JE Smith)] damage in maize: management options for flood-recession cropping smallholder farmers. *Intl.J. Pest Managt*.pp. 1-13.

Chinwada, P. (2002). Stem borer parasitism by *Cotesia sesamiae* and *Sturmiopsis parasitica* and an assessment of the need to introduce *Cotesia flavipes* in Zimbabwe. Ph.D. Thesis, Kenyatta University pp. 44-162.

Chinwada, P. and Overholt, W.A. (2001). Natural enemies of maize stem borers on the highveld of Zimbabwe. *African Entomol*. **9:** 67-75

Clive, J. (2003). Global review of commercialized transgenic crops. *Agri-Biotechnol. Appl*. **84** (3): 20-23.

Cronholm, G., Knutson, A., Parker, R., Teetes, G. and Pendleton, B. (1998). Managing insect and mite pests of Texas sorghum. *Texas Agric. Exp. Stat. Bull*. **B-1220**. pp. 26.

Day, R., Abrahams, P., Bateman, M., Beale, T., Clottey, V., Cock, M. and Gomez, J. (2017). Fall armyworm: impacts and implications for Africa. *Outl. Pest Manag*. **28**(5): 196-201.

De Groote, H. (2002). Maize yield losses from stalk borers in Kenya. *Insect Sci. Applic.* **22**: 89-96.

Dejen A., Getu E., Azerefegne F., and Ayelew A. (2014). Distribution and impact of *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) and *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) in Northeastern Ethipia. *J. Entomol. Nematol.* **6**(1): 1-13.

Dicke, F.F. and Guthrie, W.D. (1988). The most important corn insects. In: Corn and Corn Improvement. American Society of Agronomy, Madison, W.I. pp. 767-867.

Ebenebe, A.A. Van den Berge, J. and Van de Linde, T.C. (2013). Effect of planting date of maize on damage and yield loss caused by the stalk borer, *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) in Lesotho, South Africa. *J. Plant Soil.* **16**(4): 180-185.

Emana, G., Abrham, T., Asmare, D., Mulugeta, N. and Tadele, T. (2008). Review of entomological research on maize, sorghum and millet. In Abrham (ed.), Increasing Crop Production through Improved Plant Protection in Addis Ababa, Ethiopia, Institute of Agricultural Research, Addis Ababa. pp. 167-244.

Emana, G., Overholt, W.A. and Kairu, E. (2001). Ecological management of cereal stemborers in Ethiopia.. In Seventh Eastern and Southern Africa Regional Maize conference, 11-15th February 2001. Nairobi, Kenya. pp. 55-99.

FAO, (2019). Community-Based Fall Armyworm (*Spodoptera frugiperda*) Monitoring, Early warning and Management, Training of Trainers Manual, *First Edition 112.* Retrived from http://www.fao.org/3/CA2924EN/ca2924en

Ferrer, F. (2001). Biological control of agricultural insect pests in Venezuela; advances, achievements, and future perspectives. *Biocont. News Info.* **22**(3): 67N-74N.

Figueroa, R., Camino, M., Pérez-Amador, M.C., Muñoz, V., Bratoeff, E. and Labastida, C. (2002). Fatty acid composition and toxic activity of the acetonic extract of *Carica papaya* L. (Caricaceae) seeds (with 2 tables). *Phyton*. pp. 97-99.

Firake, D.M., Behere, G.T., Babu, S. and Prakash, N. (2019). Fall Armyworm: Diagnosis and Management (An extension pocket book). ICAR Research Complex for NEH Region, Umiam-793 103, Meghalaya, India. 48

Fletcher T.B. (1917). Maize Pests, Proceedings 2nd Entomological Meeting, Pusa: pp. 188-193.

Fletcher, T.B. (1914). Some South Indian Insects and Other Animals of Importance Considered Especially from Economic Point of Views. Government Printing Press, Madra. pp. 565.

Goergen, G., Kumar, P.L., Sankung, S.B., Togola, A. and Tamo, M. (2016). First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (JE Smith)(Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. *PloS One.* **11**(10): 125-126

Gu, H. and Woo, R. (2019). Crop invaders: China's small farmers struggle to defeat armyworm. Environment. Retrived from: https://www.reuters.com/article/us-crops-armyworm-china- idUSKCN1UZ0LL

Gupta, S., Handore, K. and Pandey, I.P. (2010). Effect of insecticides against *Chilo partellus* (Swinhoe) damaging Zea mays (Maize). *Int J. Paras. Res.* **2**(2): 4-7.

