EFFECTS OF Mg, S, Zn, Mn AND B ON GROWTH, YIELD AND OIL CONTENT OF SUNFLOWER

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It is a fact that the remembrance of Allah brings peace in the heart. It is better to ponder over the verses to bring us even closer to Allah (swt).

DEDICATED TO-

MY BELOVED PARENTS

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CERTIFICATE

*This is to certify that the thesis entitled **“Effects of Mg, S, Zn, Mn and B on growth, yield and oil content of sunflower”** submitted to the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in Agricultural Chemistry**, embodies the result of a piece of authentic research work carried out by **MD. SHAMIMUZZAMAN,** Registration No. **19-10386** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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- Author

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BY

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ABSTRACT

A field experiment was conducted at the research farm and Agro-Environmental Lab, Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the period from November 2021 to March 2022. The experiment comprised of eight treatments viz., T_1 =Urea @ 210 g/plot +TSP@ 84g/plot + MoP@ 98g/plot+Spraying 0.2% Borax @ 2g/L of water, T_2 = BARI recommended fertilizers + Borax 7.0 g/plot + $ZnSO_4$ 8.4 g/plot in soil, T_3= BARI recommended fertilizers + Spraying 0.5% Borax + 0.5% $ZnSO_4$ 5g/L of water , T_4= BARI recommended fertilizers + $MgSO_4$ 10 g/ Plot + Spraying MnO_2 @ 2g/L of water , T_5= BARI recommended fertilizers + Spraying Bamper Vitamix @ 2g/L of water, T_6 =BARI recommended fertilizers+Spraying 0.2% Borax @ 2g/L of water+0.2% $ZnSO_4$ @ 2gm/L of water, T_7 = BARI recommended fertilizers + Spraying 0.2% $ZnSO_4$ @ 2g/L of water and T_8= control (e.g.: no N, P, K, S, Mg, Zn, Mn and B). Data on different growth and yield parameter were recorded and statistically significant variation was found for different treatments of secondary and micronutrients. The results of this experiment showed that, the maximum plant height (180.67 cm), number of seed per head (645.5), number of leaves per plant (23.33), leaf area (65.33 cm), length of leaf (23.88 cm), leaf width (19.88 cm), weight of total seed per plot (2.51 kg), weight of seed per head (64.55 gm), weight of single seed (0.1 g), yield (1.7 t/ha), oil content (46.53 %) and protein content (22.25 %) was obtained wth T_5 treatment. While the minimum number of leaves (12.00), number of seed per head (375.9), plant height (146.73 cm), number of total head per plot (37), weight of total seed per plot (1.18 kg), yield (0.85 ton per ha), oil content (21.28 %), weight of seed per head (26.31 gm), weight of single seed (0.07 g) and protein content (13.97 %) were recorded from the control treatment. So, it can be concluded that a combination of BARI-recommended fertilizers + spraying Bamper Vitamix @ 2gm/ L of water is suitable for sunflower cultivation.

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ABBREVIATIONS

AEZ	Agro-ecological Zone
Agric.	Agricultural
ANOVA	Analysis of Variance
BARI	Bangladesh Agricultural Research Institute
Biol.	Biology
CV	Coefficient of variance
DAT	Days After Transplanting
et al.	And others
Ex.	Experiment
g	Gram
Hort.	Horticulture
i.e.	That is
J.	Journal
Kg	Kilogram
LSD	Least Significance Difference
mm	Millimeter
RCBD	Randomized Complete Blocked Design
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
spp.	Species
Technol.	Technology
Viz.	Namely
%	Percent
MSTAT	Michigan State University Statistical Package for Data Analysis
etc.	Etcetera

