EFFECT OF MICRONUTRIENTS (B, Zn & Mn) ON INCIDENCE, DAMAGE SEVERITY OF SUCKING INSECT PESTS OF SUNFLOWER AND THEIR IMPACT ON YIELD, QUALITY SEED PRODUCTION AND BENEFICIAL ARTHROPODS

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CERTIFICATE

This is to certify that thesis entitled ***"EFFECT OF MICRONUTRIENTS (B, Zn & Mn) ON INCIDENCE, DAMAGE SEVERITY OF SUCKING INSECT PESTS OF SUNFLOWER AND THEIR IMPACT ON YIELD, QUALITY SEED PRODUCTION AND BENEFICIAL ARTHROPODS"*** *submitted to the* ***INSTITUTE OF SEED TECHNOLOGY,*** *Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) IN SEED TECHNOLOGY,*** *embodies the result of a piece of bona fide research work carried out by* ***Khaled Ferdous, Registration no. 15-06558*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2022
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DEDICATED
TO
MY BELOVED
PARENTS

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ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2021 to March 2022 to evaluate the effect of micronutrients on incidence, damage severity of insect pests of sunflower and its impact on yield and beneficial arthropods. The experiment was laid out in Randomized Complete Block Design replicated with three times. For this study, T_1= Boron @ 8.0 kg/ ha + $ZnSO_4$ @ 9.6 kg/ ha; T_2= Spraying 0.2% Borax @ 2g/L of water; T_3= Spraying 0.2% $ZnSO_4$ @ 2g/L of water; T_4= Spraying 0.5% Borax @ 2g/L of water; T_5= Spraying 0.2% Borax and 0.2% $ZnSO_4$ @ 2g/L of water; T_6= Spraying 0.5% $ZnSO_4$ @ 2g/L of water; T_7= $MnSO_4$ @ 9 kg/ ha; T_8= No micronutrient (control). The maximum plant height (180.2 cm), leaf area (65.44 cm^2), capitulum diameter (12.04 cm), diameter of flower with petal (22.33 cm), number of petal (45.34), number of calex (59.33), number of seed per head (1015), weight of seeds per head (85.26 g), weight of total seed per plot (2.56 kg), weight of single seed (0.084 g), yield (2.92 t/ha), oil content (46.54 %), protein content (22.38 %), seed vigourity (78.52%) and seed viability (91.67%) were observed from T_5 treatment. Again, the minimum number of whitefly per plant at reproductive stage (9.67 whitefly), jassid per plant at vegetative stage (6.67 jassid), aphid per plant at ripening stage (5.33 aphid), stink bug per plant (0.24 stink bug), number of infested leaves (2.89 leaves) and percent leaf infestation (12.46 %) were also observed from T_5 treatment. In case of beneficial arthropod, the maximum number of syrphid fly per plot (1.50 syrphid fly), honey bee per plot (3.33 honey bee), lady bird beetle per plot (2.50 lady bird beetle) and ant per plot (1.67 ant per plot) were observed from T_5 treatment.

LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	:	Full meaning
℃	:	Degree centigrade
%	:	Per cent
ANOVA	:	Analysis of Variance
AEZ	:	Agro-ecological Zone
cm	:	Centimeter
DMRT	:	Duncan Multiple Range Test
et al.	:	*Et Alia* (And Others)
g	:	Gram
Ha	:	Hectare
hr	:	Hour
Kg	:	Kilo gram
L	:	Liter
mg	:	Milligram
ml	:	Milliliter
MoP	:	Muriate of Potash
pH	:	Potential of hydrogen
RCBD	:	Randomized Complete Block Design
SAU	:	Sher-e-Bangla Agricultural University
Tk	:	Taka
TSP	:	Triple Super Phosphate

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CHAPTER I

INTRODUCTION

Sunflower (*Helianthus annuus* L., Family: Compositae) is one of the four most important cholesterol free edible oils annual crops in the world which contains 39 to 49 per cent oil in the seed. Among oilseeds, sunflower commonly known as '*Surajmukhi*' is one of the potential oil yielding crops gaining popularity. Sunflower is regarded as symbol of success, beauty, purity and prosperity. It is native to North America. It is cultivated throughout the world, and most of its products have been commercialized as culinary or livestock feed (Yegorov *et al.,* 2019). In some countries like India and South Africa, growing of sunflowers might be more competitive to other crops like maize, soybean, and sorghum (Vijayakumar *et al.*, 2016). The adaptation of sunflowers to different climatic and soil conditions has enhanced its cultivation as an oilseed plant throughout the world (Forleo *et al.*, 2018). The nutritional components of sunflowers are numerous. Examples are sunflower meal, cake, etc.

The sunflower meal or cake representing a unique by-product obtained from the extracted sunflower processed seeds accounts for 36% mass composition, protein content ranging between 45% and 50% (Malik and Saini, 2018; Malik *et al.,* 2017). Sunflower meal is composed of essential amino acids, vitamin B and minerals, and high antioxidant property, which is fascinating as a nutritional food for humans and composite meals for livestock (Wanjari and Waghmare, 2015). Although, the use of sunflower meals in the human diet is limited due to the presence of anti-nutrients, insoluble fiber and presence of a trace of residue solvents in the meal after extraction (Grasso *et al.,* 2019). Sunflowers have been employed in the preparation of various delicacy as seed, in the processed or extracted form, or form of composite products

(Adesina, 2018). Sunflower seeds can be processed into different forms, such as flour, roasted, baked, or boiled as composite functional foods (Grasso *et al.*, 2019). The oil obtained from the processed sunflower seeds has been used in many homes for cooking and as a raw material in the food industry in the production of margarine, butter, bread, and snacks (Kottapalli *et al.*, 2020). The processed sunflower seeds are low in carbohydrates but contain high proteins, dietary fiber, and fatty acids, as well as sources of antioxidants, vitamins, and minerals (Shahbaz *et al.*, 2018). The nutritional composition of sunflower seeds and oil has dictated their functional properties, also effective in preventing or controlling human diseases such as diabetes, cancers, hypertension, hypercholesterolemia, and coronary heart disease (Katsarou *et al.*, 2015).

It does not contain harmful erucic acid but possesses linoleic acid which is beneficial to our health (Rikabder, 1987). It is an essential element of butter and margarine. The linoleic acid obtained from sunflower oil shows anti-carcinogenic effects (Bauman *et al.,* 2000). Oilseed crops contribute much in our national economy.

Over 150 phytophagous insect species have been reported from cultivated and native sunflower. However, only a few insect species have adapted to cultivated sunflower and have become economic pests (Charlet and Glogoza, 2004). The key insect pests attacking the sunflower white-spotted leaf sucking coleopteran beetle, *Monolepta signata* and hemipteran stink bug, *Nezara viridula* (L.) are of major economic importance (Rana *et al.,* 2004; Hill, 1983; Horvath, 1993; Ahmed, 2002; Reddy *et al.*, 1991; Marin, 1992). The activities of insect pests, predator and parasitoids such as aphids, leaf miner, leaf folder, ladybird beetles, Syrphids, *Diaretialla, Aponteles* were recorded on sunflower (Hugar *et al.,* 2008). Insect pollinators also play a vital role in crop plant (Müller, *et al.* 2006; Thapa, 2006). Many insect species are seen as active pollinators on flowers of plants (De Grandi and Chambers, 2006).

Environmental factors also play a vital role in the biodiversity of insect pests in a particular agro ecosystem (Aheer *et al.*, 2007), there are numerous factors which affect the speedy increase and decrease of insect's population. Both the physical and biological factors are much vital causing the variations in the densities of insect aphid population.

In Bangladesh the Sunflower is newly introduced as an oilseed crops. Sunflower is primarily a winter plant but now-a-days it is available also in summer. They are grown in homestead to farmer's field for oil production purposes as well as in larger plots for commercial purpose (Umar *et al.,* 2013). In Bangladesh per unit area Sunflower production is comparatively low with the other countries. However, low yield may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, delayed sowing, fertilizer management, disease and insect infestation and improper or limited irrigation facilities. A major and common one is the high incidence of insect pests and management practices. Sunflowers are infested with various insect right from the primordial stages of the crop to harvest of the product. The main pests of oil crops sunflower are controlling by different methods of the pest but the growers in Bangladesh frequently use chemical insecticides (Younas *et al.,* 2016). In Bangladesh farmers solely rely on chemical pesticide for their welfare against this obnoxious insect pest and fail at most of the cases and damage the ecological balance. The application of insecticide, however, can cause several problems such as development of insecticide resistance pest insects, induction of resurgence of target pests, outbreak of secondary pests and undesirable effect on nontarget organisms as well as serious environment pollution. Insecticide residues can exist in fruit which cause health hazard to consumers.

Among several plant nutrients, only 17 are essential for proper growth and development of plants and each nutrient play's important role in their growth. These nutrients are required by insects for their growth, tissue maintenance, reproduction and energy. They fulfill their requirements through feeding on plants. Nitrogen has positive effects on individual insect performance, probably due to deposition-induced improvements in host plant chemistry. These improvements include increased nitrogen and decreased carbon-based defensive compound concentrations. Potassium provides high resistance against insect pests. High levels of potassium enhance secondary compound metabolism, reduce carbohydrate accumulation and plant damage from insect pests. Phosphorus also decreases the host suitability to various insect-pests. Secondary macronutrients and micronutrients like calcium, zinc and sulphur also reduce the pest populations. Among mineral elements, silicon is involved in plant resistance against insect pest damage. The indirect effects of fertilization practices acting through changes in the nutrient composition of the crop have been reported to influence plant resistance to many insect pests (Bala *et al.,* 2018). Considering these points and as part of eco-friendly sucking pest management of sunflower this study was under taken.

Bearing these issues some objectives were set up for this study and those were:

i. To study the incidence and infestation level of different sucking insect pests on sunflower due to effect of micronutrients (B, Zn & Mn);
ii. To evaluate efficacy of micronutrients on sunflower for controlling incidence, damage severity of major sucking insect pests; and
iii. To find out the impact of micronutrients on yield and beneficial arthropods.

CHAPTER II

REVIEW OF LITERATURE

Sunflower is grown as an oilseed crop worldwide in temperate and subtropical climates in 72 countries. Among oilseeds, sunflower generally ranked 5th behind soybean, rapeseed, cottonseed, and peanut. Among the sucking insect pests sunflower white-spotted leaf sucking coleopteran beetle, hemipteran stink bug etc. are the major insect pests of sunflower. An attempt has been taken in this chapter to review the pertinent research work related to the present study. The information is given below under the following sub-headings:

2.1 Sunflower: It's production and importance

Shamimuzzaman (2021) reported that sunflower was one of the important crops in the world for edible oil having 41.3 million tones production in 2019-20. It was a good source of vegetable oil. Oil content of sunflower ranged from 260 to 720 g/kg among the genotypes. He also mentioned that, sunflower is an important oilseed crop in Bangladesh popularly known as *Surjamukhi*. Currently food security problems were also associated with oil. The production of edible oil was not enough in the country, consequently the government has to arrange import of edible oil. It was 2.4 million MT in 2019. The oil content of sunflower seed ranged between 35% to 50% that consists of about 90% unsaturated fatty acids, placing it as one of the best oils for popular consumption.

In Bangladesh, there was a good prospect of selling up to four crore taka of sunflower oil in Brahmanbaria in the fiscal year 2021-2022, which was projected by the local Department of Agricultural Extension (DAE). Another DAE official from Kishoreganj districted conformed that, the selling price of sunflower seed was taka 50 to taka 60 per kilogram in Kishoreganj district that year, where around 1160 farmers were involved to grow sunflower in that district. Beside this, sunflower cultivation became demandable in other districts in Bangladesh day by (The Daily Star, 2022).

According to data provided by the Department of Agricultural Extension (DAE), a total of 15,400 hectares were used to cultivate sunflowers in FY 2020-21, three times higher than the DAE’s target of 5,501 hectares for the fiscal year. The DAE data also shows Bangladesh produced 5,725 tonnes of sunflower seeds in the fiscal year 2019-20, which was 3,052 tons in the previous year. The company (Globe Edible Oil Ltd) was produced 6,000 tonnes to 7,000 tonnes of sunflower oil per annum. It had also been witnessing an annual growth of 7 per cent to 8 per cent (Businesspost, 2021).

Tabassum (2021) stated that, sunflower seeds contained about 50% of fat and 20% of protein and also contained high percentage of unsaturated fatty acids (Oleic and linoleic acid), light color, low quantity of linolenic acid, blend flavor and high smoke point. Sunflower seeds were also strong source of vitamins E, B1, B6, folate, niacin, Cu, Mn, Se, P, and Mg. Sunflower contained phytosterols which helps to reduce cholesterol in serum through cholesterol excretion to alter cholesterol synthesis.

Sunflower is grown as an oilseed crop worldwide in temperate and subtropical climates in 72 countries, with an average annual world production of 32–44 MT (Lotha and Dawson, 2021). It belongs to the family Compositeae. Sunflower crop was introduced to India during 1969 as a supplement to introduce oilseed crops to bridge the gap of recurring edible oil shortage in the country (Shankergoud *et al.,* 2006). Karnataka ranks first both in area (0.462 Mha) and production (1.052 Mt) of sunflower in the country (Kumar *et al.*, 2010).

Sunflower is an important oil seed crop of the world and it ranked 3rd in production next to groundnut and soybean. In India oil seeds crop occupy an area of 32.4 Mha with 28.2 Mt of production registering a productivity levels of 1041 kg ha^{-1}. About 14 million persons are engaged in production and another one million in processing of oil seeds (Sonnad *et al.*, 2011). It is one of the fastest growing oilseed crops in India and is cultivated over an area of about 5.2 lakh hectares with a production of 3.35 lakh tones and a productivity of 643 kg per hectare (Lotha and Dawson, 2021).

Sunflower seed is highly nutritious containing about 20% protein and 40 to 50% vegetable oil associated with a very high calorific value. The oil is considered to be of high quality due to its non- cholesterol properties and has been recommended for the patient having heart problem. It contains 60 to 73% linoleic acid, with sufficient amount of calcium, iron and vitamins like A, B, E and K (Rajendra *et al.*, 2013).

The lower yield of sunflower is mainly due to lack of high yielding varieties, its cultivation on marginal lands with inadequate nutrients, non- adoption of proper crop rotation and weed management practices. Hence, there is an urgent need to work out a suitable Agro-production technology to explore potentiality of sunflower to meet the increasing demand of hybrid seed. The commercial yield in sunflower is the product of interaction between three important components *viz.,* seed, nutrients and climatic conditions (Lotha and Dawson, 2021).

In this interaction seed plays a decisive role and it is therefore, necessary to use seeds of high quality and genetic purity. Organic agricultural practices aim to enhance biodiversity, biological cycles and soil biological activity so as to achieve optimal natural systems that are socially, ecologically and economically sustainable (Samman *et al.*, 2008).

2.2 Insect pests of sunflower

2.2.1 Aphid

Aphid has been reported from many hosts, individual clones do not have the ability to feed on all reported hosts (Liu *et al.*, 2002) and it has over 40 synonyms (Ilharco and Harten, 1987).

Taxonomic tree

Domain: Eukaryota
  Kingdom: Metazoa
    Phylum: Arthropoda
      Subphylum: Uniramia
       Class: Insecta
          Order: Hemiptera
            Suborder: Sternorrhyncha
              Superfamily: Aphidoidea
                Family: Aphididae
                  Genus: *Aphis*
                     Species: *Aphis gossypii*

Biology

A. gossypii exhibits an anholocyclic life cycle, while in cooler areas it exhibits either a heteroecious or autoecious holocyclic life cycle (Zhang and Zhong, 1990). The heteroecious cycle involves a migration from a winter host to a summer host in the spring and a return to a winter host in the autumn for laying eggs. Population Growth Reproductive rates in *A. gossypii* are reported in two ways; net reproductive rate which is an interaction between birth rate and survival rate (Wilson and Bossert, 1971), and birth rate as measured in nymphs produced per day per aphid. *A. gossypii* takes 5.2 days to reach maturity on cotton at 28°C. The optimal temperature for reproduction is 20-25°C when the aphid can produce an average of 2.8 nymphs per day (in the USA) (Isely, 1946). Crowding effects have been shown for *A. gossypii* on cotton. One study examined crowding using leaf disks with a single apterous aphid which was removed following reproduction. The resulting colonies contained 1-7 nymphs. From 52 colonies with 1-2 nymphs, no alates were produced. From 41 colonies with 3-4 nymphs, less than 10% of the colony became alate. However, of 29 colonies with 5-7 nymphs, over 30% of the total number of aphids became alate (Graham, 1968). This experiment was repeated as part of the control for another experiment. Two possibly significant differences were apparent: alate production only occurred in colonies with four or more nymphs, and colonies with 5-7 nymphs only produced 12% alates (Graham, 1968). In laboratory colonies, the flight period lasted from 1 to 4 days (Nozato, 1990). Older colonies produced fewer alates that flew for 1 day and more that flew for 2 days. Aphids flew from one to several (about 5) times each day, with the first flight always longer than the others. Alates that flew longer had a shorter reproductive period and produced fewer total progeny (Nozato, 1987).