Gutierrez-Martinez, A., Tolon-Becerra, A. and Lastra-Bravo, X.B. (2012). Biological control of *Spodoptera frugiperda* eggs using Telenomus remus Nixon in maize-bean-squash polyculture. *American J. Agric. Biol. Sci.* 7(3): 285-292.

H.R. (2001). Cereal stem borer species complex and establishment of *Cotesia flavipes* Cameron in Eastern Uganda. *Insect Sci. Applic.* **21**: 317- 325.

Hardke, J.T., Lorenz III, G.M. and Leonard, B.R. (2015). Fall armyworm (Lepidoptera: Noctuidae) ecology in southeastern cotton. *J. Integ. Pest Manag.* **6**(1): 10.

Harris, K.M. and Nwanze, K.F. (1992). *Busseola fusca*, the African maize stalkborer: a handbook of information. Info. Bulletin 33, ICRISAT, Patancheru, India. pp. 84.

Hicks, D.R. (2004). Corn lodging-what can we expect? University of Minnesota, Crop Extent. Bulletin, No 1.pp. 3

Hruska, A.J. and Gould, F. (1997). Fall armyworm (Lepidoptera: Noctuidae) and *Diatraea lineolata* (Lepidoptera: Pyralidae): Impact of larval population level and temporal occurrence on maize yield in Nicaragua. *J. Econ. Entomol*. **90**(2): 611–622.

ICIPE (International Centre of Insect Physiology and Ecology).2000. Agricultural Entomology, Biological control of cereal stem borers in East and Southern Africa at: http://nbo.icipe.org/agriculture/stemborers/default.html.

ISU (Iowa State University), (2012). Field Crop Insects. Iowa Soybean Association pp. 4-5

Jacobs, A., van Vuuren and A., Rong, I.H. (2018). Characterisation of the fall armyworm (*Spodoptera frugiperda* JE Smith) (Lepidoptera: Noctuidae) from South Africa. *African Entomol.* **26**(1): 45-49.

Jasmine, D., Prasai, T., Pant, S. and Jayana, B. (2008). Study on major pesticides and fertilizers used in Nepal. *Scientific World*. **6**(6): 76-80.

Kansiime, M. K., Mugambi, I., Rwomushana, I., Nunda, W., Lamontagne-Godwin, J., Rware, H. and Day, R. (2019). Farmer perception of fall armyworm (*Spodoptera frugiderda* JE Smith) and farm-level management practices in Zambia. *Pest Managt Sci.* **75**(10): 2840-2850.

Kaur, J., Pradyumn, K., Jagbir, S., Suby, S.B. and Deva, R.B. (2015). Egg laying pattern of *Sesamia inferens* on maize, *Zea mays* L. *Indian J. Agri. Sci*. **85**(1)

Kfir, R., Overholt, W.A., Khan, Z.R. and Polaszek, A. (2002). Biology and management of economically important lepidopteran cereal stem borers in Africa. *Ann. Rev. Entomol.* **47**: 701-731.

Kumar, P., Sharma, R.K., Siwach, P., Raghav, D. and Sharma, A. (2004). Validation of IPM in Maize in Punjab. In: National Symposium on Biotechnological Approaches for the Management of Plant Diseases, January 30-31, 2004, Agrawal P.G. College, Jaipur, Rajasthan. Abs.: pp 49- 50.

Kumar, P., Singh, S.P., Chandish, R. and Jalali, S.K. (1988). Relationship between the host age and fitness components of *Hyposoter didymator* Thumb. (Hymenoptera:Ichneumonidae). *J. Bio. Cont.* **2** (2): 69 - 71.

Kumela, T., Simiyu, J., Sisay, B., Likhayo, P., Mendesil, E., Gohole, L. and Tefera, T. (2019). Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya. *Intl. J. Pest Managt.* **65**(1): 1-9.

Kundu, G.B. and Srivastava, K.P. (1984). Estimation of loss in grain yield of sorghum by beetle, *Chiloloba acuta* Wield. *J. Entomol. Res.* **8**(2): 223-224.

Lima, R.K., Cardoso, M.D.G., Moraes, J.C., Andrade, M.A., Melo, B.A. and Rodrigues, V.G. (2010). Chemical characterization and inseticidal activity of the essential oil leaves of *Ageratum conyzoides* L. On fall armyworm *Spodoptera frugiperda* (Smith, 1797) (Lepidoptera: Noctuidae). *Biosci. J.* **26**(1): 1-5.

Luckman, W.H. (1978). Insect Control in Corn: Practices and Prospects. In: *Pest Control Strategies.* (Ed. E.H. Smith and David Pimentel). Academic, New York.