CHAPTER-I
INTRODUCTION

Sunflower (*Helianthus annuus* L.) is considered as one of the important crops in the world for edible oil having 41.3 million tones production in 2019-20, it is the fourth wildly produced oil crop in the world, after soybean, rapeseed, and cotton seed (FAO, 2020). The seed yield and oil concentration are exclusive characteristics for sunflower breeders due to being a vegetable oil source. Oil content of sunflower, which might range from 260 to 720 g/kg among the genotypes, is the most important property for marketing. (Hu *et al.,* 2010). Sunflower (*Helianthus annuus L.*) being photo-insensitive has good potential to produce edible oil. It is an important oilseed crop of the family composite originated in southern Asia and is known to have been cultivated in China, India, Egypt and Iran (Ashri and Knowles, 1960). Sunflower is an important oilseed crop in Bangladesh popularly known as Surjamukhi. Edible oil is the part and parcel of our food. Currently food security problems are also associated with oil. Firstly, the production of edible oil is not enough in the country, consiquently the government has to arrange import of edible oil. It was 2.4 million MT in 2019. Secondly, the other oils produced locally are reportedly cause problems for health in some aspects. So, to meet up the requirement and in respect to food security, we need an alternative oil yielding crop, sunflower may be one of them. 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 (Rahamatalla *et al.,* 2001). In another study (Farokhi *et al.,* 2014) reported sunflower seeds contain 24-49% oil, where the cake contains 25-35% protein which can be used as livestock feed. Sunflower oil is characterized by its high content of unsaturated fatty acids such as oleic and lenoleic which represent 90% of total fatty acids (Al-Qubaie, 2011 and Arshad *et al.,* 2013), quite palatable and also contains soluble vitamins A, D, E and K used in manufacturing of margarine (Iqbal *et al.,* 2009), contains different types of saturated and unsaturated fatty acids (palmitic, stearic, oleic and linoleic acids etc.). Palmitic and stearic acids are the major saturated fatty acids, whereas oleic and linoleic acids are unsaturated. Fatty acid composition of sunflower in particular and that of other oil seed crops in general are influenced by fertilizing managements. Oilseed crops are very sensitive to Fe, B, Mn, Zn (Rahimi *et al.,* 2012). The most consumed micronutrients are iron, manganese, boron and copper for sunflower development (Kaya, 2008). The absence of these elements causes some deficiencies on sunflower plants and oil quality. Use of sufficient amount of micronutrients increased the quality and quantity of the products and at the same time decreased the amount of contaminant elements (Rahimi, 2014). Sunflower seeds are a good source of plant protein, providing 6 grams or 12% of the daily value per ounce. Vitamin E is an antioxidant that may protect against heart disease by getting rid of harmful molecules called free radicals that can lead to atherosclerosis. Sunflower seeds are the best whole food source of vitamin E. Just one ounce of sunflower seeds provides 76 percent of the recommended dietary allowance (RDA) for vitamin E. Selenium works with vitamin E as an antioxidant and protects cells from damage that may lead to cancer, heart disease, and other health problems. It contains sufficient amount of calcium, iron and vitamins like A, D, E and B complex. Sunflower (*Helianthus annuus* L.) occupies the fourth position among vegetable oilseeds after soybean, oil palm and canola in the world (Rodriguez *et al.,* 2002 and Ahmad *et al.,* 2011). It is currently cultivated on approximately 23 million hectares in 40 countries of the world, including some countries in humid tropical Africa because it is quite rustic and can perform well under varying climatic and soil conditions (Seiler *et al.,* 2008; Kaleem *et al.,* 2011b and Konyalt, 2017). Sunflower is considered an important oilseed crop as its oil is widely chosen for cooking purposes. It is grown in two seasons in Pakistan, spring and summer (PARC, 2019). Although it is a high yielding, high oil containing crop which gives promising returns to the farmers, no serious effort has been made to augment the local production of this crop. Therefore, it is extremely important to introduce new improved genotypes of sunflower, as well as adaptive production technology which would play an important role in improving its per unit area yields in the Bangladesh soil and climatic condition.

Sunflower is quite responsive to Zn deficiency which is prevalent on a wide range of soils in many countries of the world (Tiwari *et al.,* 2014). Semi-arid areas having calcareous soil are highly impacted. As a fertilizer, zinc sulfate plays a major role in regulation of stomata influencing the photosynthesis, and ionic balance in plants which is further involved in drought tolerance (Babaeian *et al.,* 2010). It is one of the most sensitive field crops to low B supply, and B deficiency has been reported from around the World (Blamey *et al.,* 1997). Boron is absorbed by the roots of sunflower and accumulates in other organs and tissues of the plant and in larger leaves (Husa, 1965), in reproduction and pollen spikelet formation (Bolanos *et al.,* 2004).

This crop adapted to relatively low rainfall areas receiving winter and spring rainfall with a low humidity during flowering and maturation (Knowles, 1976). One of the most important issues of increasing crop yield and improving the quality of agricultural products is balanced plant nutrition. Application of high NPK fertilizers and very limited use of organic fertilizers cause micronutrient depletion in soils which appears to have special role in influencing the weight and seed filling. Micronutrients play a major role in increasing seed setting and influence growth and yield. Adequate and balanced fertilizer is essential for obtaining better yield. Therefore, for wide spread adoption and exploitation of higher yield potential of the crop, it is necessary to work with some important secondary and micronutrient elements like Mg, S, Zn, Mn and B at the field levels.

Objectives:

This study was therefore conducted to investigate the effect of secondary and micronutrients like Mg, S, Zn, Mn and B on growth, yield and oil content of sunflower with the following objectives**:**

- To observe the growth and yield of sunflower at different treatments of Mg, S, Zn, Mn and B
- To study the effect of Mg, S, Zn, Mn and B on oil and protein content in sunflower seeds

CHAPTER-II
REVIEW OF LITERATURE

A brief review of the literature pertaining to the "effects of Mg, S, Zn, Mn and B on growth, yield and oil content of sunflower" is presented in this chapter. An attempt has been made to cite all available literature on sunflower but due to paucity of adequate published information, research work on other related vegetable crops has also been reviewed.