Damage

A. gossypii causes direct feeding damage to cotton, okra, sunflower and some other crops, by sucking the sap directly from the phloem, causing the removal of nutrients. The drain on plant nutritional resources can be considerable. Adverse physiological responses of plants to direct feeding can also occur. The undersides of young leaves are preferred, but the entire plant may be covered when populations are large. Infested leaves curl downwards and may appear wrinkled or reddened. Heavy infestations can result in wilting. Young plants often have reduced or stunted growth, and may sometimes be killed. *A. gossypii* is the principal aphid attacking cotton, on which it is an early through mid-season pest; although damaging late season infestations can occur, especially if broad-spectrum insecticides have reduced natural enemy populations (Matthews, 1989; Ebert and Cartwright, 1997).

In the USA, *A. gossypii* caused more insect-related damage to cotton than any other pest in 1991. Of 13 million acres harvested, around 10 million acres were classified as infested with aphids, resulting in losses of over 360,000 bales (Head, 1992).

Helianthus attracts a variety of aphid types, including the melon, peach, and leaf curling plum aphid. Regardless of the type, aphids are small insects that will suck on leaves, young stems, and flower petals. They also secrete honeydew, which ants and painted lady butterflies like to feed on, and which can develop sooty mold (Dekker, 2021).

2.2.2. Whitefly

The genus Bemisia contains 37 species and is thought to have originated from Asia (Mound and Halsey, 1978). Bemisia tabaci, being possibly of Indian origin (Fishpool and Burban, 1994), was described under numerous names before its morphological variability was recognized.

Taxonomic tree

Domain: Eukaryota
 Kingdom: Metazoa
  Phylum: Arthropoda
   Subphylum: Uniramia
    Class: Insecta
     Order: Hemiptera
      Suborder: Sternorrhyncha
       Superfamily: Aleyrodoidea
        Family: Aleyrodidae
         Genus: *Bemisia*
          Species: *Bemisia tabaci*

Biology

Eggs are pear shaped with a pedicel spike at the base, approximately 0.2 mm long. Larva is Yellow-white scales, 0.3-0.6 mm long. Puparium is flat, irregular oval shape, 0.7 mm long. On a smooth leaf the puparium lacks enlarged dorsal setae, but if the leaf is hairy, two to eight long dorsal setae are present. Adults are about 1 mm long, the male slightly smaller than the female. The body and both pairs of wings are covered with a powdery, waxy secretion, white to slightly yellowish in colour (Martin, 1987).

Damage

The feeding of *B. tabaci* adults and nymphs causes chlorotic spots to appear on the surface of the leaves. Depending on the level of infestation, these spots may coalesce until the whole of the leaf is yellow, apart from the area immediately around the veins. Such leaves are later shed. The honeydew produced by the feeding of the nymphs covers the surface of the leaves and can cause a reduction in photosynthetic potential when colonized by moulds. Honeydew can also disfigure flowers and, in the case of cotton, can cause problems in processing the lint. With heavy infestations, plant height, number of internodes and quality and quantity of yield can be affected. Most biotypes of *B. tabaci* can vector over 60 plant viruses in the genera Geminivirus, Closterovirus, Nepovirus, Carlavirus, Potyvirus and a rod-shaped DNA virus (Markham *et al.*, 1994; Alegbejo, 2000). Those biotypes that are poor vectors, appear so, due to their inability to feed on alternative host plant species (Bedford *et al.*, 1994b). Whitefly-transmitted geminiviruses, now called begomoviruses, are by far the most important agriculturally, causing yield losses to crops of between 20 and 100% (Brown and Bird, 1992; Cathrin and Ghanim, 2014).

2.2.3. Jassid

Amrasca is a genus of true bugs belonging to the family Cicadellidae. The species of this genus are Southeastern Asia.

Taxonomic tree

Domain: Eukaryota
Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Suborder: Auchenorrhyncha
Family: Cicadellidae
Genus: *Amrasca*
Species: *Amrasca biguttula*

Biology

The adult cotton jassid is a long and slender insect about 2.6 mm in length. It is yellowish-green, with a conspicuous black spot on either side of the head and another near the tip of the fore wing. The head is pale green and the membranous wings transparent and iridescent. On leaf surfaces, the insect tends to move about diagonally, and when disturbed it immediately jumps and flies away. Leafhoppers undergo direct development from nymph to adult without undergoing metamorphosis. On okra, eggs are mainly oviposited inside the tissue of leaf blades, but may also be laid in leaf stalks or in soft twigs. The eggs hatch in six or seven days. There are five nymphal instars, developing over a period of about seven days. Nymphs are wingless. Total lifespan is about one month, with females living a little longer than males. The fecundity of females is about fifteen eggs. Adults are attracted to light, females more than males (Koul *et al.,* 2014).

Damage

Heavy infestations on cotton, okra, and sunflower make the leaves turn yellow, curl up and fall off. The insects also secrete honeydew, and sooty mould often grows on this, restricting the amount of light reaching the plant's photosynthetic surfaces and reducing the yield. In many areas, this pest regularly occurs on cotton in epidemic numbers. A number of natural enemies help to control populations including ladybirds, predatory lygaeid bugs, and several species of mantis. Neem oil can be used as a biopesticide (Jayasimha *et al.*, 2012).

2.2.4. Stink bug

The brown marmorated stink bug (*Halyomorpha halys*) is an insect in the family Pentatomidae, native to China, Japan, Korea and other Asian regions. In September 1998 it was collected in Allentown, Pennsylvania, where it is believed to have been accidentally introduced (Steve, 2010).

Taxonomic tree

Domain: Eukaryota
  Kingdom: Animalia
    Phylum: Arthropoda
      Class: Insecta
        Order: Hemiptera
          Suborder: Heteroptera
            Family: Pentatomidae
              Genus: *Halyomorpha*
                Species: *Halyomorpha halys*

Biology

Adult brown marmorated stink bugs are approximately 1.7 cm (0.67 in) long and about as wide, forming the heraldic shield shape characteristic of bugs in the superfamily Pentatomoidea. They are generally a dark brown when viewed from above, with a creamy white-brown underside. Individual coloration may vary, with some bugs being various shades of red, grey, light brown, copper, or black. The term "marmorated" means variegated or veined, like marble, which refers to the markings unique to this species, including alternating light-colored bands on the antennae and alternating dark bands on the thin outer edge of the abdomen. The legs are brown with faint white mottling or banding (Rice *et al.*, 2014).

The nymph stages are black or very dark brown, with red integument between the sclerites. First instar nymphs have no white markings, but second through fifth instar nymphs have black antennae with a single white band. The legs of nymphs are black with varying amounts of white banding (Rice *et al.*, 2014). Freshly molted individuals of all stages are pale white with red markings. Eggs are normally laid on the underside of leaves in masses of 28 eggs, and are light green when laid, gradually turning white (Rice *et al.*, 2014).

Like all stink bugs, the glands that produce the defensive chemicals (the smell) are located on the underside of the thorax, between the first and second pair of legs (Steve, 2009).

Damage

The nymphs and adults of the brown marmorated stink bug feed on over 100 species of plants, including many agricultural crops, and by 2010–11 had become a season-long pest in orchards in the Eastern United States. In 2010, in the Mid-Atlantic United States, $37 million in apple crops were lost, and some stone fruit growers lost more than 90% of their crops (Rice *et al.*, 2014).

The brown marmorated stink bug is a serious agricultural pest that has been readily causing damage to crops across the Eastern United States. They feed on a wide array of plants including apples, apricots, Asian pears, cherries, corn, grapes, lima beans, peaches, peppers, tomatoes, and soybeans. This makes them extremely versatile, as they do not require a specific plant on which to feed. To obtain their food, stink bugs use their stylets to pierce the plant tissue to extract the plant fluids (McPherson and McPherson, 2000). In doing so, the plant loses necessary fluids, which can lead to deformation of seeds, destruction of seeds, destruction of fruiting structures, delayed plant maturation, and increased vulnerability to harmful pathogens. While harvesting the plant's juices, the stink bug injects saliva into the plant, creating a dimpling of the fruit's surface and rotting of the material underneath (O'Brien, 2019).

The most common signs of stink bug damage are pitting and scarring of the fruit, leaf destruction, and a mealy texture to the harvested fruits and vegetables. In most cases, the signs of stink bug damage make the plant unsuitable for sale in the market, as the insides are usually rotten. In field crops such as corn and soybeans, the damage may not be as evident as the damage seen in fruit plants. When stink bugs feed on corn, they go through the husk before eating the kernels, hiding the damage until the husks are removed during harvesting. The same damage is seen in soybeans, as the stink bug goes through the seed pods to acquire the juices of the seeds. One visual cue of stink-bug damage to soybean crops is the "stay green" effect, where damaged soybean plants stay green late into season, while other plants in the field die off normally. One can usually tell that a field of crops is infected because stink bugs are known for the "edge effect", in which they tend to infest crops 30–40 ft from the edge of the field (Barkham, 2021).

2.3. Damage assessment of insect pests of sunflower

A number of insects cause defoliation damage to sunflowers during the course of the season (e.g., palestriped flea beetle, sunflower beetle, painted lady caterpillar, and grasshoppers). The effect of these insects on sunflower yield varies with the extent of defoliation and the plant growth stage at the time of defoliation. The percent yield loss resulting from various levels of defoliation. These values can be used to estimate treatment thresholds for defoliating insects. Economic losses fall in the range of about 5 to 10 percent yield loss, as these losses would generally equal the cost of an insecticide treatment. For example, 5 percent yield loss of a 1,200 pound yield on oil-seed types would equal 60 pounds and at $0.25 per pound the loss would be $15, the approximate cost of an insecticide treatment. Higher yields or crop value would result in a lower threshold yield loss and lower yields or crop value would result in a higher threshold yield loss (Peairs, 2018).

Since plants are capable of compensatory growth during vegetative stages, defoliation levels from 50 to 70 percent are required to result in about a 5 percent yield loss. Damage during early reproductive stages (R-2 to R-5) has the greatest effect on yield. During this time, defoliation thresholds vary from 15 to 40 percent and before and after these stages, thresholds are not reached until more than 40 percent of the leaf area has been lost (Bala *et al.*, 2018).

2.4. Effect of micronutrients against insect pests of sunflower

Sulphur, zinc and boron has an effect on the growth, yield components and yield of hybrid sunflower. The growth components of sunflower (plant height, leaf area index, dry matter production, leaf area duration (LAD) and growth analysis parameters such as crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) and chlorophyll content, yield components and seed yield were significantly influenced by foliar application of 0.5% Zn on bud initiation stage and seed formation stage and B @ 0.3% on bud initiation stage and ray floret formation stage along with S (sulphur) @ 40 kg ha^{-1} and RDF (recommended dose of fertilizers) as a soil application. They found that foliar application of Zn @ 0.5% and B @ 0.3% along with S @ 40 kg ha^{-1} and RDF recorded the highest percentage of dry matter production (44.4%), number of filled seeds (30.1%) and yield (32.4%) of hybrid sunflower (Ravikumar *et al.*, 2021).

The relationship among yield attributes and achene yield of sunflower was also determined through correlation analysis. Solo applied boron (0.7%) remained unmatched by recording the maximum yield attributes such as plant height, stem girth, number of leaves, head diameter and weight, number of achenes per head and 100-achene weight which led to the highest achene yield (0.96 t ha^{-1}). The co-application of zinc and boron followed solely applied boron, while manganese applied solely or in conjunction with zinc and boron remained inferior to rest of the micronutrients. The correlation analysis revealed direct interrelationships among yield attributes (plant height, stem girth, head diameter and weight) and achene yield of sunflower and thus indicating the need to exogenously supply micronutrients especially boron for improving the agro-botanical traits and economic yield of sunflower under temperate conditions of rainfed regions (Faisal *et al.*, 2020).

Phenolics interfere with digestion, slow growth, block enzyme activity and cell division. Terpenes like monoterpenes, sesquiterpenes, terpene polymers interfere with neural transmission, block phosphorylation and gum up insects. Excessive dietary P (1%) reduced growth and survival of some insects. e.g.- *Schistocerca Americana* (Bala *et al.*, 2018).

Production of antibiosis effects like toxic metabolites (alkaloids, glucosides) and by inducing sufficiency of essential nutrients. e.g. zinc and iron content produces antibiosis effect in paddy against Brown plant hopper. With increase in zinc and sulphur content the brown plant hopper population decreased. Application of silicon in crops provides a variable component of integrated management of insect pests and diseases because it leaves no pesticide residue in food or environment, and it can be easily integrated with other pest management practices. Almeida *et al.* (2009) observed that increase in number of applications of calcium silicate reduced population thrips due to mortality of nymphs in tomato. Silicon reduced borer survival and percentage stalk length bored (Keepling *et al.*, 2012).

A field experiment was carried out in 2008 to 2009 growing season at Research Farm of Faculty of Agriculture, Zabol University, Iran by Galavi *et al.* (2012). The experiment treatments included: F1: control, F2: Fe, F3: Zn, F4: B, F5: Mn, F6: Fe+B, F7: Fe+Mn, F8: Fe+Zn and F9: Zn+B. These micronutrient fertilizers were used in two times as: 60 days after planting and 80 days after planting. The results revealed that micronutrients foliar application had a significant effect on seed and biological yield, 1000-seed weight and seed oil percentage; but the harvest index and number of seed per head was not significantly influenced by applied treatments. The maximum seed yield and biological yield as well as 1000-seed weight obtained from F2 treatment and the maximum oil percentage was achieved from F6 and also maximum number of seed per capitol was obtained from F3.

The sunflower variety HO-1 was treated with 0-0, 10- 1.5, 10-2, 15 -1.5, 15-2.0, 20-1.5 and 20- 2.0 Zn-B kg ha^{-1}. A basal dose of N, P and K was applied at the rates of 90, 45 and 45 kg ha^{-1} respectively across Zn-B treatments. The increase in Zn and B fertilizers from 10-1.5 to 20-2 kg ha^{-1} increased physiological parameters, nutrient uptake and seed yield of sunflower. The maximum yield response was noted when Zn and B were applied at the rates of 15 and 1.5 kg ha^{-1} respectively, beyond this level, no further increase were noted in any sunflower traits. Under this optimal Zn -B treatments, sunflower recorded higher dry matter, leaf area index, leaf area duration, crop growth rate and net assimilation rate all measured at flowering stage. Under the chosen macronutrient fertility level on this farm, sunflower growth and yield was optimized with micronutrient levels of 15 kg ha^{-1} Zn and 1.5 kg ha^{-1} B (Siddiqui *et al.*, 2009).

2.5 Effect of micronutrients

Application of micronutrients plays a major role in increasing seed setting percentage and influence growth and yield (Kumbhar *et al.*, 2017). There are positive effects of micronutrient application on the growth of sunflower, in terms of plant height, number of leaves and dry matter production per plant (Siddiqui *et al.*, 2009).

The heads consist of many individual flowers which mature into seeds on a receptacle base (Seghatoleslami *et al.*, 2012). To ameliorate seed filling problems and for increasing seed yield and quality in sunflower, several approaches including application of micro nutrients have been suggested. Area under this crop is gradually decreasing due to its inherent problems like improper seed filling, low seed yield per hectare and non-availability of quality seed for seed production. Therefore, there is a need to circumvent these problems by using modern techniques like adequate mother plant nutrition, application of micro nutrients like boron, sulphur and zinc in combination with major nutrients to mitigate the problem of poor setting and seed yield. Boron, as a foliar spray was found to increase thousand seed weight and seed oil content (Kastori and Grujie, 1992).

Zinc has emerged as an indispensable nutrient for plant growth. It is involved in the bio- synthesis of plant hormone, Indole Acetic Acid (IAA) and is a component of variety of enzymes. It plays an important role in nucleic acid and protein synthesis and helps in utilization of phosphorous and nitrogen as well as seed formation and development. Soil application of zinc at the rate of four kg per ha at the time of sowing increased the leaf area index, crop growth rate, net assimilation rate and seed yield in sunflower (Sarkar *et al.*, 1998).