Mamudu, D. (2011). Stem borer infestation and yield response of three maize varieties to rates of nitrogen fertilizer in the Mampong Ashanti Municipality of Ghana, Msc. Thesis School of Research and Graduate Studies. pp. 4-97

Martínez, A.M., Aguado-Pedraza, A.J., Viñuela, E., Rodríguez-Enríquez, C.L., Lobit, P., Gómez, B. and Pineda, S. (2017). Effects of ethanolic extracts of *Argemone ochroleuca* (Papaveraceae) on the food consumption and development of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Florida Entomol.* **100**(2): 339-345.

Matama-Kauma, T., Kyamanywa, S., Ogwang, J.A., Omwega, C.O and Willson, H.R. (2001). Cereal stem borer species complex and establishment of *Cotesia flavipes* Cameron in Eastern Uganda. *Insect Sci. Applic.* **21**: 317-325.

Mathur, L.M.L. (1992). Changing complex of maize pests in India. Proceedings: National Seminar on Changing Scenario in Pest Complex, January 31-February 1, 1992, Hyderabad.

Mathur, LML. (1987). Bibliography of Maize Pests in India. AICMIP, IARI, New Delhi. pp. 40-47.

Meagher Jr, R.L. (2001). Collection of fall armyworm (Lepidoptera: Noctuidae) adults and non-target Hymenoptera in different colored unitraps. *Florida Entomol.* **3***(1):* 77-82.

Melaku, W., Fritz, S., Kairu, E. and Charles, O. (2006). Cereal yield losses caused by Lepidopterous stem borers at different nitrogen fertilizers rates in Ethiopia. *J.App. Entomol.* **130**: 220-229.

Moolman, J., Van den Berg, J., Conlong, D., Cugala, D., Siebert, S. and Le Rü, B. (2014). Species diversity and distribution of lepidopteran stem borers in South Africa and Mozambique. *J. Appl. Entomol.* **138**: 52-66.

Muhammad, A.Z., Muhammad, A.S., Muhammad, A.R., Amir, H., Asim, H. and Hasan, K. (2010). Effect of temperature and relative humidity on the population dynamics of some insect pests of maize. *Pakistan. J. Life Soc. Sci.* **8**(1): 16-18.

Murthy, M. Shankara and Nagaraja, S.K. (2014). Outbreak of maize leaf roller, *Cnaphalocrocis trapezalis* Guenee (= *Marasmia trapezalis*) (Crambidae: Lepidoptera) on sorghum in Karnataka, South India. *Insect Environ.* **19**(4): 250-253.

Mushore, K. (2005). Assessment of suitability of different populations of stemborer species for the development of *Cotesia flavipes* (Hymenoptera: Braconidae) and the Establishment of the latter in Zimbabwe, MS Thesis, University of Zimbabwe. pp. 14

Mutyambai, D.M., Midega, C.A.O., Bruce, T.J.A, Van den Berg, J., Pickett, J.A. and Khan, Z.R. (2014). Behavior and biology of *Chilo partellus* on maize landrances. *Ento. Exp. Appl.* **153**: 170-181.

Nagaraja, H. (2013). Mass production of trichogrammatid parasitoids. In Biological control of insect pests using egg parasitoids Springer, New Delhi. (pp. 175-189).

Nagoshi, R.N., Silvie, P., Meagher, R.L., Lopez, J. and Machado, V. (2007). Identification and comparison of fall armyworm (Lepidoptera: Noctuidae) host strains in Brazil, Texas, and Florida. Annals of the Entomol. Society of America. **100**(3): 394-402.

Ndemah, R., Schulthess, F., Korie, S., Borgemeister, C. and Cardwell, K.F. (2001). Distribution, relative importance and effect of lepidopterous borers on maize yields in the forest zone and midaltitude of Cameroon. *J. Econ. Entomol.* **94**: 1434-1444.

Nsami, E., Pallangyo, B., Mgoo, V. and Omwega, C.O. (2001). Distribution and species composition of cereal stem borers in the eastern Zone of Tanzania. *Insect Sci. Applic.* **21**: 289-295.

Pant, N.C. and Kalode, M.B. (1964). Pests of wheat, maize and millet. In: Entomology in India. Entomological Society of India, New Delhi. pp. 279-292.

Panwar, V.P.S. and Sarup, P. (1985). Distribution and host plants of shoot fly species attacing maize in different parts of the world. *J. Entomol. Res.* **9**(2): 207-217.