Ravikumar *et al.* (2021) experimental trials were conducted to study the effect of sulphur, zinc and boron application on the growth, yield components and yield of hybrid sunflower during the summer seasons of 2016 and 2017. 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 (level of significance $P>0.05$) 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.

Hellal *et al.* (2021) an experiment was carried out on the farm of the National Research Centre at El-Nubaria district, El-Buhaira Governorate (Egypt) with sunflower during 2018 and 2019 summer seasons. The treatments were 80%, 60% and 40% of water holding capacity (WHC), and micronutrients (vitamins B, E and microminerals iron, cobalt, chromium, copper, iodine, manganese, selenium, zinc, and molybdenum) at 4 mixture levels (0, 1%, 2% and 3%). Results found that the simulated and observed values of seed yield were in agreement for the water stress treatments. NPK content and the protein ratio in sunflower leaves were generally increased by increasing the mixture of micronutrients. There was a direct relationship on the vegetative growth and yield of the sunflower plants. It could be concluded that using maximum of water treatment (80% WHC) and the 3% and 2% mixture of micronutrients was better due to the increases in values of vegetative growth, seed yield and water productivity of sunflower.

Sher *et al.* (2021) two-year field study was conducted to assess the influence of foliage applied micronutrients (individual/or in combination) on the yield and quality of sunflower hybrids. For this study, they hypothesized that foliage application of micronutrients will improve achene yield, oil quality and net returns in sunflower hybrids. The results indicated that sunflower hybrid 'Parsun' produced the higher head diameter, and had more 1000-achene weight, achene yield, oil content, stearic acid, palmitic acid and linolenic acid. Likewise, the tallest plants, greater number of leaves, maximum seed weight, the highest achene yield and oil content were noted with the combined application of Zn+B. Highest achene yield with combined application of Zn+B also resulted in highest net income. The application of micronutrient also improved the oil content and oil quality.

Faisal *et al.* (2020) a field trial was executed to evaluate the impact of foliage applied micronutrients (zinc 0.5%, boron 0.7% and manganese 0.7%) solely and in co-application on agro-morphological traits and achene yield of sunflower. 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.

Keerio *et al.* (2020) conducted an experiment at field of Oil Seeds Section, Agriculture Research Institute (ARI), Tandojam, Sindh, Pakistan using RCBD design with three replications. The maximum plant height (203.33 cm), stem girth (11.67

cm), head diameter (19.71 cm), number of seeds head^{-1} (1300.0), seeds weight head^{-1} (62.74 g), seeds index (60.12 g), seed yield (1927.8 kg ha^{-1}) and oil content (41.92%) were observed under 2.00% Zn, while and minimum plant height (143.67 cm), stem girth (6.19 cm), head diameter (12.65 cm), number of seeds head^{-1} (715.3), seeds weight head^{-1} (35.53 g), seed index (43.82 g), seed yield (1062. 7 kg ha^{-1}) and oil content (29.28%) was recorded under control (no foliar spray of Zn). It was concluded on the basis of these findings that the foliar application of Zn in 2.0% concentration can be employed to increase the sunflower yield and oil content.

Kawade *et al.* (2018) *a* field experiment was conducted during kharif season of 2016 at the Experimental Farm of Agronomy Section, College of Agriculture, Latur to study the response of hybrid sunflower to micronutrient in kharif season. The result indicated that yield of sunflower was significantly influenced by different micronutrients. The maximum leaf area plant^{-1} (76.97 dm^2), stem girth (8.09 cm), head diameter plant^{-1} (18.83cm), seed yield (1644 kg ha^{-1}), oil yield (575 kg ha^{-1}) and protein yield (312 kg ha^{-1}) with RDF + Borax @ 5.0 kg ha^{-1} (T_{10}). The higher stalk yield (3676 kg ha^{-1}) and biological yield (5084 kg ha^{-1}) by application of RDF along $FeSO_4$ @ 10 kg ha^{-1} (T_5).

Raghu *et al.* (2017) a field experiment was carried out to study the effect of secondary and micronutrients on growth, yield parameters and nutrient uptake of sunflower (*Helianthus annuus* L). The results revealed that the highest seed yield was recorded in the treatment with application of T_8 (RDF + secondary nutrients + micronutrients + cow urine spray at 30 and 50 DAS) (1391.73 kg ha^{-1}) and it was significantly superior over T_1 (1166.66 kg ha^{-1}) and T_4 (1263.21 kg ha^{-1}) but on par with the rest of treatments. The highest total dry matter accumulation was observed in treatment T_8 (RDF + secondary nutrients + micronutrients and cow urine spray at 30 and 50 DAS) (4117.67 kg ha^{-1}) and significantly superior over T_1 (3444 kg ha^{-1}), T_3 (3462 kg ha^{-1}), T_4 (3490 kg ha^{-1}) and T_7 (3541 kg ha^{-1}) but it was on par with other treatment. Significantly highest growth parameters noticed in T_8 than others treatments. The application with T_8: RDF + secondary nutrients + micronutrients and cow urine spray at 30 and 50 DAS, recorded, higher uptake of Nitrogen (76.92 kg ha^{-1}), Phosphorous (13.87 kg ha^{-1}) and Potassium (72.48 kg ha^{-1}). Significantly higher seed oil content (38.44 per cent) and oil yield (535 kg ha^{-1}) in application of secondary and micronutrients along with RDF (T_8) compared to control (35.34 percent and 413 kg ha^{-1} respectively).