Among micronutrients, boron is known to play an important role in seed setting and yield of sunflower. Boron can influence photosynthesis and respiration and activate a number of enzymatic systems of protein and nucleic acid metabolism in plants (Kibalenko, 1972). It also stimulates germination of pollen tubes which results in better fertilization and higher seed set in sunflower (Johri and Vasil, 1961).

Zinc and boron play a very important role in quantitative and qualitative development of plants which results in higher seed weight. Baloch *et al.* (2015), application of zinc promotes reproduction and development of seed Sepehr *et al.* (2002).

Farokhi *et al.* (2014) reported that consumption of FeSO4, ZnSO4 and boron either single or combined had optimistic effect on plant height and head diameter. Similar findings were also reported by Chowdhary *et al.* (2010); Reddy *et al.* (2011); Hadi *et al.* (2014); Sudarsan and Ramaswamy (1993).

Zinc-deficient plants are stunted with distorted upper leaves. As the deficiency intensifies, leaves tend to wilt. Zinc deficiencies, or responses to added zinc, are not likely in the region (Vigil *et al.*, 2001).

Bahaa El-Din (2015) reported that application of 300 ppm B resulted in an increase of palmitic, stearic and oleic acids as compared to the treatment with 600 ppm B and control plants but the linoleic acid increased gradually with increasing B up to 600 ppm and cleared that B plays a vital role for increasing the productivity and quality of sunflower plants, especially when grown under B deficient soil. Significant decline in stearic acid and oleic acid contents while considerable increase in palmitic acid and linoleic acid contents was recorded by individual use of nitrogen and boron supplements. Farokhi *et al.* (2014) who found that oil yield and oil percent were increased with B application in sunflower. They also showed the effect of B on sunflower yield. They reported that the maximum oil contents were observed when B was applied at a rate of 8 kg ha^{-1} at the time of bud initiation.

Zn fertilization with 10 to 20 kg per hectare increases oil content of the sunflower seed. In contrast, increasing in Zn concentration reduced oil content of the sunflower seeds (Mirzapour and Khoshgoftar, 2006). According to Khurana and Chatterjee (2001), more than 0.65 mg. L^{-1} zinc supply inhibits oil content of sunflower seeds.

Ebrahimian *et al.* (2010) reported that oil content increases by use of Zn microelement and soil application of Zn micronutrients is more beneficial to oil biosynthesis. In addition, they concluded that foliar application of Zn microelement significantly increased POD (peroxidase) and SOD (superoxide dismutase) but decreased significantly CAT (catalase) activity and Zn foliar application significantly increased palmitoleic, linolenic, oleic and myristic acid content in sunflower. In another study, conducted by Eslami *et al.* (2015), spraying zinc sulfate to sunflowers effected oil content of the plants.

Asad *et al.* (2003) also reported that sunflower growing on boron deficient soils responded to B application by increasing both vegetative and reproductive mass and B concentration in several parts of the plant shoot. Thus, application of adequate fertilizers led to increase the crop yields,

CHAPTER III

MATERIALS AND METHOD

This study was undertaken to analyze the effect of micronutrients (B, Zn & Mn) on incidence, damage severity of sucking insect pests of sunflower and their impact on yield and other beneficial arthropods. The experiment was conducted during rabi season of 2021-22. The details of experimental site, materials and method followed for conducting the experiment were as follows:

3.1. Location

The experimental site was located at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from October, 2021 to July, 2022. The experimental field was located at 90°335' east longitude and 23° 774' north latitude at a height of 4 meter above the sea level. The land was medium high and well drained.

3.2. Climate

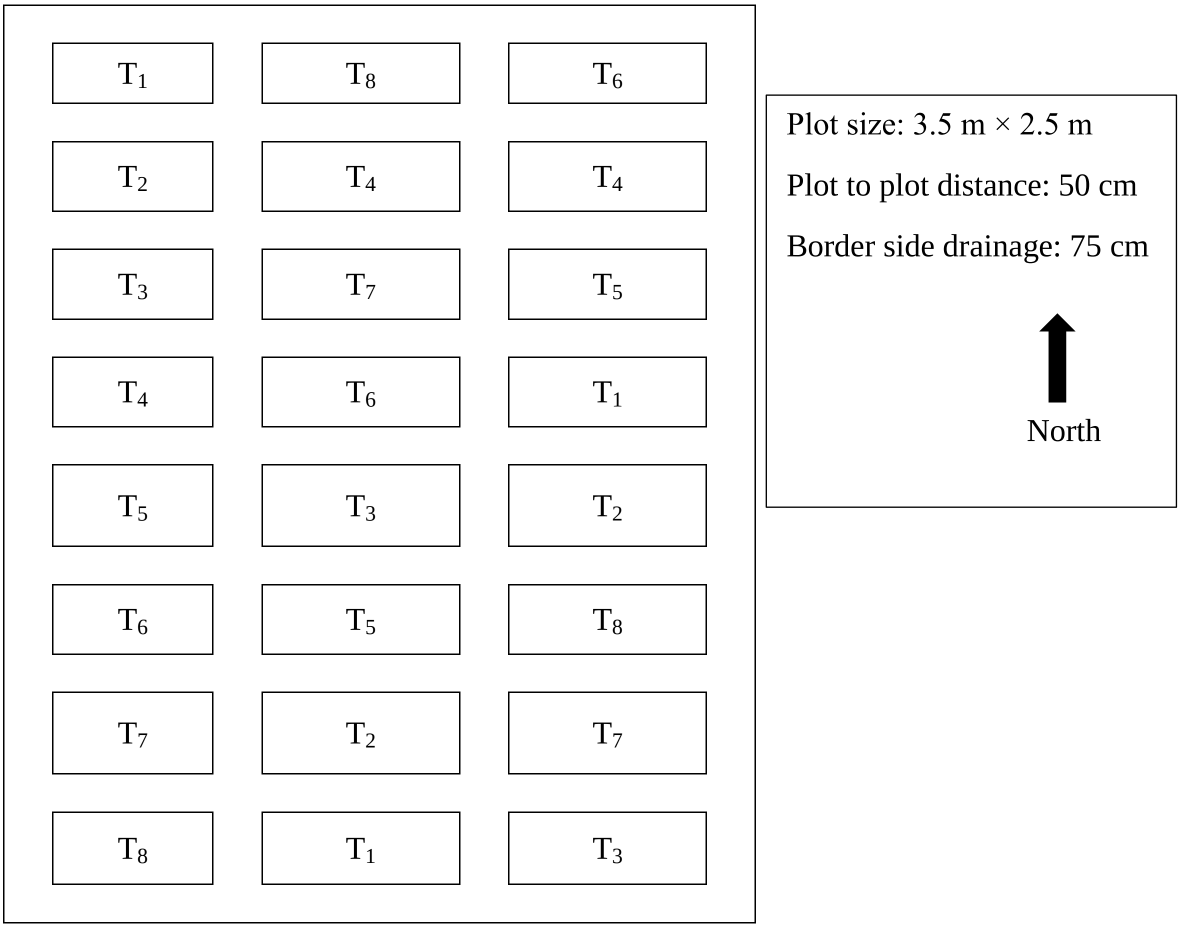
The experimental site was situated in the sub-tropical climatic zone, characterized by lower rainfall during the month of October, 2021 to July, 2022. Monthly maximum and minimum temperature, relative humidity and total rainfall recorded during the period of study at the SAU experimental farm was recorded. The recorded and calculated as monthly average temperature, relative humidity and rainfall for the crop growing period of experiment were noted from the Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1207 and has been presented.

3.3. Soil

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

3.4. Design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in the field of the Entomology Department. The whole field was divided three blocks of equal size and each block was sub divided into eight plots. The unit plot size was 3.5 m × 2.5 m accommodating twelve pits per plot. The distance between row to row was 50 cm and that of the plants to plants was 25 cm. Layout of the experimental field was given bellow:



3.5. Land preparation

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

3.6. Manuring and fertilization

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

Manure/ Fertilizers	Dose per ha
Cow-dung	10 tons
Urea	200 Kg
Triple Super Phosphate (TSP)	180 Kg
Muriate of Potash	170 Kg

The full dose cow-dung and TSP were applied as basal dose during final land preparation. One-third of the MP and urea were applied in the pits one week before transplanting and rest of the MP and urea were applied as the top dressing at 25 and 50 days after transplanting.

3.7. Raising of seedling and transplanting

Sunflower seeds (Vatiety: High Sun-33, Kironi (DS-1)) were collected from Siddique bazar, Dhaka. A seedbed measuring 3.5m×4.0m was prepared and seeds were sown in the plot at SAU experimental field on 15th October 2021. The plots were lightly irrigated regularly for ensuring seed proper development of the seedlings. Seeds of each entry were sown in 2 rows x 4 m long plot, keeping 50 cm inter-row spacing with 25-30 cm between plants. Three to four seeds were sown per hill to facilitate better emergence and to maintain uniform stand.

3.8. Intercultural operations

3.8.1. Thinning

At the time of transplanting a few seedlings were transplanted in the border of the experimental plots for gap filling. Very few numbers of seedlings were weak after germination were thinned out from the experimental plot.

3.8.2 Irrigation

After transplanting light irrigation was given to each plot. Supplementary irrigation was applied at 25, 50 and 70 days after emergence. Stagnant water was effectively drained out at the time of over irrigation. The urea was top dressed in three splits as mentioned earlier.

3.9.3 Gap filling

The seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after germination and such seedling were replaced by new seedlings Replacement was done with healthy seedling having a boll of earth which was also planted on the same date by the side of the unit plot. The seedlings were given watering for 7 days starting from germination for their proper establishment.

3.8.4 Weeding

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

3.9. Treatment for control measures

The experiment was evaluated to determine the effect of micronutrients on incidence, damage severity of insect pests of sunflower and its impact on yield and beneficial arthropods. micronutrient based treatments as well as their doses to be used in the study are given bellow:

Treatment	Dose for plot
T_1	Boron @ 7.0 g/ plot+ $ZnSO_4$ @ 8.4 g/ plot
T_2	Spraying 0.2% Borax @ 2g/ L of water
T_3	Spraying 0.2% $ZnSO_4$ @ 2g/ L of water
T_4	Spraying 0.5% Borax @ 2g/ L of water
T_5	Spraying 0.2% Borax and 0.2% $ZnSO_4$ @ 2g/ L of water
T_6	Spraying 0.5% $ZnSO_4$ @ 2g/ L of water
T_7	$MnSO_4$ @ 8 g/ plot
T_8	No micronutrient (control)

3. 10. Data collection

Data were collected some pre-selected parameters like number of leaves and number of plants per plot, weight of seeds per head, number of seeds per head and yield of sunflower. The number of whitefly, jassid, aphid etc. were counted from treated and untreated plots of sunflower throughout the cropping season starting from 20 days after transplanting. Among the characters days to 50 % flowering, days to maturity, plant height (cm), stem diameter (cm) and head diameter (cm) were recorded from the standing plants in the field. The other characters were recorded in the laboratory after harvest. The observations on days to 50% flowering and days to maturity were recorded on plot basis. The characters were:

3.10.1. Plant height

Plant height was measure from the base of the plant to the point of attachment of the capitulum at harvest and expressed in centimeters.

3.10.2. Number of seed per head

Total number of seeds per head was counted from the five plants of each of unit plot and mean number of seeds produced per head was calculated.

3.10.3. Number of leaves per plant

Number of leaves per plant was counted at harvest. The number of leaves plant^{-1} was counted from five tagged plants excluding the small leaves, which were produced by axillary shoots. The fallen leaves were counted on the basis of scar marks on the stem and mean value was calculated.

3.10.4. Number of infested leaves per plant

Number of infested leaves per plant was counted at harvest. The number of infested leaves plant^{-1} was counted from five tagged plants excluding the small leaves, which were produced by axillary shoots. The fallen leaves were counted on the basis of scar marks on the stem and mean value was calculated.

3.10.5. Leaf area

The leaf area (cm^2) was measured with a meter scale from the top of two diagonal leaves. Mature leaves were measured all the time and were expressed in cm^2 and mean

value was calculated.

3.10.6. Diameter of capitulum sunflower

Diameter of head per capitulum was measured at middle portion of 5 sunflowers from each plot with a meter scale. Their average was taken and expressed in cm.

3.10.7. Diameter of single flower with petal

Diameter of single flower with petal was measured at the capitulum diameter with diagonal petals of 5 sunflowers from each plot with a meter scale. Their average was taken and expressed in cm.

3.10.8. Number of petals

Total number of petals was counted from the plant of each head of five flowers and number of petals produced per plant was calculated.

3.10.9. Number of calyx

Total number of calyx produced per plant was counted from the head of five flowers.

3.10.10. Number of total head per plot

Total number of head produced per plant was counted.

3.10.11. Weight of total seed per plot

Weight of total seeds per plot of sunflower recorded by using digital weight machine and was expressed in gram.

3.10.12. Weight of seed per head

Weight of seeds per head of sunflower was recorded by using digital weight machine and was expressed in gram.

3.10.13. Weight of single seed

Weight of single seed of sunflower was recorded by a mini electronic weighing machine and was expressed in gram.

3.10.14. Yield

Heads of sunflower were harvested, sundried and threshed separately according to treatments. Finally, yield data was recorded on the basis of plot size.

3.10.15. Number of insect pests per plot

Number of insect pests (jassid, whitefly, aphid and stink bug) were counted by eye sight presence of insect pests in the plot. Data was collected from five tagged plants and average data was recorded.

3.10.16. Seed germination (%) and seed vigour (%): Carried out with two sub-samples of 50 seeds for each treatment and replication, which were preconditioned on paper towels moistened with distilled water for 16 hr in a germinator set at 25°C ± 2°C. After this period, the seeds were transferred to plastic cups (50 ml) and were completely submerged in 0.075% tetrazolium solution for three hours, in an incubator set at 40°C in the dark. After staining, the seeds were classified for vigour and viability at levels from 1 to 8, according to the criteria proposed by França-Neto *et al.* (1998). The vigour and germination potentials were expressed as a percentage (França-Neto *et al.*, 1999).

3.10.17. The infested leaves were calculated by the following procedure

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

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

3.10.18. The infested plants were calculated by the following procedure

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

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

3.10.19 Determination of protein content (AOAC, 2000)

The reagents were used in the treatment were-

- Kjedahl catalyst: Mix 9 part of potassium sulphate (K2SO4) with 1 part of coppersulphate ($CuSO_4$)
- Sulfuric acid ($H2SO_4$)
- 40% NaOH solution
- 0.2 N HCl solution
- 4% H_3BO_3
- Indicator solution: Mix 100 ml of 0.1% methyl red (in 95% ethanol) with 200 ml of 0.2% bromocresol green (in 95% ethanol).

Procedure:

Samples were placed (0.5-1.0 g) in digestion flask. Kjedahl catalyst 5g was added in the flask and also added 200ml of concentration H_2SO_4. A tube containing the above chemical except sample as blank was prepared. Flasks were placed in inclined position and heated gently unit frothing ceases and boiled briskly until solution became clear. The solution was cooled and then 60ml distilled water was added cautiously. Flask was connected to digestion bulb on condenser immediately and with tipped of condenser immersed in standard acid and 5-7 drops of mix indicator in receiver. Flask was rotated to mix content thoroughly; then heated until all NH_3 was distilled. Receiver was removed, washed tip of condenser and titrate excess standard acid distilled with standard NaOH solution.

To calculate the protein percent following formula was used:

$$\text{Protein (\%)} = \frac{(A-B) \times N \times 14.007 \times 6.25}{W}$$

Where, A= Volume (ml) of 0.2 N HCl used sample titration

B= Volume (ml) of 0.2 N HCl used in blank titration

N= Normality of HCl

W= Weight of sample (g)

14.007= Atomic weight of nitrogen

6.25= The protein-nitrogen conversation factor for oil seed.

3.11. Statistical analysis

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

CHAPTER IV

RESULTS AND DISCUSSION

Results of the experiment entitled “effect of micronutrients (B, Zn & Mn) on incidence, damage severity of sucking insect pests of sunflower and their impact on yield, quality seed production and beneficial arthropods”, conducted during rabi season 2021-22 at the farm of Sher-e-Bangla Agricultural University, Dhaka are presented in this chapter. The observations pertaining to growth and yield attributes of sunflower recorded during the course of investigation were statistically analyzed and significance of results verified. Some of the characters have also been represented graphically to show the treatment effect wherever necessary to provide better understanding of the results.