Pathak, P.K., Sharma, V.K. and Singh, J.M. (1971). Effect of date of planting on the spring maize on the incidence of shootfly *Atherigona* spp. and loss in yield due to its attack. In: Annual Report 1970-71, Experiment Station, UPAU, Pantnagar. pp. 279-281.

Phambala, K., Tembo, Y., Kabambe, V.H., Stevenson, P. C. and Belmain, S.R. (2020). Bioactivity of common pesticidal plants on fall armyworm larvae (*Spodoptera frugiperda*). Plants**. 9**(1): 112.

Pradhan, B., Rusinamhodzi, L. and Subedi, R. (2019). System uses plants to lure fall armyworm away from maize fields. Retrived from https://www.cimmyt.org/news/system-uses-plants-to-lure-fall-armyworm- away-from-maize-fields/

Pradhan, S. and Peshwami, K.M. (1961). Studies on the ecology and control of *Hieroglyphus nigrorepletus* Bolivar (Phadka). *Indian J. Entomol.* **23**(2): 79-105.

Ramirez-cabral, N.Y.Z., Kumar, L. and Shabani, F. (2017). Future climate scenarios project a decrease in the risk of fall armyworm outbreaks. *J. Agric. Sci.* **155**(8): 1219-1238.

Rao, A.B. (1983). Technique of scoring for resistance to maize talk borer (*Sesamia inferens*) In: Techniques of scoring for resistance to the major insect pests of maize. AICMIP, IARI, New Delhi pp. 16-26.

Rathore, Y.S., Chatterji, S.M. and Asnani, V.L. (1969). A note on the screening of maize varieties for resistance to shoot fly, *Atherigona* spp. *Indian J. Entomol.* **31**: 277-278.

Reddy, J. (2019). Fall Armyworm control methods and symptoms. Agrifarming. Retrived from https://www.agrifarming.in/fall-armyworm-control-methods-and-symptoms

Rioba, N.B. and Stevenson, P.C. (2017). *Ageratum conyzoides* L. for the management of pests and diseases by small holder farmers. *Industr. Crops Protect.* **110**: 22-29.

Rioba, N.B. and Stevenson, P.C. (2020). Opportunities and scope for botanical extracts and products for the management of fall armyworm (*Spodoptera frugiperda*) for small holders in Africa. *Plants*. **9**(2): 207.

Rizzo, G., Monzon, J. P., Tenorio, F. A., Howard, R., Cassman, K. G. and Grassini, P. (2021). Climate and agronomy, not genetics, underpin recent maize yield gains in favorable environments. *Proc. Nat. Acad. Sci.* **119**(4): e2113629119

Sangomla, A. and Kukreti, I. (2019). Fall Armyworm attack: The damage done. https://www.downtoearth.org.in/coverage/agriculture/fall-armyworm- attack-the-damage-done-63445

Silva, D.M.D., Bueno, A.D.F., Andrade, K., Stecca, C.D.S., Neves, P. M.O.J. and Oliveira, M.C.N.D. (2017). Biology and nutrition of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) fed on different food sources. *Scien. Agric.* **74**(1): 18-31.

Silva, M.S., Broglio, S.M.F., Trindade, R.C.P., Ferreira, E.S., Gomes, I.B., Micheletti, L.B. (2015). Toxicity and application of neem in fall armyworm. *Comun. Scien.* **6**(3): 359-364.

Sisay, B., Simiyu, J., Malusi, P., Likhayo, P., Mendesil, E., Elibariki, N. and Tefera, T. (2018). First report of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), natural enemies from Africa. *J. Appl. Entomol*. **142**(8): 800-804.

Sisay, B., Tefera, T., Wakgari, M., Ayalew, G. and Mendesil, E. (2019). The efficacy of selected synthetic insecticides and botanicals against fall armyworm, *Spodoptera frugiperda*, in maize. *Insects.* **10**(2): 45.

Sparks, A.N. (1979). A review of the biology of the fall armyworm. *Florida Entomol*. **7**(3): 82-87

Thrash, B., Adamczyk, J.J., Lorenz, G., Scott, A.W., Armstrong, J.S., Pfannenstiel, R. and Taillon, N. (2013). Laboratory evaluations of lepidopteran-active soybean seed treatments on survivorship of fall armyworm (Lepidoptera: Noctuidae) larvae. *Florida Entomol*. **96**(3): 724- 728.

Westbrook, J.K. and Sparks, A.N. (1986). The role of atmospheric transport in the economic fall armyworm (Lepidoptera: Noctuidae) infestations in the southeastern United States in 1977. *Florida Entomol.* **14***(5)* 492-502.