Oils, proteins and carbohydrates are essential nutrients for human consumption and an important role as energy source. A large amount of edible oils is obtained from plants. Sunflower oil, which has high nutritional value with higher unsaturated oil (69%) and lower saturated oil (11%) ratio, is considered an important oil among the plant-based oils. It is, therefore, accepted as a good and healthy edible oil source. Storage conditions of the oil and also applied cultural techniques highly influence the quality properties of the oil. Especially, micronutrient applications may alter oil quality. This study aims to investigate the effect of micronutrients use on oil quality in sunflower.

Saad and Al-Doori (2017) a field experiment was conducted during spring and autumn growing seasons of 2009 to study the effect of foliar application of zinc and boron on growth characters, yield components and quality of some sunflower genotypes (*Helianthus annuus* L.). The experiment was carried out according to the factorial experiment in a randomized completely block design, consisting of three zinc application (0, 6, 12 $mg.L^{-1}$) and three boron application (0, 4 and 8 mgL^{-1}) with three sunflower genotypes (Myogen, Isaanka and Ginmus). The results indicated that foliar application of zinc to the leaves with concentration 12 mg L^{-1} showed a significant increase in plant height, stem diameter, leaf area, head diameter, number of seeds $head^{-1}$, 1000 seed weight and seed yield ha^{-1}. Addition of boron sprayed on the plant leaves with concentration 4 mgL^{-1} lead to a significant increase in plant height, stem diameter, leaf area, head diameter, number of seeds $head^{-1}$, 1000 seed weight and seed yield ha^{-1}, oil percentage, oil, protein yield (tha^{-1}), while increasing concentration of boron to 8 mgL^{-1} caused a significant increase in protein percentage in the two seasons. Results showed that the Isaanka genotype gave a high value for characters stem diameter, leaf area, head diameter, number of seeds. $head^{-1}$, 1000 seed weight and seed yield ha^{-1}, oil percentage, oil, protein yield (tha^{-1}) in both seasons. The triple interaction among Isaanka genotype × foliar application of 12 mg ZnL^{-1} × concentration of 4 mg BL^{-1} sprayed on the plant leaves, achieved the highest mean for the characteristics of: plant height, stem diameter, number of seeds $head^{-1}$, seed yield ha^{-1} and oil, protein yield (tha^{-1}) for both seasons. In general, it could be concluded that for maximizing total seed and oil yields per unit area may be achieved by planting Isaanka genotype with adding zinc and boron to the leaves plant with concentration 12 Zn and 4 B mg. L^{-1} under the environmental conditions of this study.

Galavi *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. The experiment treatments included: F_1: control, F_2: Fe, F_3: Zn, F_4: B, F_5: Mn, F_6: Fe+B, F_7: Fe+Mn, F_8: Fe+Zn and F_9: 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 F_2 treatment and the maximum oil percentage was achieved from F_6 and also maximum number of seed per capitol was obtained from F_3.

Khan *et al.* (2009) two field experiments were conducted at National Agricultural Research Centre, Islamabad, Pakistan during spring seasons 2002-03 to evaluate response of sunflower (*Helianthus annus* L.) to different levels of zinc and iron under irrigated conditions. Three levels of zinc 0, 5 and 10 kg ha^{-1} and three levels of iron 0, 2.5 and 5 kg ha^{-1} were applied in soil to see their effect alone and in different combination on grain yield, oil contents, other agronomic parameters and concentrations of zinc and iron in leaves of sunflower. The highest grain yields (2743 kg ha^{-1}) and 1000-seed weight were obtained in treatment that received combined application of 10 kg zinc and 5 kg iron ha^{-1}. Addition of 0, 2.5 and 5.0 kg ha^{-1} iron and 5.0 kg ha^{-1} zinc alone increased yield non-significantly as compared to control. The combined application of zinc + iron at 5.0 kg ha^{-1} produced significantly ($P \leq 0.05$) higher yield than control but was similar to the lower doses. Highest plant height (167.0cm) and greater head diameter (17.6 cm) and highest oil contents (39.7%) were achieved with the application of 10 kg zinc and 5 kg Iron ha^{-1}. The concentrations of zinc and total iron in the leaves were increased with zinc and iron application. Maximum concentration of zinc (70.5 mg kg^{-1}) and iron (553.5 mg kg^{-1}) in leaves was recorded with application of 10 kg zinc + 5 kg iron ha^{-1}.