4.1. Insect pest incidence of sunflower

4.1.1. Whitefly

Whitefly is one of the most important sucking insect pests of sunflower which attacks at the early stage. The incidence of whitefly decreased significantly due to different treatments of micronutrients applied on sunflower (Figure 1). At the early stage, the maximum number of whitefly per plant (8.17 whitefly) was recorded from T_8 treatment and the minimum number of whitefly per plant (2.83 whitefly) was observed from T_5 treatment (Figure 1). More or less same trend was observed in vegetative stage, reproductive stage and ripening stage of sunflower. The maximum incidence of whitefly was observed during reproductive stage of the plant. At the reproductive stage, the maximum number of whitefly per plant (19.00 whitefly) was recorded from T_8 treatment and the minimum number of whitefly per plant (9.67 whitefly) was observed from T_5 treatment. Similar result was also observed by Nayak *et al.* (2022) and Geetha and Hegde (2018).

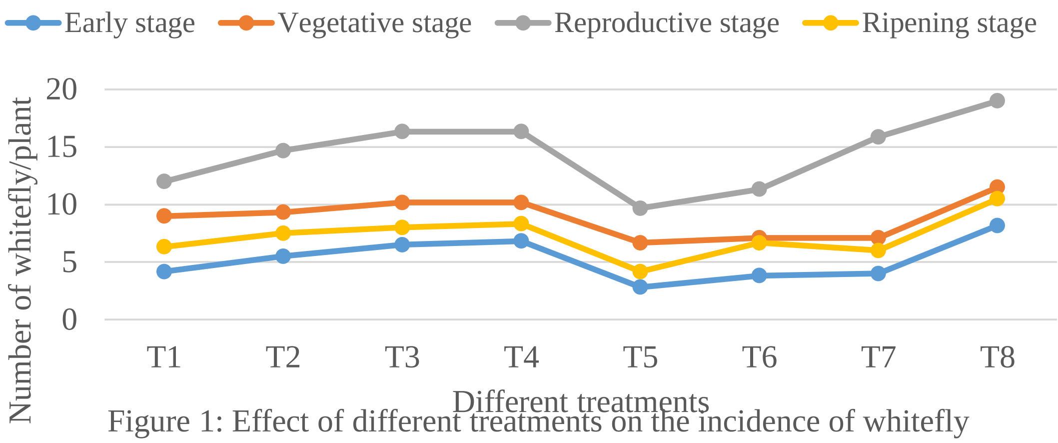


Figure 1: Effect of different treatments on the incidence of whitefly at different growing stage of sunflower

4.1.2. Jassid

Jassid is also important sucking insect pests of sunflower which also attacks at the early stage. The incidence of jassid decreased significantly due to different treatments of micronutrients applied on sunflower (Figure 2). At the early stage, the maximum number of jassid per plant (8.84 jassid) was recorded from T_8 treatment and the minimum number of jassid per plant (1.50 jassid) was observed from T_5 treatment (Figure 2). More or less same trend was observed in vegetative stage, reproductive stage and ripening stage of sunflower. The incidence of jassid was picked at vegetative stage and after that it was decreased. At the vegetative stage, the maximum

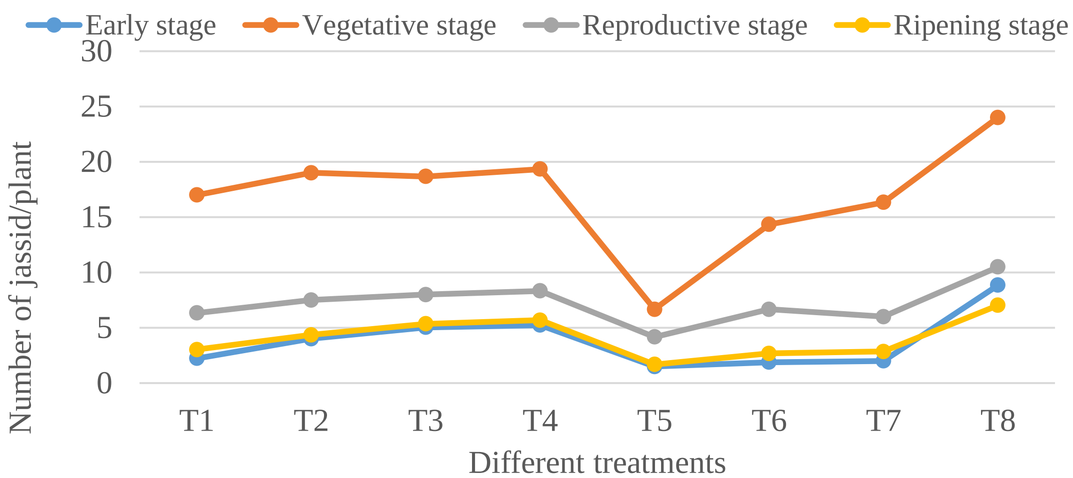


Figure 2: Effect of different treatments on the incidence of jassid at different growing stage of sunflower

number of jassid per plant (24.00 jassid) was recorded from T_8 treatment and the minimum number of jassid per plant (6.67 jassid) was observed from T_5 treatment Similar result was also observed by Nayak *et al.* (2022) and Geetha and Hegde (2018).

4.1.3. Aphid

Aphid is another sucking insect pests of sunflower which attacks at the vegetative stage. The incidence of aphid decreased significantly due to different treatments of micronutrients applied on sunflower (Figure 3). At the early stage, there was no incidence of aphid in the sunflower field. At the vegetative stage, the maximum number of aphid per plant (9.67 aphid) was recorded from T_8 treatment and the minimum number of aphid per plant (1.75 aphid) was observed from T_5 treatment (Figure 3). More or less same trend was observed in reproductive stage and ripening stage of sunflower. But the maximum incidence of aphid was found during the ripening stage of the plant. In the ripening stage, the maximum number of aphid per plant (25.00 aphid) was recorded from T_8 treatment and the minimum number of aphid per plant (5.33 aphid) was observed from T_5 treatment the Similar result was also observed by Nayak *et al.* (2022) and Geetha and Hegde (2018).

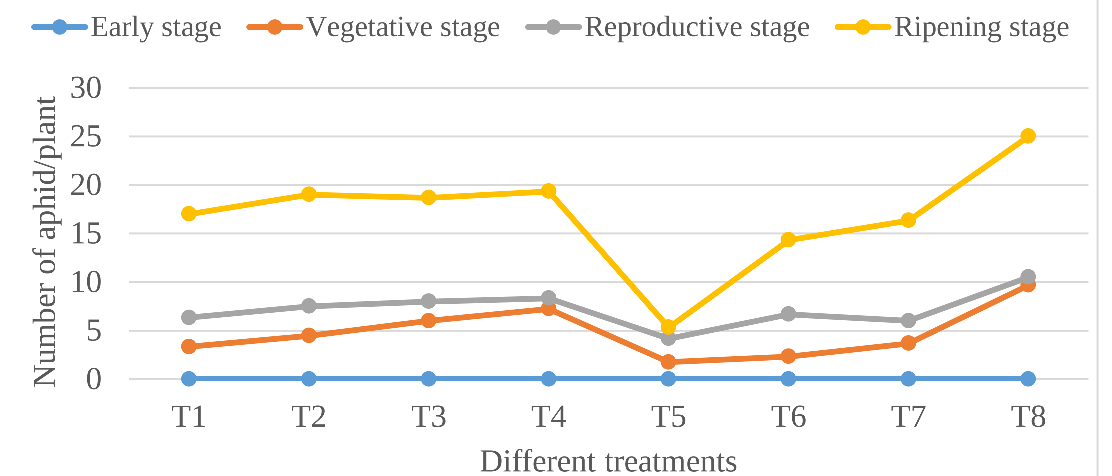


Figure 3: Effect of different treatments on the incidence of aphid at different growing stage of sunflower

4.1.4. Stink bug

Stink bug is a foliar insect pest of sunflower which attacks at the reproductive stage. The incidence of stink bug decreased significantly due to different treatments of micronutrients applied on sunflower (Figure 4). At the early and vegetative stages, there was no incidence of stink bug in the sunflower field. At the reproductive stage, the maximum number of stink bug per plant (0.96 stink bug) was recorded from T_8 treatment and the minimum number of stink bug per plant (0.24 stink bug) was observed from T_5 treatment (Figure 4). More or less same trend was observed in ripening stage of sunflower. Similar result was also observed by Nayak *et al.* (2022) and Geetha and Hegde (2018).

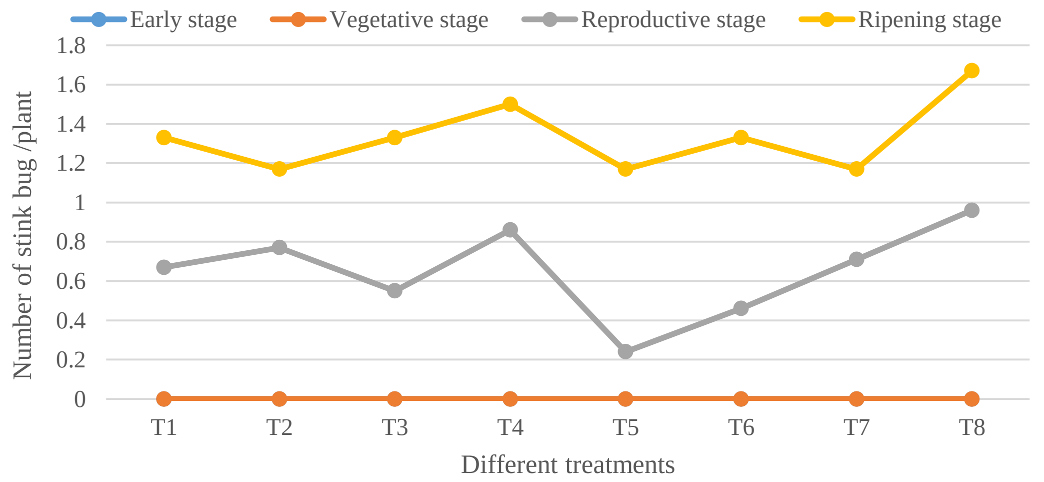


Figure 4: Effect of different treatments on the incidence of stink bug at different growing stage of sunflower

4.2. Leaf infestation by the insect pests

4.2.1. Number of leaves

As a part of the observation of leaf infestation by the insect pests of sunflower it is important to know the number of leaves of sunflower. From the result it was observed that leaf number of sunflower varied significantly with application of different rates of micronutrients (Table 1). The maximum number of leaves (23.11 leaves) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_6 (19.89), T_7 (17.56), T_1 (17.18) and T_2 (15.89 leaves). On the other hand, the minimum number of leaves (12.11 leaves) was observed from T_8 treatment which was statistically different from other treatments and followed by T_3 (14.56) and T_4 (15.11 leaves). Similar findings were also reported by Shamimuzzaman (2021) and Faisal *et al.* (2020).

4.2.2. Number of infested leaves

As a part of the observation of leaf infestation by the insect pests of sunflower it is important to know the number of infested leaves of sunflower. From the result it was observed that the number of infested leaves of sunflower varied significantly with application of different rates of micronutrients (Table 1). The minimum number of infested leaves (2.89 leaves) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_1 (3.77), T_6 (4.45), T_7 (4.89) and T_2 (5.22 leaves). On the other hand, the maximum number of leaves (8.22 leaves) was observed from T_8 treatment which was statistically different from other treatments and followed by T_3 (6.33) and T_4 (5.67 leaves).

4.2.3. Percent leaf infestation

As a part of the observation of leaf infestation by the insect pests of sunflower it is important to know the percent leaf infestation of sunflower. From the result it was observed that the percent leaf infestation of sunflower varied significantly with application of different rates of micronutrients (Table 1). The minimum percent leaf infestation (12.46 %) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_1 (21.93), T_6 (22.36), T_7 (27.86) and T_2 (32.86). On the other hand, the maximum percent of leaf infestation (67.93 %) was observed from T_8 treatment which was statistically different from other treatments and followed by T_3 (43.51) and T_4 (37.57 %).

Table 1: Effect of micronutrients on the infested leaves caused by different sucking insect pests in sunflower field

Treatments	Number of leaves	Number of infested leaves	% leaf infestation
T_1	17.18 c	3.77 e	21.93 e
T_2	15.89 d	5.22 cd	32.86 cd
T_3	14.56 e	6.33 b	43.51 b
T_4	15.11 de	5.67 bc	37.57 c
T_5	23.11 a	2.89 f	12.46 f
T_6	19.89 b	4.45 de	22.36 e
T_7	17.56 c	4.89 cd	27.86 de
T_8	12.11 f	8.22 a	67.93 a
CV (%)	3.33	9.54	10.15
LSD $_{(0.05)}$	0.99	0.87	5.92

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Boron @ 8.0 kg/ ha + ZnSo4 @ 9.6 kg/ ha; T_2= Spraying 0.2% Borax @ 2g/L of water; T_3= Spraying 0.2% ZnSo4 @ 2g/L of water; T_4= Spraying 0.5% Borax @ 2g/L of water; T_5= Spraying 0.2% Borax and 0.2% ZnSo4 @ 2g/L of water; T_6= Spraying 0.5% ZnSo4 @ 2g/L of water; T_7= $MnSO_4$ @ 9.0 kg/ ha; T_8= No micronutrient (control).]

4.3. Yield attributing characteristics

4.3.1. Plant height

Plant height is an important parameter of physiological characteristics of a plant. Plant height increased significantly due to different treatments of micronutrients applied on sunflower (Table 2). The maximum plant height (180.2 cm) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_6 (171.7), T_7 (166.1), T_1 (163.1) and T_2 (156.1 cm). On the other hand, the minimum plant height (144.5 cm) was observed from T_8 treatment which was statistically different from other treatments and followed by T_3 (152.1) and T_4 (154.7 cm) (Table 2). Similar result was also observed by Ravikumar *et al.* (2021), Shamimuzzaman (2021) and Faisal *et al.* (2020).

4.3.2. Leaf area

Leaf area is an important parameter of yield attributing characteristics for a plant. From the results it was observed that applications of micronutrient on sunflower showed significantly variation on leaf area (Table 2). The maximum leaf area (65.44 cm^2) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_2 (59.11), T_7 (58.78), T_6 (55.56) and T_1 (54.56 cm^2). On the other hand, the minimum leaf area (48.89 cm^2) was observed from T_8 treatment which was statistically different from other treatments and followed by T_3 (53.11) and T_4 (54.33 cm^2). Similar findings were also reported by Kawade *et al.* (2018); Saad and Al-Doori (2017) and Siddiqui *et al.* (2009).

Table 2: Effect of micronutrients on plant height and leaf area of sunflower

Treatments	Plant height (cm)	Leaf area (cm^2)
T_1	163.1 d	54.56 d
T_2	156.1 e	59.11 b
T_3	152.1 f	53.11 e
T_4	154.7 e	54.33 d
T_5	180.2 a	65.44 a
T_6	171.7 b	55.56 c
T_7	166.1 c	58.78 b
T_8	144.5 g	48.89 f
CV (%)	0.64	0.77
$LSD_{(0.05)}$	1.81	0.76

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Boron @ 8.0 kg/ ha + ZnSo4 @ 9.6 kg/ ha; T_2= Spraying 0.2% Borax @ 2g/L of water; T_3= Spraying 0.2% ZnSo4 @ 2g/L of water; T_4= Spraying 0.5% Borax @ 2g/L of water; T_5= Spraying 0.2% Borax and 0.2% ZnSo4 @ 2g/L of water; T_6= Spraying 0.5% ZnSo4 @ 2g/L of water; T_7= $MnSO_4$ @ 9.0 kg/ ha; T_8= No micronutrient (control).]

4.3.3. Diameter of capitulum of sunflower

The diameter of capitulum of sunflower showed statistically significant variation due to the application of different levels of micronutrients (Table 3). The highest capitulum diameter (12.04 cm) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_2 (10.05), T_6 (9.73), T_1 (8.36) and T_4 (7.96 cm). On the other hand, the lowest capitulum diameter (5.22 cm) was observed from T_8 treatment which was statistically different from other treatments and followed by T_3 (6.43) and T_7 (7.40 cm). Similar findings were also reported by Keerio *et al.* (2020) and Faisal *et al.* (2020).

4.3.4. Diameter of single flower with petal

Diameter of single flower with petal varied significantly due to different levels of micronutrient application on sunflower (Table 3). The maximum diameter of flower with petal (22.33 cm) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_4 (21.70), T_3 (21.42), T_2 (20.53) and T_1

(19.07 cm). On the other hand, the minimum diameter of flower with petals (15.33 cm) was observed from T_8 treatment which was statistically different from other treatments and followed by T_7 (17.22) and T_6 (17.52 cm). Similar findings were also reported by Shamimuzzaman (2021).

4.3.5. Number of petals

Number of petals varied due to application of different levels of micronutrient on sunflower (Table 3). The maximum number of petal (45.34 petals) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_6 (40.44), T_3 (39.11), T_1 (38.22) and T_7 (38.22 petals). On the other hand, the minimum number of petals (29.89 petals) was observed from T_8 treatment which was statistically different from other treatments and followed by T_4 (34.11) and T_2 (35.78 petals). Similar findings were also reported by Shamimuzzaman (2021).

4.3.6. Number of calyx

Number of calyx of sunflower varied significantly due to application of different levels of micronutrient (Table 3). The maximum number of calyx (59.33 calyx) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_2 (54.45), T_6 (54.22), T_4 (52.22), T_3 (52.11) and T_7 (51.56 petals). On the other hand, the minimum number of petals (42.55 petals) was observed from T_8 treatment which was statistically different from other treatments and followed by T_1 (48.11 calyx). Similar findings were also reported by Shamimuzzaman (2021).

Table 3: Effect of micronutrients on diameter of capitulum, diameter of single flower with petals, number of petals and number of calyx of sunflower

Treatments	Capitulum diameter (cm)	Diameter of single flower with petals (cm)	Number of petals	Number of calyx
T_1	8.36 c	19.07 d	38.22 d	48.11 d
T_2	10.05 b	20.53 c	35.78 e	54.45 b
T_3	6.43 e	21.42 b	39.11 c	52.11 c
T_4	7.96 cd	21.70 b	34.11 f	52.22 c
T_5	12.04 a	22.33 a	45.34 a	59.33 a
T_6	9.73 b	17.52 e	40.44 b	54.22 b
T_7	7.40 d	17.22 e	38.22 d	51.56 c
T_8	5.22 f	15.33 f	29.89 g	42.55 e
CV (%)	4.29	1.84	1.01	0.71
LSD $_{(0.05)}$	0.63	0.62	0.67	0.64

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Boron @ 8.0 kg/ ha + ZnSo4 @ 9.6 kg/ ha; T_2= Spraying 0.2% Borax @ 2g/L of water; T_3= Spraying 0.2% ZnSo4 @ 2g/L of water; T_4= Spraying 0.5% Borax @ 2g/L of water; T_5= Spraying 0.2% Borax and 0.2% ZnSo4 @ 2g/L of water; T_6= Spraying 0.5% ZnSo4 @ 2g/L of water; T_7= $MnSO_4$ @ 9.0 kg/ ha; T_8= No micronutrient (control).]

4.3.7. Number of seeds per head

Number of seeds per head varied significantly with different treatments applied on sunflower (Table 4). The maximum number of seed per head (1015 seeds) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_6 (934), T_1 (897), T_3 (884), T_4 (823) and T_7 (742 seeds). On the other hand, the minimum number of seeds per head (623 seeds) was observed from T_8 treatment which was statistically different from other treatments and followed by T_2 (692 seeds). Shamimuzzaman (2021) also observed the highest number of seeds per head (375.9) in sunflower which was similar to the present study. Similar Findings Keerio *et al.* (2020) and Saad and Al-Doori (2017) also in agreement with the results.

4.3.8. Weight of seed per head

Weight of seed per head varied significantly due to application of micronutrients (Table 4). The maximum weight of seed per head (85.26 g) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_6 (75.65), T_3 (67.18), T_1 (61.89), T_7 (53.42) and T_4 (51.05 g). On the other hand, the minimum weight of seed per head (36.13 g) was observed from T_8 treatment which was statistically different from other treatments and followed by T_2 (44.98 g). Similar findings were also reported by Shamimuzzaman (2021), he found that maximum weight of seeds per head (64.55 g) in sunflower.

Table 4: Effect of micronutrients on number of total head per plot, number of seeds per head and weight of seeds per head of sunflower

Treatments	Number of seeds/head	Weight of seeds/head (g)
T_1	897 c	61.89 d
T_2	692 g	44.98 g
T_3	884 d	67.18 c
T_4	823 e	51.05 f
T_5	1015 a	85.26 a
T_6	934 b	75.65 b
T_7	742 f	53.42 e
T_8	623 h	36.13 h
CV (%)	7.91	3.62
LSD $_{(0.05)}$	1.84	1.26

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Boron @ 8.0 kg/ ha + ZnSo4 @ 9.6 kg/ ha; T_2= Spraying 0.2% Borax @ 2g/L of water; T_3= Spraying 0.2% ZnSo4 @ 2g/L of water; T_4= Spraying 0.5% Borax @ 2g/L of water; T_5= Spraying 0.2% Borax and 0.2% ZnSo4 @ 2g/L of water; T_6= Spraying 0.5% ZnSo4 @ 2g/L of water; T_7= $MnSO_4$ @ 9.0 kg/ ha; T_8= No micronutrient (control).]

4.3.9. Weight of total seed per plot

Total seed weight per plot varied significantly due to application of different level of micronutrients (Table 5). The maximum weight of total seed per plot (2.56 kg) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_6 (2.27), T_3 (2.02), T_1 (1.86), T_7 (1.60) and T_4 (1.53 kg). On the other hand, the minimum weight of total seed per plot (1.08 kg) was observed from T_8 treatment which was statistically different from other treatments and followed by T_2 (1.35 kg). Shamimuzzaman (2021) also observed the highest weight of seeds per plot (2.51 kg) in sunflower which was similar to the present study. Similar findings were also reported by Sher *et al.* (2021).

4.3.10. Weight of single seed

Effects of different level of micronutrients on weight of single seed of sunflower varied significantly (Table 5). The results revealed that all the treatments were found significantly superior over control. The highest weight of single seed (0.084 g) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_6 (0.081), T_3 (0.076) and T_7 (0.072 g). On the other hand, the minimum weight of single seed (0.058 g) was observed from T_8 treatment which was statistically different from other treatments and followed by T_4 (0.062), T_2 (0.065) and T_1 (0.069 g). Shamimuzzaman (2021) also observed the highest weight of single seed (0.10 g) in sunflower which was similar to the present study. The results obtained by Sher *et al.* (2021), which was also supported the present findings.

4.3.11. Yield (t/ha)

Yield of sunflower seeds varied due to application of different levels of micronutrients under study (Table 5). The maximum yield per hectare (2.92 t) was recorded from T_5 treatment which was statistically different from others and followed by T_6 (2.59), T_3 (2.30), T_1 (2.12), T_7 (1.83) and T_4 (1.75 t). On the other hand, the minimum yield per hectare (1.24 t) was observed from T_8 treatment which was statistically different from other treatments and followed by T_2 (1.54 t). Chang *et al.* (2016) conducted an experiment to evaluate different insecticides against sucking insect pest on sunflower crop and found maximum yield of sunflower (34 kg/plot (4×3 m^2)), which was similar with the result of present study. Shamimuzzaman (2021) also observed the highest yield per hectar (1.70 t) of sunflower seed which was similar to the present study. Beside this, Keerio *et al.* (2020) and Kawade *et al.* (2018) also reported similar results.

Table 5: Effect of micronutrients on weight of total seed per plot, single seed weight and yield of sunflower

Treatments	Weight of total seed/plot (kg)	Single seed weight (g)	Yield/ha (t)
T_1	1.86 d	0.069 e	2.12 d
T_2	1.35 g	0.065 f	1.54 g
T_3	2.02 c	0.076 c	2.30 c
T_4	1.53 f	0.062 g	1.75 f
T_5	2.56 a	0.084 a	2.92 a
T_6	2.27 b	0.081 b	2.59 b
T_7	1.60 e	0.072 d	1.83 e
T_8	1.08 h	0.058 h	1.24 h
CV (%)	2.69	4.79	2.62
$LSD_{(0.05)}$	0.043	0.005	0.052

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Boron @ 8.0 kg/ ha + ZnSo4 @ 9.6 kg/ ha; T_2= Spraying 0.2% Borax @ 2g/L of water; T_3= Spraying 0.2% ZnSo4 @ 2g/L of water; T_4= Spraying 0.5% Borax @ 2g/L of water; T_5= Spraying 0.2% Borax and 0.2% ZnSo4 @ 2g/L of water; T_6= Spraying 0.5% ZnSo4 @ 2g/L of water; T_7= $MnSO_4$ @ 9.0 kg/ ha; T_8= No micronutrient (control).]

4.4. Beneficial arthropods in sunflower field

4.4.1. Honey bee

Honey bee is one of the most important and number one pollinators of sunflower. There was significant difference among the treatments of micronutrients applied on sunflower in case of incidence of honey bee (Table 6). The maximum number of honey bee per plant (3.33 honey bee) was recorded from T_5 treatment and the minimum number of honey bee per plant (1.33 honey bee) was observed from T_8 treatment (Table 6). Similar result was also observed by Geetha and Hegde (2018).

4.4.2. Syrphid fly

Syrphid fly is one of the most important predators of sunflower. There was no significant difference among the treatments of micronutrients applied on sunflower in case of incidence of syrphid fly (Table 6).

4.4.3. Lady bird beetle

Lady bird beetle fly is one of the most important predators of sunflower. There was no significant difference among the treatments of micronutrients applied on sunflower in case of incidence of lady bird beetle (Table 6).

Table 6: Effect of micronutrients on the incidence of different beneficial arthropods in sunflower field

Treatments	Pollinator	Predator		
	Honey bee	Syrphid fly	Lady bird beetle	Ant
T_1	2.87 ab	1.17 a	2.17 a	1.17 ab
T_2	3.13 a	1.16 a	1.87 a	1.17 ab
T_3	2.17 c	1.50 a	1.63 a	1.67 a
T_4	2.00 c	1.00 a	1.50 a	1.17 ab
T_5	3.33 a	1.50 a	2.50 a	1.67 a
T_6	2.67 b	0.83 a	2.33 a	1.50 ab
T_7	2.50 b	1.00 a	1.76 a	1.00 ab
T_8	1.33 d	0.83 a	1.33a	0.67 b
CV (%)	4.48	5.88	2.96	4.73
LSD $_{(0.05)}$	0.47	0.90	1.84	0.87

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Boron @ 8.0 kg/ ha + ZnSo4 @ 9.6 kg/ ha; T_2= Spraying 0.2% Borax @ 2g/L of water; T_3= Spraying 0.2% ZnSo4 @ 2g/L of water; T_4= Spraying 0.5% Borax @ 2g/L of water; T_5= Spraying 0.2% Borax and 0.2% ZnSo4 @ 2g/L of water; T_6= Spraying 0.5% ZnSo4 @ 2g/L of water; T_7= $MnSO_4$ @ 9.0 kg/ ha; T_8= No micronutrient (control).]

4.4.4. Ant

Ant is also the most important predator of sunflower. There was significant difference among the treatments of micronutrients applied on sunflower in case of incidence of ant (Table 6). The maximum number of ants per plant (1.67 ant) was recorded from T_5 treatment and the minimum number of ants per plant (0.67 ant) was observed from T_8 treatment (Table 6). Similar result was also observed by Geetha and Hegde (2018).

4.5. Seed characteristics

4.5.1. Oil content of sunflower

Remarkable variation was observed on oil content of sunflower when micronutrients were applied on sunflower (Table 7). The highest oil content (46.54 %) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_3 (43.45), T_1 (40.60), T_7 (40.25), T_2 (38.22) and T_4 (37.77 %). On the other hand, the lowest oil content (21.43 %) was observed from T_8 treatment which was statistically different from other treatments and followed by T_6 (37.13 %). Our results are in agreement with those of Sher *et al.* (2021).

4.5.2. Protein content of sunflower

Remarkable variation was observed on protein content of sunflower due to the micronutrient (Table 7). The highest protein content (22.38 %) was recorded from T_5 treatment which was statistically different from other treatments and followed by T_3 (21.22), T_1 (20.34), T_7 (19.37), T_2 (18.44) and T_4 (17.44 %). On the other hand, the lowest protein content (13.96 %) was observed from T_8 treatment which was statistically different from other treatments and followed by T_6 (15.59 %). Kawade *et al.* (2018) also reported similar results.

Table 7: Effect of micronutrients on oil content and protein content of sunflower

Treatments	Oil content (%)	Protein content (%)
T_1	40.60 c	20.34 c
T_2	38.22 d	18.44 e
T_3	43.45 b	21.22 b
T_4	37.77 de	17.44 f
T_5	46.54 a	22.38 a
T_6	37.13 e	15.59 g
T_7	40.25 c	19.37 d
T_8	21.43 f	13.96 h
CV (%)	1.41	1.59
LSD $_{(0.05)}$	0.95	0.52

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Boron @ 8.0 kg/ ha + ZnSo4 @ 9.6 kg/ ha; T_2= Spraying 0.2% Borax @ 2g/L of water; T_3= Spraying 0.2% ZnSo4 @ 2g/L of water; T_4= Spraying 0.5% Borax @ 2g/L of water; T_5= Spraying 0.2% Borax and 0.2% ZnSo4 @ 2g/L of water; T_6= Spraying 0.5% ZnSo4 @ 2g/L of water; T_7= $MnSO_4$ @ 9.0 kg/ ha; T_8= No micronutrient (control).]

4.5.3. Seed vigour: According to tetrazolium test, different micronutrients differed significantly in terms of seed vigour of sunflower. The highest seed vigour (78.52 %) was found from T_5 and the lowest seed vigour (63.50 %) was observed from T_8 treatment (Figure 5).

4.5.4. Seed viability: According to tetrazolium test, different micronutrients differed significantly in terms of seed viability of sunflower. The highest seed viability (91.67 %) was found from T_5 and the lowest seed viability (75.50 %) was observed from T_8 treatment (Figure 5).

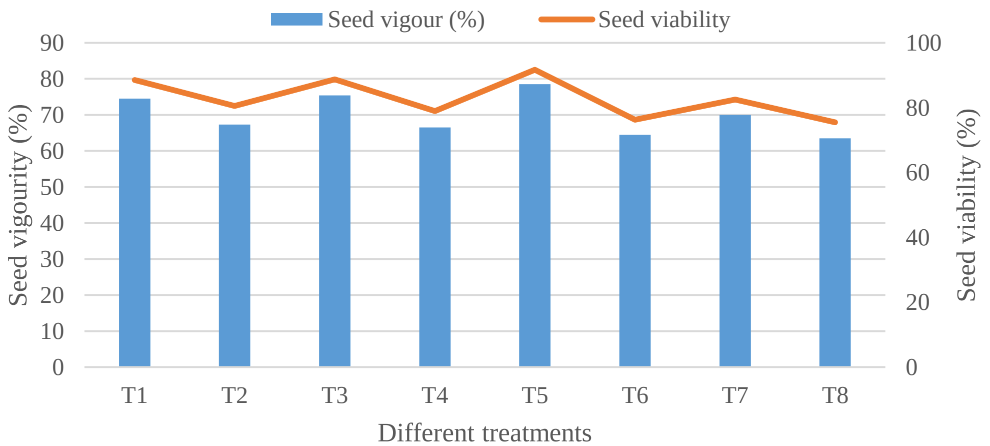


Figure 5: Effect of different treatments on seed vigourity and seed viability of sunflower

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Research Farm under the Department of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the period from October, 2021 to July, 2022 to study the effect of micronutrients (B, Zn & Mn) on incidence, damage severity of sucking insect pests of sunflower and their impact on yield and beneficial arthropods. The experiment comprised of eight treatments. Thus, there were 24 treatments and the experiment was laid out in randomized complete block design with three replications. All the growth and yield contributing characters like plant height, number of leaves, number of seed per head, leaf area, capitulum diameter, diameter of flower with petal, number of petals, number of cylix, number of total head per plot, weight of total seed per plot, weight of seed per head, weight of single seed and yield per hectare; seed characteristics like percent oil and protein content, seed vigour and seed viability; insect infestation like number of whitefly, jassid, aphid, and stink bug per plant and percent leaf infestation caused by the insect pest of sunflower; and incidence of beneficial arthropods like syrphid fly, honey bee, lady bird beetle and ant were studied. All the parameters varied significantly due to application of different level of micro nutrients in sunflower field.

The maximum plant height (180.2 cm), leaf area (65.44 cm^2), capitulum diameter (12.04 cm), diameter of flower with petal (22.33 cm), number of petal (45.34), number of calex (59.33), number of seed per head (1015), weight of seeds per head (85.26 g), weight of total seed per plot (2.56 kg), weight of single seed (0.084 g), yield (2.92 t/ha), oil content (46.54 %), protein content (22.38 %), seed vigourity (78.52%) and seed viability (91.67%) were observed from T_5 treatment. Again, the minimum number of whitefly per plant (2.83; 6.67; 9.67 and 4.17 whitefly) at early stage, vegetative stage, reproductive stage and ripening stage, respectively, jassid per plant (1.5 at early stage, 6.67 at vegetative stage, 4.17 at reproductive stage and 1.68 at ripening stage), aphid per plant (1.75 at vegetative stage, 4.17 at reproductive stage and 5.33 at ripening stage), stink bug per plant (0.24 stink bug), number of infested leaves (2.89 leaves) and percent leaf infestation (12.46 %) were also observed from T_5 treatment.