Siddiqui *et al.* (2009) conducted a field research at Students Farm, Sindh Agriculture University, Tandojam, Pakistan, during 2005 and 2006. 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.

Mirzapour and Khoshgoftar (2006) an experiment conducted in a randomized complete block design with six treatments in three replicates. Treatments were: Zn_0 (nonZn fertilized), Zn_{10}, Zn_{20}, Zn_{30}, and Zn_{60} (soil application of 10, 20, 30, and 60 kg Zn ha^{-1}, respectively) and Zn spray (foliar spraying of 0.5 kg Zn ha^{-1} using $ZnSO_4$). Seeds of sunflower (*Helianthus annuus* cv. 'Record') were planted on June 20, 2000 and June 15, 2001. At harvest, shoot and seed yields as well as concentration of Zn, iron (Fe), manganese (Mn), sodium (Na) and chloride (Cl) in leaves of sunflower were determined. Addition of 20 kg Zn ha^{-1} significantly increased seed production and shoot dry-matter yield of sunflower, while other Zn treatments had no significant effect on shoot drymatter yield, or decreased it. The thousand-seed weight was the yield component most affected by Zn fertilization, while plant height and head diameter did not change. The maximum content of seed oil was achieved under the Zn_{10} treatment, then decreased at higher rates of soil-applied Zn such that oil content of seed under the Zn_{30} and Zn_{60}, treatments. Seed oil content was unaffected by foliar spraying of Zn. The concentration of Zn in sunflower leaves was increased with an increase in soil-added Zn from 0 to 60 kg Zn ha^{-1}. The highest leaf concentrations of Zn (162 and 175 mg kg^{-1} day matter in the first and second year, respectively) were achieved by foliar application of $ZnSO_4$. Leaf concentration of Fe was significantly increased in the Zn_{20} treatment compared with the control but decreased at the higher rates of soil-added $ZnSO_4$. The addition of different levels of $ZnSO_4$ in soil decreased the concentration of Na and Cl in leaves. The lowest concentration of Na and Cl in leaves was observed under Zn_{20}.

Sepehr *et al.* (2002) carried out a field experiment in northwestern part of Iran in Azarbaijan province to determine the response of sunflower to deferent rates of potassium fertilizer with and without micronutrients application. Potassium application at the rate of 50 kg K_2O ha^{-1} increased the grain yield and oil content of the sunflower crop significantly. The increases of 6.5 percent in oil content and 950 kg ha^{-1} in grain yield were obtained with the application of potassium at the rate of 200 kg K_2O ha^{-1} with micronutrients. The growth characteristics such as diameter of head and 1,000-seed weight were also improved with the application of potassium.

B is important for water relations, sugar translocations, cation and anion absorption and metabolism of N, P, carbohydrates and fat (Stiles, 1961; Shkolnik *et. al.,* 1970). Boron deficiency occurs firstly in young leaves with bronze color and hardiness (Oyinlola, 2007a). During fertilization of the sunflower field, the B concentration should be optimizated. In the study conducted by Oyinlola (2007b), the optimized B concentration is 5.60-8.40 $kg.ha^{-1}$; on the other hand, there is a sharp decrese in oil content when the concentration up to 12 $kg.ha^{-1}$. Brighenti and Castro (2008) demonstrated that oil yield was increased by B consumption, and stated that B consumption increased the pollen fertility.

Thus, with increase of the number of filled grain, yield is increased. Bahaa El-Din (2008) 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 percantage were increased with B application in sunflower. Tahir and his collauges (2014) conducted a study to show effect of B on sunflower yield. They (2014) 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.

Zinc nutrient is very important to plants due to the role on membrane integrity of root cells. Besides, zinc is assigned on protein synthesis such as auxins, which is a very important growth regulator. On the other hand, zinc could decrease the toxic effect of boron, sodium and chloride (Mirzapour and Khoshgoftar, 2006). Zinc sulfate ($ZnSO_4$) is commonly used for Zn fertilization due to high solubility in water (Mordvedt and Gilkes, 1993), 4.5-34 kg.ha^{-1} zinc, which depends on the soil need, is enough for inhibiting zinc deficiency in the field (Martens and Westermann, 1991). 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, improved the nutrient element concentrations in plant tissue and soil macro- and micronutrient status (Adediran *et al.,* 2004). Keeping in view the key role played by Zn and B nutrition in plant growth, this study was designed to find out the suitable dose of Zn and B for sunflower production under soil and environmental conditions of Sindh Province.