In case of beneficial arthropod, the maximum number of syrphid fly per plot (1.50 syrphid fly), honey bee per plot (3.33 honey bee), lady bird beetle per plot (2.50 lady bird beetle) and ant per plot (1.67 ant per plot) were observed from T_5 treatment.

Spraying 0.2% Borax and 0.2% $ZnSO_4$ @ 2g/L of water showed the best performance for maximum parameters of sunflower. So, it can be concluded that spraying 0.2% Borax and 0.2% $ZnSO_4$ @ 2g/L of water along with the recommended fertilizer dose for urea, TSP and MoP is suitable for sunflower cultivation.

Considering the situation of the present experiment, further study might be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performances. The experiment was however, conducted in one season only and hence the results should be considered as a tentative. It is imperative that similar experiment should be carried out with more variables to reconfirm the recommendation.

CHAPTER VI

REFERENCES

Adesina, S. (2018). Effect of processing on the proximate composition of sunflower (*Helianthus annuus*) seeds. *Agro-Science*. **17**(3): 27–33.

Aheer, G.M., Ahmad, K.J. and Ali, A. (2007). Impact of weather factors on population of wheat aphids at Mandi Baha-ud-din District. *J. Agric. Res*. **45**(1): 61-68.

Ahmed, K.N. (2002). Use of bio-pesticide in the control of the pests of oilseeds in pre-harvest and postharvest conditions. Research Report submitted to the Ministry of Science and Information and Communication Technology on 1.12.2002, Bangladesh.

Alegbejo, M.D. (2000). Whitefly transmitted plant viruses in Nigeria. *J. Sus. Agri.* **17**(2/3): 99-109.

Almeida, G.D., Pratissoli, D., Zanuncio, J.C., Vicenthi, V.B., Holtz, A.M. and Serrao, J.E. (2009). Calcium silicate and organic mineral fertilizer increase the resistance of tomato plants to *Frankliniella schultzei*. *Phytoparasitica*. **37**: 225-230.

Asad, A., Blamey, F.P.C. and Edwards, D.G. (2003). Effects of Boron Foliar Applications on vegetative and reproductive growth of sunflower. *Ann. Bot.* **92**(4): 656-570.

Bahaa-El-Din, M. (2015). Effect of boron foliar application on yield and quality of some sunflower (*Helianthus annuus* L.) Cultivars. *J. Agril. Sci. Tech.* **5**: 309-316. doi: 10.17265/2161-6264/2015.05.002.

Bala, K., Sood, A.K., Pathania, V.S. and Thakur, S. (2018). Effect of plant nutrition in insect pest management: a review. *J. Pharma. Phytochemistry.* **7**(4): 2737-2743

Baloch, R.A., Baloch, S.U., Baloch, S.K., Baloch, A.B., Bashir, W. and Kashan, S.D. (2015). Effect of Zinc and Boron in combination with NPK on Sunflower (*Helianthus annuus* L.) growth and yield. *J. Bio. Agri. Health*. **5**(19): 101-107.

Barkham, P. (2021). UK scientists confirm arrival of brown marmorated stink bugs. The Guardian. Retrieved March 1, 2021.

Bauman, D.E., Barbano, D.A., Dwyer, D.A. and Giriinari, J.M. (2000). Technical Note: production of butter with enhanced conjugated linoleic acid for use in biomedical studies with animal models. *J. Dairy Sci.* **83**: 2422-25.

Bedford, I.D., Pinner, M., Liu, S. and Markham, P.G. (1994b). *Bemisia tabaci* - potential infestation, phytotoxicity and virus transmission within European agriculture. **In:** Proceedings Brighton Crop Protection Conference, Pests and Diseases, vol. 2. Bracknell, UK: British Crop Protection Council, BCPC Publications. pp.: 911-916.

Brown, J.K. and Bird, J. (1992). Whitefly-transmitted geminiviruses and associated disorders in the Americas and the Caribbean Basin. *Plant Disease*. **76**(3): 220-225.

Businesspost. (2021). Sunflower production shoots up as demand grows steadily. 18 Jul 2021 00:00:00. Update: 18 Jul 2021 10:17:29

Cathrin, P.B. and Ghanim, M. (2014). Recent advances on interactions between the whitefly *Bemisia tabaci* and begomoviruses, with emphasis on Tomato yellow leaf curl virus. **In:** Plant Virus-Host Interaction: Molecular Approaches and Viral Evolution. *Amsterdam, The Netherlands: Elsevier*. pp.: 79-103.

Charlet, L.D. and Glogoza, P.A. (2004). Insect problems in the sunflower production regions based on the 2003 sunflower crop survey and comparisons with the 2002 survey. Proc. 26th Sunflower Research Workshop, Natl. Sunflower Assoc., Fargo, ND, 14-15 January 2004.

Chowdhary, A.R., Setty, P. and Nagarathna, T.K. (2010). Growth and yield of sunflower as influenced by micronutrients application in alfisols. *Karnataka J. Agric. Sci.* **23**(3): 495-496.

De Grandi-Hoffman, G. and Chambers, M. (2006). Effects of honey bee (Hymenoptera: Apidae) foraging on seed set in self-fertile sunflowers *Helianthus annuus*, L. *Environ. Entomol*. **35**(4): 1103-1108.

Dekker, S. (2021). How to identify and control common sunflower pests. Gardener's Path. https://gardenerspath.com/how-to/disease-and-pests/sunflower-pests/

Ebrahimian, E., Bybordi, A. and Eslam, B.P. (2010). Efficiency zinc and iron application methods on sunflower. *J. Food Agric. Envin*. **8**(3&4): 783-789.

Ebert, T.A. and Cartwright, B. (1997). Biology and ecology of *Aphis gossypii* Glover (Homoptera: Aphididae). *Southwestern Entomologist*. **22**(1): 116-153.

Eslami, M., Deghanzadeh, H. and Najafi, F. (2015). The effect of drought stress on oil percent and yield and type of sunflower (*Helianthus annus* L.) fatty acids. *Agric. Sci. Dev.* **4**: 4-6.

Faisal, M., Iqbal, M.A., Aydemir, S.K., Hamid, A., Rahim, N., Sabagh, A., Khaliq, A. and Siddiqui, M.H. (2020). Exogenously foliage applied micronutrients efficacious impact on achene yield of sunflower under temperate conditions. *Pak. J. Bot.*, ***52***(4): 1215-1221.

Farokhi, H., Shirzadi, M.H. and Ahmadizadeh, G.A.M. (2014). Effect of different micronutrients on growth parameters and oil percent of Azargol sunflower cultivar in Jiroft region. *Bull. Env. Pharmacol. Life Sci*. **3**(7): 97-101.

Fishpool, L.D.C. and Burban, C. (1994). *Bemisia tabaci*: the whitefly vector of African cassava mosaic geminivirus. *Trop. Sci.* **34**(1): 55-72.

Forleo, M.B., Palmieri, N., Suardi, A., Coaloa, D., & Pari, L. (2018). The eco-efficiency of rapeseed and sunflower cultivation in Italy. Joining environmental and economic assessment. *J. Cleaner Prod.* **172**: 3138–3153.

França-Neto, J.B., Krzyzanowski, F.C. and Costa, N.P. (1998). O teste de tetrazólio em sementes de soja [Tetrazolium test in soybean seeds]. EMBRAPA-CNPSo, Londrina. (Documentos, 116). p. 72.

França-Neto, J.B., Krzyzanowski, F.C. and Costa, N.P. (1999). Metodologia do teste de tetrazólio em sementes de soja [Methodology of tetrazolium test in soybean seeds]. In: Vigor de sementes: conceitos e testes [Seed vigor: concepts and tests], (eds. F.C. Krzyzanowski, R.D. Vieira and J.B. França-Neto), Chapter 8, ABRATES, Londrina. pp. 1-28.

Galavi, A. M., Kafi, M. and Rostami, M. (2012). Yield characteristics and oil content of three sunflower (*Carthmus tinctorius* L.) cultivars under drought in reproductive stage and irrigation with saline water. *J. Agric. Res*. **5**(1): 121-131.

Geetha, S. and Hegde, M.G. (2018). Incidence of insect pests and natural enemies in sunflower crop ecosystem. *Int. J. Curr. Microbiol. App. Sci.* **7**(9): 1593-1601.

Graham, J. (1968). Principles of crowding effect in *Aphis gossypii* Glover (Aphididae, Homoptera). North Carolina State University at Raleigh.

Grasso, S., Omoarukhe, E., Wen, X., Papoutsis, K. and Methven, L. (2019). The use of upcycled defatted sunflower seed flour as a functional ingredient in biscuits. *Foods*. **8**(8): 305. https://doi.org/10.3390/foods8080305

Hadi, F., Mohammad, H.S., Gholamreza, A. and Mostafa, A. (2014). Effect of different micronutrients on growth parameters and oil percent of Azargol sunflower cultivar in Jiroft region. *Bull. Env. Pharmacol. Life Sci.* **3**(7): 97-101.

Head, R.B. (1992). Cotton insect losses 1991. **In:** Proceedings Beltwide Cotton Conference. National Cotton Council of America, Memphis, TN. pp.: 621-625.

Hill, D.S. (1983). Agricultural Insect Pests of the Tropics and their Control. 2nd Ed. Cambridge Univ. Press. p. 746.

Horvath, Z. (1993). Biological control methods and breeding for resistance against the sunflower moth (*Homoeosoma nebulellum* Hb.) (In Bulgarian). *Novenyvedelen*. **29**: 259-63.

Hugar P.G., Anandhi P., Varma S.S.L. (2008). Seasonal incidence of important insect pests of sunflower and their natural enemies in relation to weather parameters, *in Allahabad region Department of Plant Protection*, AAI-DU, Allahabad - 211 007, U.P, India.

Ilharco, F.A. and Harten, V. (1987). Systematics. Aphids: their biology, natural enemies and control (World crop pests, 2A). Amsterdam, The Netherlands: Elsevier Science Publishers. pp.: 51-78.

Isely, D. (1946). The cotton aphid. *Uni. Arkansas Agril. Exp. Station Bull*. **462**: 1-29.

Jayasimha, G.T., Rachana, R.R., Manjunatha, M. and Rajkumar, V.B. (2012). Biology and seasonal incidence of leafhopper, *Amrasca biguttula biguttula* (Ishida) (Hemitpera:Cicadellidae) on okra. *Pest Manag. Hortil. Ecos*. **18**(2): 149–153.

Johri, B.M. and Vasil, I.K. (1961). Physiology of phloem. *Bot. Rev*. **27**: 325-381.

Kastori, R. and Grujie, S. (1992). Institute *Dichimica agarina*, University delistudi. pp. 507-518.

Katsarou, A.I., Kaliora, A.C., Papalois, A., Chiou, A., Kalogeropoulos, N., Agrogiannis, G. and Andrikopoulos, N.K. (2015). Serum lipid profile and inflammatory markers in the aorta of cholesterol-fed rats supplemented with extra virgin olive oil, sunflower oils and oil-products. *Inter. J. Food Sci. Nutrition.* **66**(7): 766–773.

Kawade, B., Jadhav, D.B. and Arshewar, S.P. (2018). Effect of micronutrients on growth, yield and quality of sunflower in kharif season Manjushri. *Int. J. Curr. Microbiol. App. Sci.* **6**: 2189-2196.

Keepling, M.G. and Meyer, J.H. (2003). Effect of four sources of silicon on resistance of sugarcane varieties to *Eldana saccharina* Walker (Lepidoptera: Pyralidae). Proceeding of the South African Sugar Technologists' Association. **77**: 99-103.

Keerio, R.A., Soomro, N.S., Soomro, A.A., Siddiqui, M.A., Khan, M.T., Nizamani, G.S., Kandhro, M.N., Siddiqui, M., Khan, H. and Soomro, F.D. (2020). Effect of foliar spray of zinc on growth and yield of sunflower (*Helianthus annuus* L.). *Pakistan J. Agric. Res*. **33**(2): 264-269.

Khurana N. and Chatterjee C. (2001). Influence of variable zinc on yield, oil content, and physiology of sunflower, COMMUN. *Soil Sci. Plant Anal*. **32**: 3023-3030.

Kibalenko, A.P. (1972). Investigations on the influence of the boron on nucleic acid metabolism. *Thaer-Arch*. **14**: 725-737.

Kottapalli, B., Nguyen, S.P., Dawson, K., Casulli, K., Knockenhauer, C. and Schaffner, D.W. (2020). Evaluating the risk of Salmonellosis from dry roasted sunflower seeds. *J. Food Prot.* **83**(1): 17–27. https://doi.org/10.4315/0362-028X.JFP-19-171

Koul, O., Dhaliwal, G.S., Khokhar, S. and Singh, R. (2014). Biopesticides in Sustainable Agriculture Progress and Potential. Scientific Publishers. pp. 102, 132.

Kumar, B.N.A., Bhat, S.N. and Shanwad, U.K. (2010). Effect of micronutrients on growth and yield in sunflower (*Helianthus annuus*). *Curr. Adv. Agril. Sci.* **2**(1): 51-52.

Kumbhar, C.S., Indulkar, B.S. and Wagh, C.B. (2017). Effect of micronutrients application on availability of Zn, Fe and B of sunflower (*Helianthus annus* L.) in Inceptisol. *Inter. J. Cur. Microb. App. Sci*. **6**(11): 438-442.

Lotha, N. and Dawson, J. (2021). Effect of micronutrients on growth and yield of sunflower (*Helianthus annus* L.) Variety DRSH-1. *Pharma Innov. J.* **10**(11): 1023-1026.

Liu, X.D., Zhai, B.P. and Zhang, X.X. (2002). Studies on the host biotypes and its cause of cotton aphid in Nanjing, China. *Agril. Sci. China*. **1**(11): 1211-1215.

Malik, M.A. and Saini, C.S. (2018). Rheological and structural properties of protein isolates extracted from dephenolized sunflower meal: effect of high intensity ultrasound. *Food Hydrocolloids*. **81**: 229–241.

Malik, M.A., Sharma, H.K. and Saini, C.S. (2017). High intensity ultrasound treatment of protein isolate extracted from dephenolized sunflower meal: effect on physicochemical and functional properties. *Ultrasonics Sonochemistry*. **39**: 511–519.

Marin, I.V. (1992) Method of determining the number of florets (achenes) and the density of their development in the single flower of sunflower (*Helianthus annuus* L.) (In Russian). *Selektsiya-i-Semenovodostvo-Moskva.* **(2-3)**:10-14.

Markham, P.G., Bedford, I.D., Liu, S.J. and Pinner, M.S. (1994). The transmission of geminiviruses by *Bemisia tabaci*. *Pesticide Science*. **42**(2): 123-128.

Martin, J.H. (1987). An identification guide to common whitefly pest species of the world (Homoptera, Aleyrodidae). *Trop. Pest Manag.* **33**(4): 298-322.

Matthews, G.A. (1989). Cotton insect pests and their management. Harlow, CM20 2JE, UK; Longman Scientific & Technical, x + 199 pp.

McPherson, J.E. and McPherson, R.M. (2000). Stink Bugs of Economic Importance in America North of Mexico, Boca Raton, FL. 253 pp.

Michaud, J.P., Grant, A.K. and Jyoti, J.L. (2007). Impact of the stem borer *Dectes texanus* on yield of the cultivated sunflower, *Helianthus annuus*. *J. Ins. Sci*. **7**: 21.

Mirzapour, M.H. and Khoshgoftar, A.H. (2006). Zinc application effects on yield and seed oil content of sunflower grown on a saline calcareous soil.

Mound, L.A. and Halsey, S.H. (1978). Whitefly of the world. A systematic catalogue of the Aleyrodidae (Homoptera) with host plant and natural enemy data. Chichester, UK: John Wiley and Sons.

Müller, A., Diener, S., Schnyder, S., Stutz, K., Sedivy, C. and Dorn, S. (2006). Quantitative pollen requirements of solitary bees: implications for bee conservation and the evolution of bee-flower relationships. *Bio. Conservation*. **130**: 604-615.

Nayak, S.K., Khura, N. and Moharana, R.L. (2022). Seasonal abundance of insect pests and natural enemies in sunflower in the Western Undulating zone of Odisha. *Pharma Innov. J.* **SP-11**(5): 245-248.