Among the factors responsible for increasing yield, judicious use of micronutrients is of prime importance. Crops require a sufficient, but not excessive, supply of essential mineral elements for optimal productivity. Insufficient supply of mineral elements may lead to limit in plant growth. In some agricultural soils, particularly in clay soil, insufficient micronutrients like zinc (Zn) and boron (B) are often common (Gitte *et al.,* 2005). Hence, these elements can be supplied as fertilizers in both intensive and extensive agricultural systems. However, excess Zn and B may be toxic to plants. Increased fertilizer used efficiency can be achieved agronomically, through improved fertilizer management practices (Milutinoc and Stanojevic, 1988; Asad *et al.,* 2002). Sunflower is one of the most sensitive crops to low zinc and boron supply, developing the characteristic of Zn, B deficiency symptoms on leaves, stems and reproductive parts (Oyinlola, 2007b). Plants growth is significantly influenced by soil Zn, B content. It has been shown that sunflower roots are sensitive to Zn, B deficiency as they stop their growth in less than 6 h after the removal of Zn, B from the growth media (Beyersmann and Haase, 2002).

Similarly, a considerable increase in dry weight of sunflower by foliar application of 28 mg boron. L-1 has been reported (Iskander, 1993). Boron application, not only increased root growth but also increased shoot dry weight of sunflower (Asad *et al.,* 2002). Applications of above-mentioned mineral partially overcomes the negative effects of stress and provide plants balanced nutrients. Spray of $ZnSO_4$ and H_3BO_3 was better in all the vegetative growth characteristics Tahsin and Yankov, (2007) also observed a significant effect of micronutrients in growth including yield in sunflower plants by application of zinc, boron and iron. Such enhancement effect of application might be attributed to the favorable influence of these nutrients on metabolism and biological activity and its stimulating effect on photosynthetic pigments and enzymes activity which in turn encourage vegetative growth of plants (Milutinoc and Stanojevic, 1988). Significantly affects biomass production of plants irrespective to their growth under different soil conditions. The application of above-mentioned minerals appears to minimize these toxic affects through mitigating the nutrient demands of stressed plants.

These minerals increased photosynthetic and enzymatic activities and an effective translocation of assimilate to reproductive parts resulting in higher yield (Lindsay, 1996). Spray of boron as an individual mineral element was found to be better in stimulating the pollen viability and germination as compared to zinc. High boron levels in the stigma and style are required for physiological inactivation of callus which is an important polysaccharide component of the pollen tube wall by the formation of borate callus complexes (Sharma *et al.*, 1999). When boron levels are low, callus levels increase and induce the synthesis of phytoalexins including phenols which can cause an injury to membrane structure and cellular functions and bring some alteration in the morphology and structure of pollen tubes (Rani and Reddy, 1993).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study the effect of Mg, S, Zn, Mn and B on growth, yield and oil content of sunflower. The details of the materials and methods i.e., experimental period, location, soil and climatic condition of the experimental site, experimental treatment and design, growing of crops, data collection and analytical procedures followed for this experiment have been presented below under the following headings:

3.1 Description of the experimental Site

3.1.1 Experimental period

The field experiment was conducted during Robi season from November, 2021 to March, 2022 at research farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

3.1.2 Experimental location

The geographic location of the site is $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude with an elevation of 8.2 meter from sea level. Experimental location presented in Appendix I.

3.1.3 Climatic condition

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February, the pre-monsoon period or hot season from the month of March to June and monsoon period from the month of July to October (FAO, 1988). During the experimental period the maximum temperature (36.4^{0}C), highest relative humidity (88%) and highest rainfall (591 mm) were recorded for the month of November, 2021, and the minimum temperature (16.4^{0}C), minimum relative humidity (74%) and rainfall (12 mm) were recorded for the same period. Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during study period are presented in Appendix II.

3.1.4 Soil characteristics

The soil of the experimental field belongs to "The Madhupur Tract", AEZ-28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish-brown mottles. The experimental field is situated above flood level area having available irrigation and drainage system. The soil having a texture of clay loam, organic matter content 0.84% which composed of 33.33% sand, 33.02% silt and 33.65% clay respectively. Details morphological, physical and chemical properties of the experimental field soil are presented in Table 3.1, 3.2 and 3.3.

Table 3.1 Morphological characters of experimental field

Morphological Features	Characteristics
Location	Sher-e-Bangla Agricultural University Farm
AEZ No. and name	AEZ-28, Madhupur Tract
General soil type	Shallow red brown terrace soil
Soil series	Tejgaon
Topography	Fairly leveled
Depth of inundation	Above flood level
Drainage condition	Well drained
Land type	Medium high land

Table 3.2 Physical characters of the initial soil of the experimental field

Physical characters	Percent
Sand (2-0.02 mm)	33.33
Silt (0.02-0.002 mm)	33.02
Clay (<0.002 mm)	33.65
Textural Class	Clay loam
Particle density	2.5-2.6 g cc^{-1}

Table 3.3 Chemical characters of the initial soil of the experimental field

pH	6.20
Organic Matter (%)	0.84
Organic Carbon (%)	0.48
Total N (%)	0.065
Available P (ppm)	16
Exchangeable K (meq)	0.12
Available S (ppm)	12.00

3.2 Experimental details

3.2.1 Planting material

BARI Sunflower-2 was used as the test crop in the experiment.

Developed by	Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh
Method of development/origin	Developed by open pollination and selection method.
Year of release	2004
Main characteristics	Plant height 125-140 cm, radius 2.0-2.4 cm, ripen inflorescence of head radius 15-18 cm, seed color black, number of seed/head 350-450, crop duration in rabi season 95-100 days and kharf season 85-90 days.
Planting season and time	Cultivation in rabi and kharif season
Yield	Yield in rabi season 2.0-2.3 t/ha and kharif season 1.5-1.8 t/ha
Quality of the product	Oil, 42-44%

(BARI, 2004).

3.2.2 Application of fertilizers

The following doses of fertilizers and manures were applied for the cultivation of sunflower as recommended by BARI.

Fertilizers/Manures	Dose	
	Kg/ha	g/plot
Urea	180	210
TSP	150	180
MoP	120	150
Gypsum	120	54
Cow dung	8000	3600

1/3rd of urea and whole quantity of other fertilizers were applied during final land preparation as basal dose and rest 2/3rd of urea was applied at 30 DAS and 50 DAS followed by irrigation.

3.2.3 Treatment of the experiment

The experiment comprised of the following 8 treatments:

T_1 =Urea @ 210 g/plot +TSP@ 84g/plot + MoP@ 98g/plot + Spraying 0.2% Borax @ 2g/L of water

T_2 = BARI recommended fertilizers + Borax 7.0 g/plot + $ZnSO_4$ 8.4 g/plot in soil

T_3= BARI recommended fertilizers + Spraying 0.5% Borax + 0.5% $ZnSO_4$ @ 5g/L of water

T_4= BARI recommended fertilizers + $MgSO_4$ 10 g/ Plot + Spraying MnO_2 @ 2g/L of water

T_5= BARI recommended fertilizers + Spraying Bamper Vitamix (contain nutrients Mg, S, Zn, Mn, B) @ 2g/L of water

T_6 =BARI recommended fertilizers + Spraying 0.2% Borax @ 2g/L of water + 0.2% $ZnSO_4$ @ 2gm/L of water

T_7 = BARI recommended fertilizers + Spraying 0.2% $ZnSO_4$ @ 2g/L of water

T_8= control (e.g.: no N, P, K, S, Mg, Zn, Mn and B)

(BARI recommended fertilizers; Urea 180 kg/ha, TSP 150 kg/ha, MoP 120 kg/ha, Gypsum 120 kg/ha, Cow dung 8000 kg/ha)

3.2.4 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and unit plot was 3.5 m × 4 m. The space between two blocks and two plots were 1 m each and plant to plant distance was 0.5 m. The layout of the experiment is shown in Figure 1.