Nozato, K. (1987). Population growth of the melon aphid, *Aphis gossypii* Glover (Homoptera: Aphididae) during the winter season in the warmer region of Japan and effects of temperature on the reproduction of the aphid in the laboratory. *Japanese J. App. Entom. Zoo.* **31**(2): 162-167.

Nozato, K. (1990). Behavioral traits of *Aphis gossypii* Glover alatp (Homoptera: Aphididae), in relation to its flight and reproduction. *Japanese J. App. Entom. Zoo.* **34**(2): 121-126.

O'Brien, D. (2019). USDA Researchers Identify Stink Bug Attractant. www.ars.usda.gov. Agricultural Research Service. Archived from the original on February 6, 2017.

Peairs, F.B. (2018). https://wiki.bugwood.org/HPIPM:Darksided_Cutworm

Rajendra, K., Pushpavathi, B., Santha, M. and Naersh, N. (2013). Cultural, Morphological and Pathogenic Characterization of Isolates of *Alternaria helianthi* causing sunflower blight. *Indian J. plant prot*. **41**(1): 76-78.

Rana, J.S. and Sheoran, R.K. (2004). Evaluation of sunflower *Helianthus annuus* L. hybrids against insect pests in semi-arid tropics. *J. Oilseeds Res*. **21**(2): 374-375.

Ravikumar, C., Karthikeyan, A., Senthilvalavan, P. and Manivannan, R. (2021). Effect of sulphur, zinc and boron on the growth and yield enhancement of sunflower (*Helianthus annuus* L.). *J. Applied and Natural Sci.,* **13**(1): 295-300.

Ready, M.M., Padmaja, B., Reddy, U.R. and Reddy, V.V.D. (2011). Response of sunflower to the foliar spray fertilization of micronutrients under no till condition in rice fallows. *Andra. Agric. J*. **58**(3): 271-275.

Reddy, P.P., Patil, S.J., Advani, M.R. and Patil, S.A. (1991). Rapid method of estimating leaf area in sunflower (*Helianthus annuus* L.). *J. Oilseeds Res.* **8**: 110-112.

Rice, K.B., Bergh, C.J., Bergmann, E.J. and Biddinger, D.J. (2014). Biology, ecology, and management of brown marmorated stink bug (Hemiptera: Pentatomidae). *J. Integ. Pest Manag*. **5**(3): A1–A13.

Rikabder, F.H. (1987). Oilseeds Crop Production Technology. Agriculture Information Service, Ministry of Agriculture, Dhaka-1000. p. 21.

Saad, A. and Al-Doori, M. (2017). Effect of zinc and boron foliar application on growth, yield and quality of some sunflower genotypes (*Helianthus annuus* L.) Mesopotamia. *J. of Agric*., **54**(1): 299-318.

Samman, S., Chow, J.W.Y., Foster, M.J., Ahmad, Z.I., Phuyal, J.L. and Petocz. (2008). Fatty acid composition of edible oils derived from certified organic and conventional agricultural methods. *Food Chem.* **109**: 670-674.

Sarkar, R.K., Chkaraborty, A. and Bala, B. (1998). Analysis of growth and productivity of groundnut (*Arachis hypogaea* L.) in relation to micronutrients application. *Indian J. Plant Physiol.* **3**: 234-236.

Seghatoleslami, M.J., Bradaran, R., Ansarinia, E. and Mousavi, S.G. (2012). Effect of irrigation and nitrogen level on yield, yield components and some morphological traits of sunflower. *Pakistan J. Bot.* **44**(5): 1551-1555.

Sepehr, E., Malakouti, M.J. and Rasouli, M.H. (2002). The effect of K, Mg, S, and micronutrients on the yield and quality of sunflower in Iran. 17^{th} The World Congress of Soil Science (WCSS), Thailand.

Shahbaz, A.K., Lewińska, K., Iqbal, J., Ali, Q., Iqbal, M.M., Tauqeer, H.M. and Ramzani, P.M.A. (2018). Improvement in productivity, nutritional quality, and antioxidative defense mechanisms of sunflower (*Helianthus annuus* L.) and maize (*Zea mays* L.) in nickel contaminated soil amended with different biochar and zeolite ratios. *J. Environ. Manage*. **218**: 256–270.

Shamimuzzaman, M. (2021). Effects of Mg, S, Zn, Mn and B on growth, yield and oil content of sunflower. MS thesis. Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207.

Shankergoud, I., Shadakshari, Y.G., Parameshwarappa, K.G., Chandranath, H.T., Katti, and Mesta, R.K. (2006). Sunflower and Castor Research in Karnataka – An Overview, University of Agricultural Sciences, Dharwad. pp. 1-41.

Sher, A., Sattar, A., Ijaz, M., Nawaz, A., Yasir, T. A., Hussain, M. and Yaseen, M. (2021). Combined foliage application of zinc and boron improves achene yield, oil quality and net returns in sunflower hybrids under an arid climate. *Turk J Field Crops*, **26**(1): 18-24. DOI: 10.17557/tjfc.943470.

Siddiqui, M.H., Oad, F.C., Abbasi, M.K. and Gandahi, A.W. (2009). Effect of NPK, micronutrients and N-Placement on the growth and yield of sunflower. *Sarhad J. Agri.* **25**(1).

Sonnad, J.S., Raveendran, N., Aijan, and Selvaraj, K.N. (2011). Growth analysis of oil seed crops in India during pre and post WTO periods. *Karnataka J. Agric. Sci.* **24**: 184-187.

Steven, J.B. (2009). Entomological Notes: Brown Marmorated Stink Bug. Pennsylvania State University Department of Agriculture. Archived from the original (PDF) on October 7, 2011.

Steve, J. (2010). Brown Marmorated Stink Bug. Entomology. Penn State University. State College, PA: Penn State University College of Agricultural Sciences.

Sudarsan, S. and Ramaswamy, P.P. (1993). Micronutrient nutrition in groundnut–blackgram cropping system. *Fertilizer News*. **38**: 51-57.

Tabassum, A. (2021). Influence of organic and inorganic fertilizers on growth and yield of sunflower (*Helianthus annuus* L.). MS thesis. Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207.

Thapa, R.B. (2006). Honeybees and other insect pollinators of cultivated plants: *J. Inst. Agric. Anim. Sci*. **27**: 1-23.

The Daily Star. (2022). Farmers turn to sunflowers for a decent profit. Tue Mar 8, 2022 12:00 AM Last update on: Tue Mar 8, 2022 06:47 AM.

Umar, S., Anjana, A.N.A. and Khan, N.A. (2013). Nitrate management approaches in leafy vegetables. Nitrate in leafy vegetables: toxicity and safety measures. IK International Publishing House Pvt. Ltd, New Delhi. pp. 166-181.

Vigil, M.F., Benjamin, J.G. and Schepers, J.S. (2001). Yield response and fertilizer nitrogen recovery by dry land sunflowers in a no-till rotation. Proceedings of the 23rd Sunflower Production Workshop. Jan. 17-18, Fargo, North Dakota. **23**: 90-94.

Vijayakumar, M., Vasudevan, D.M., Sundaram, K.R., Krishnan, S., Vaidyanathan, K., Nandakumar, S. and Mathew, N. (2016). A randomized study of coconut oil versus sunflower oil on cardiovascular risk factors in patients with stable coronary heart disease. *Indian Heart J.* **68**(4): 498–506.

Wanjari, N. and Waghmare, J. (2015). Phenolic and antioxidant potential of sunflower meal. *Adv. App. Sci. Res.* **6**: 221–229.

Wilson, E.O. and Bossert, W.H. (1971). A primer of population biology. Massachusetts, USA: Sinauer Associates Inc. Sunderland.

Yegorov, B., Turpurova, T., Sharabaeva, E. and Bondar, Y. (2019). Prospects of using by-products of sunflower oil production in compound feed industry. *J. Food Sci. Tech. Ukraine*. **13**: 106–113. https://doi.org/10.15673/ fst.v13i1.1337

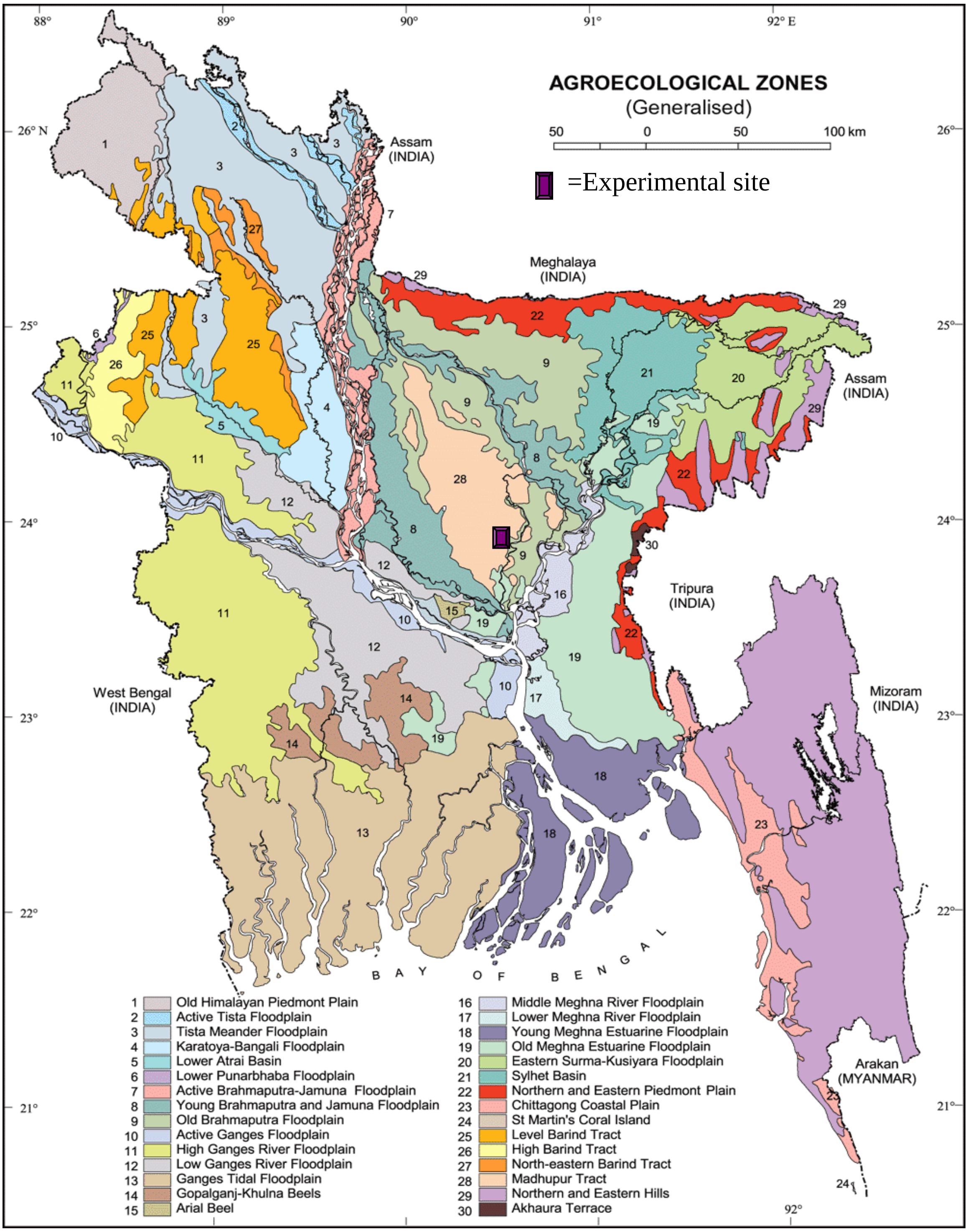
Younas, A., Khan, Z., Waqil, W., Shaaban, M. and Prager, S.M. (2016). The efficacy of *Beauveria bassiana*, jasmonic acid and chlorantraniliprole on larval populations of *Helicoverpa armigera* in chickpea crop ecosystems. *Pest Manage. Sci*. doi: 10.1002/ps.4297.

Zhang, G.X. and Zhong, T.S. (1990). Experimental studies on some aphid life-cycle patterns and the hybridization of two sibling species. **In:** Aphid-Plant genotype interactions. Campbel, R.K. and Eikenbary, R.D. (eds.). New York, USA: Elsevier Press.

CHAPTER VII

APPENDICES

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



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

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

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

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

Appendix III. Some pictorial representation of the experiment

Plate 1: Sunflower research field in the central farm of SAU

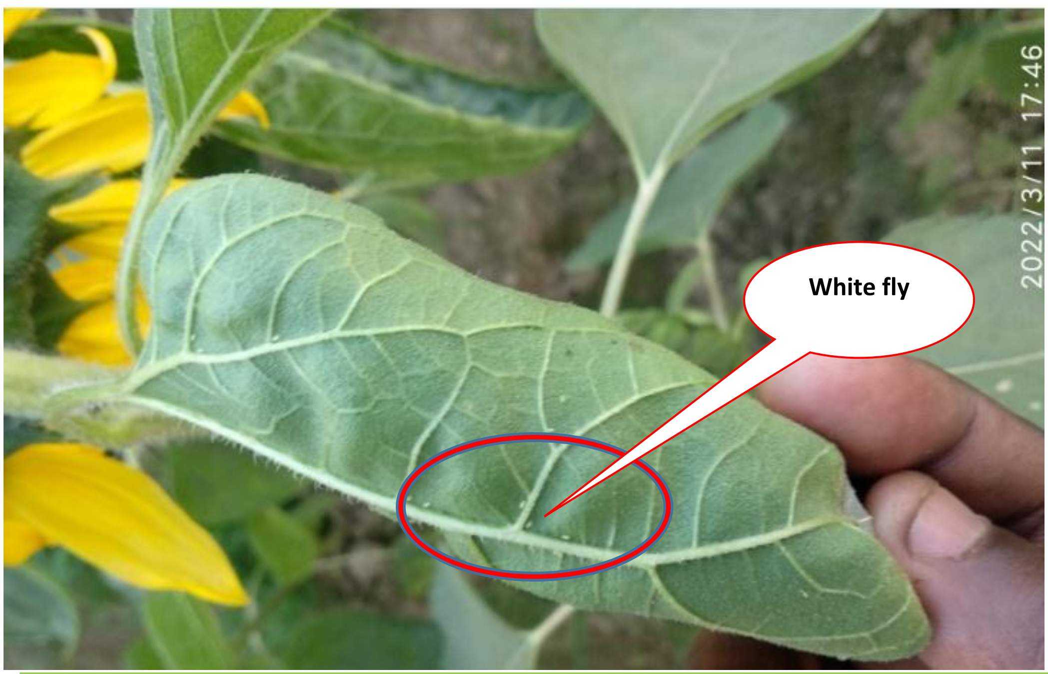


Plate 2: White fly infested leaves of Sunflower in research field

Plate 3: Unhealthy insect infested Sunflower capitulum in research field

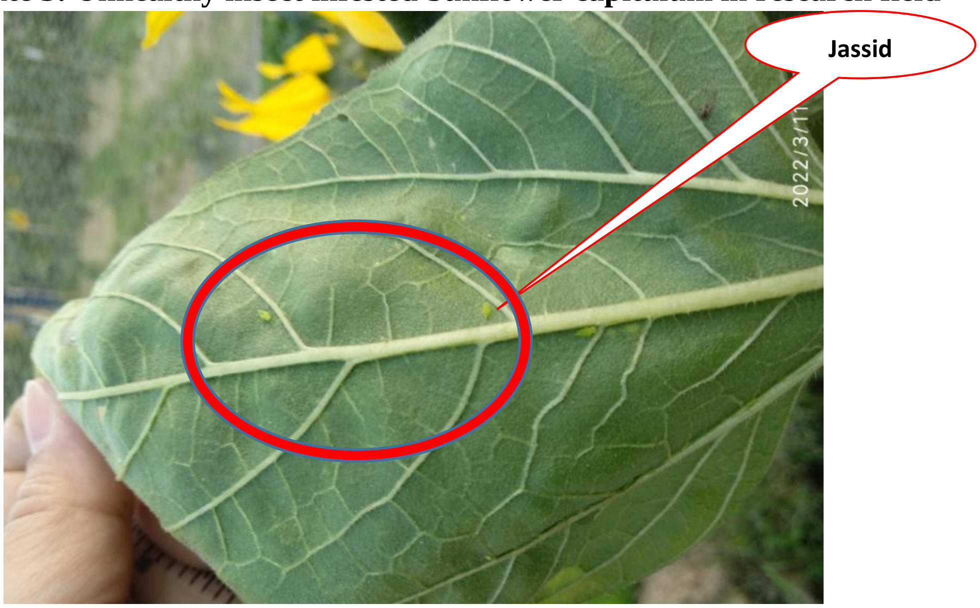


Plate 4: Jassid infested leaves of Sunflower in research field

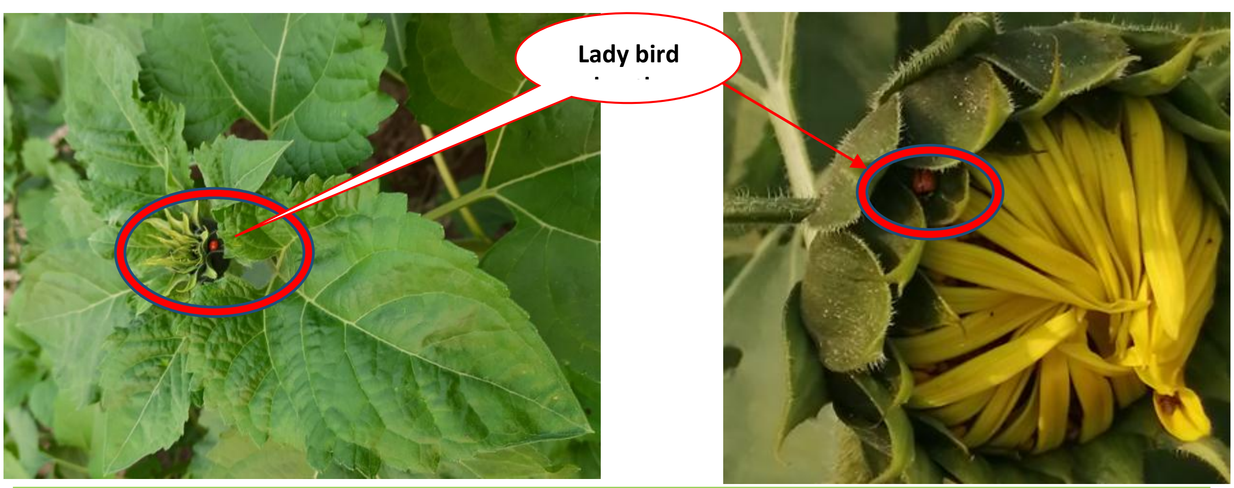


Plate 5: Some photographs on Insect predator (Lady bird beetle) in Sunflower research field

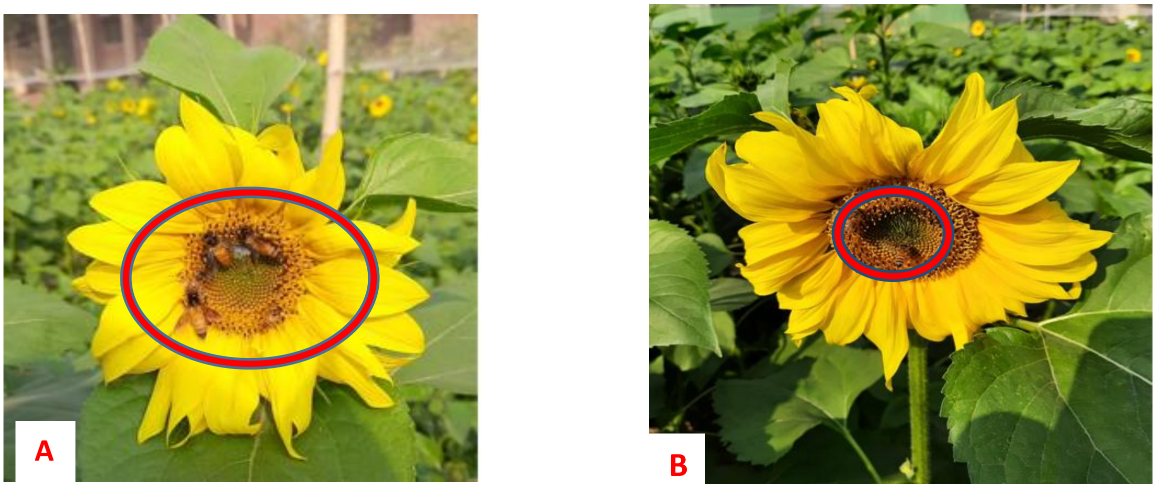


Plate 6: Some photographs on Insect pollinators (Honey bee **[A]** and bumble bee **[B]** in Sunflower research field

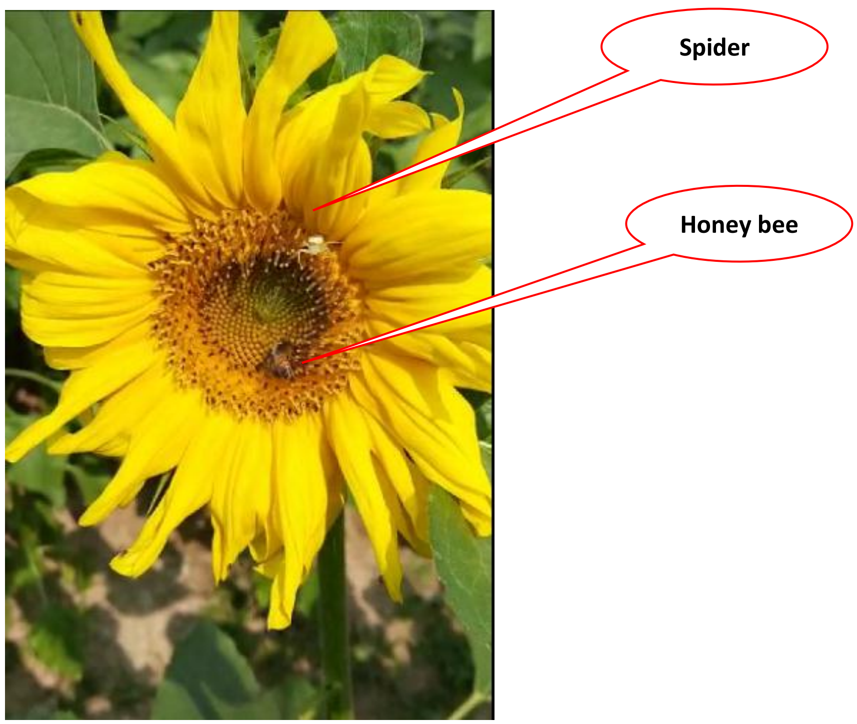


Plate 7: Some photographs on Insect pollinators Honey bee and Predator Spider in Sunflower research field

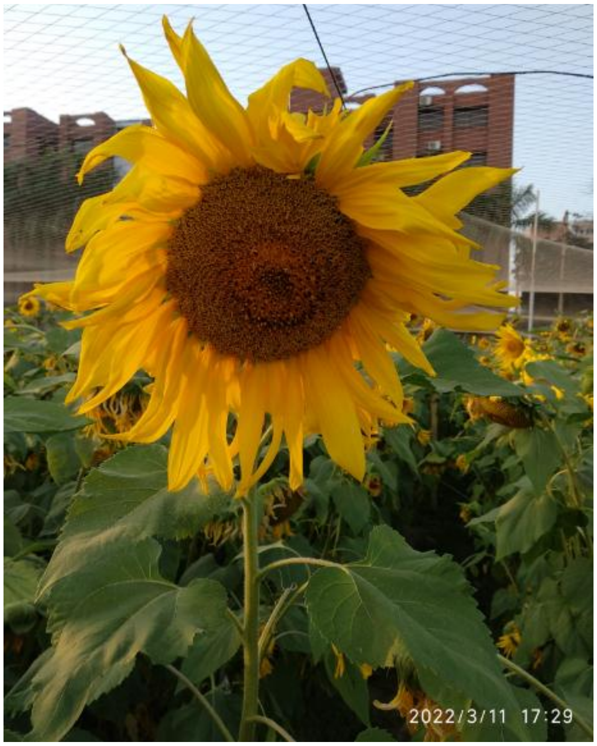


Plate 8: Healthy Sunflower in research field

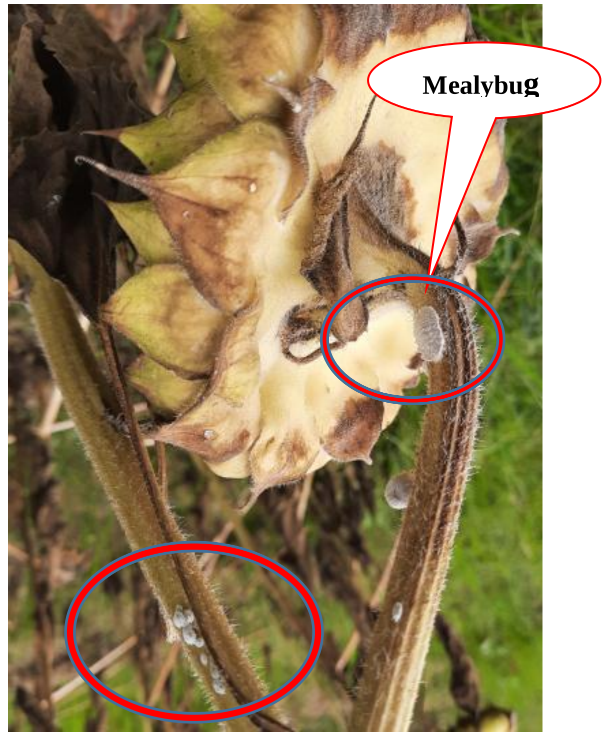


Plate 9: Mealybug infested Sunflower in research field

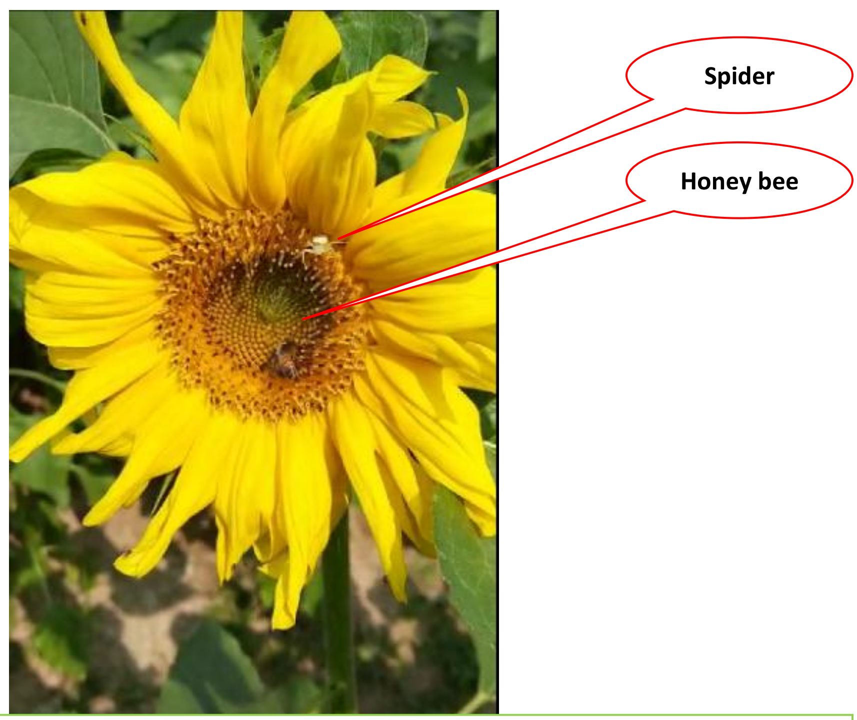


Plate 10: Some photographs on Insect pollinators Honey bee and Predator Spider in Sunflower research field

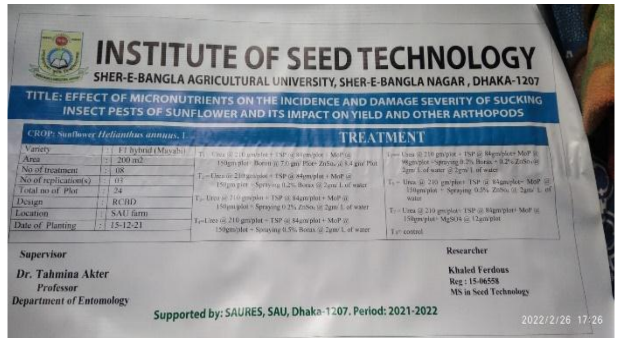


Plate 11: Teachers visited the experimental field

Plate 12: Signboard for the experiment

Plate 13: Seed germination at sunflower field

Plate 14: Experimental field

Plate 15: Intercultural operation (Irrigation)

Plate 16: Healthy sunflower

Plate 17: Data collection

Plate 18: Ripening stage of sunflower

Appendix IV: Analysis of variance of the data on incidence of whitefly at early vegetative, vegetative, reproductive and ripening stages of sunflower

Source of variance	Degrees of freedom	Mean square			
		Early vegetative stage	Vegetative stage	Reproductive stage	Ripening stage
Replication	2	1.135	3.219	21.948	0.031
Factor A	7	0.857	2.143	0.903	0.905
Error	14	0.362	0.897	1.126	0.865

Appendix V: Analysis of variance of the data on incidence of jassid at early vegetative, vegetative, reproductive and ripening stages of sunflower

Source of variance	Degrees of freedom	Mean square			
		Early vegetative stage	Vegetative stage	Reproductive stage	Ripening stage
Replication	2	0.009	0.04	0.006	0.003
Factor A	7	0.851	2.712	0.472	0.278
Error	14	0.002	0.001	0.002	0.001

Appendix VI: Analysis of variance of the data on incidence of aphid at vegetative, reproductive and ripening stages of sunflower

Source of variance	Degrees of freedom	Mean square		
		Vegetative stage	Reproductive stage	Ripening stage
Replication	2	0.292	1.219	4.031
Factor A	7	0.284	0.356	0.357
Error	14	0.28	0.338	0.281

Appendix VII: Analysis of variance of the data on incidence of stink bug at reproductive and ripening stages of sunflower

Source of variance	Degrees of freedom	Mean square	
		Reproductive stage	Ripening stage
Replication	2	0.00	0.01
Factor A	7	0.158	0.095
Error	14	0.001	0.153

Appendix VIII: Analysis of variance of the data on leaf infestation of sunflower

Source of variance	Degrees of freedom	Mean square		
		Number of leaves	Number of infested leaves	Percent leaf infestation
Replication	2	0.156	0.075	2.69
Factor A	7	34.554	8.006	872.167
Error	14	0.318	0.244	11.425

Appendix IX: Analysis of variance of the data on plant height and leaf area of sunflower

Source of variance	Degrees of freedom	Mean square	
		Plant height	Leaf area
Replication	2	0.609	0.075
Factor A	7	398.699	72.939
Error	14	1.064	0.186

Appendix X: Analysis of variance of the data on capitulum diameter, diameter of single flower with petals, number of petals and number of calyx of sunflower

Source of variance	Degrees of freedom	Mean square			
		Capitulum diameter	Diameter of single flower with petals	Number of petals	Number of calyx
Replication	2	0.374	0.063	0.128	0.422
Factor A	7	14.125	18.945	62.536	72.462
Error	14	0.13	0.127	0.144	0.135

Appendix XI: Analysis of variance of the data on number of total head/plot, number of seeds/head and weight of seeds/head of sunflower

Source of variance	Degrees of freedom	Mean square		
		Number of total head/plot	Number of seeds/head	Weight of seeds/head
Replication	2	0.186	0.097	0.006
Factor A	7	24.173	63.73	0.209
Error	14	0.471	0.216	0.005

Appendix XII: Analysis of variance of the data on number of weight of total seed/plot, single seed weight and yield of sunflower

Source of variance	Degrees of freedom	Mean square		
		Weight of total seed/plot	Single seed weight	Yield/ha
Replication	2	0.1321	0.001	0.008
Factor A	7	4.879	0.001	0.34
Error	14	0.043	0.001	0.001

Appendix XIII: Analysis of variance of the data on syrphid fly, honey bee, lady bird beetle and ant of sunflower

Source of variance	Degrees of freedom	Mean square			
		Syrphid fly	Honey bee	Lady bird beetle	Ant
Replication	2	0.219	0.198	0.031	0.031
Factor A	7	0.208	0.804	0.113	0.272
Error	14	0.266	0.103	0.234	0.246

Appendix XIV: Analysis of variance of the data on oil content and protein content of sunflower seed

Source of variance	Degrees of freedom	Mean square	
		Oil content	Protein content
Replication	2	0.732	0.149
Factor A	7	166.995	24.30
Error	14	0.291	0.087

Appendix XV: Analysis of variance of the data on seed vigour and seed viability of sunflower seed

Source of variance	Degrees of freedom	Mean square	
		Seed vigour	Seed viability
Replication	2	0.204	0.221
Factor A	7	22.665	34.996
Error	14	0.001	0.002