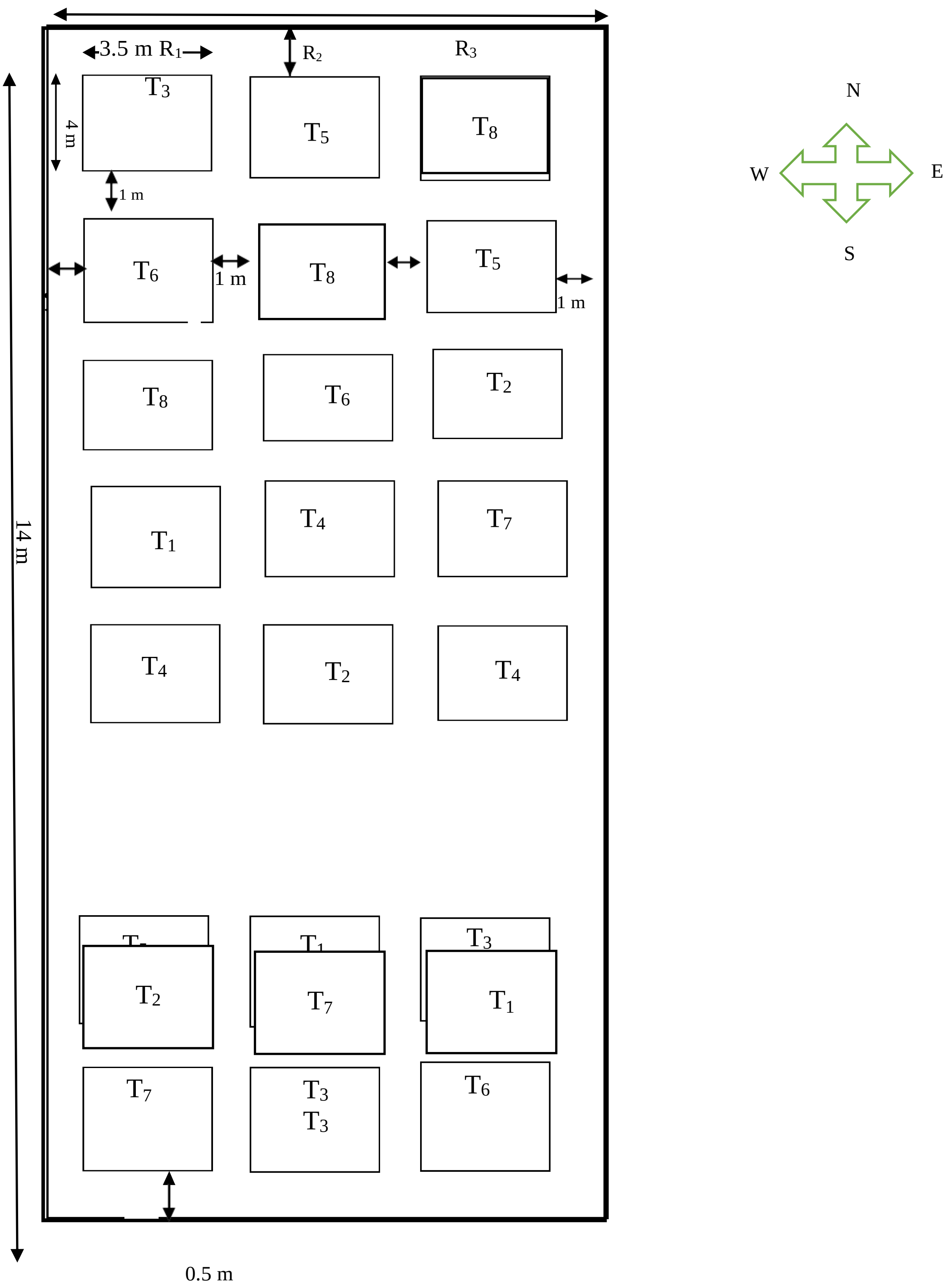

Figure 1. Layout of the experimental plot

3.3 Growing of crops

3.3.1 Variety selection and collection

BARI Surjamukhi-2 was selected as test crop considering its resistance against alternaria leaf blight disease and seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701.

3.4 Land preparation

The field for conducting the experiment was opened on the 9th November, 2021 with a power tiller and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was divided into unit plots in accordance with the experimental design on 20th November, 2021. Basal dose of fertilizers were applied in respective plots as per treatments and mixed it with soil.

3.5 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.5.1 Irrigation and drainage

Irrigation was done at 7-10 days interval as per necessity.

3.5.2 Thinning and gap filling

Extra plants were removed at 25 DAS by keeping a healthy plant per hill to maintain optimum population number. Gap filling was also done according to necessity.

3.5.3 Weeding

Weeding was done in the experimental plots as per necessary.

3.6 Disease of the plants

Natural infection of the plants was considered in this experiment.

3.7 Insect control

Furadan 5G was applied at 25 DAT in the plot. Leaf roller (*Chaphalocrosis medinalis*) was found and applied Malathion @ 1.12 L ha^{-1} at panicle initiation stage using sprayer.

3.8 Harvesting, threshing and cleaning

The selected sunflower plants were harvested at 105 DAS when all plants were fully matured. Yield of each treatment in all replications were recorded separately. Fresh weight of sunflower was recorded plot wise from 5 m^2 were recorded from each plot and converted to hectare yield and expressed in t ha^{-1}. The seeds were dried, cleaned and weighed for individual plot. The weight was adjusted to 12% moisture content.

3.9 Data recording

Five plants were randomly selected from each plot and the data was recorded on the following parameters-

3.9.1 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 centimetres.

3. 9.2 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. 9.3 Number of leaves per plant

Number of leaves per plant was counted at harvest. The number of leaves $plant^{-1}$ was counted from 10 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. 9.4 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. 9.5 Leaf length

The length (cm) of leaf was measured with a meter scale from the top of the leaf to the bottom of 5 selected sunflowers from each plot and there average was taken and expressed in cm.

3. 9.6 Leaf width

The leaf width **(**cm**)** of five randomly selected sunflowers was measured in centimeter (cm) by using meter scale. It was measured from every leaf upper, middle and lower portion scaling and their average was taken.

3. 9.7 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. 9.8 Diameter of inflorescence with petal

Diameter of inflorescence 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. 9.9 Number of petal

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. 9.10 Number of calyx

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

3. 9.11 Number of total head per plot

Total number of head produced per plant was counted.

3. 9.12 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. 9.13 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. 9.14 Weight of single seed

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

3. 9.15 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 Preparation of seeds and extraction of oil

To begin the process, physical impurities were cleaned and air-dried to reduce the moisture content of the seed samples. The next steps were to crack the size of the seeds down and then they were flattened to form flakes, which facilitated increasing the surface area for easier extraction of oil. Lateron food grade n-Hexane (for solvent extraction) was fed to extract oil from the flakes and refluxed using Soxhlet apparatus. The refluxed mixture was filtered to remove all the visible flasks and residues. In addition to that, the solvent of the filtrate was removed by rotary evaporation. Finally, the obtained oil from seed samples was calculated. During the oil extraction and solvent evaporation process, degradation of all the samples was protected from light. All the measurements were performed trice of each sample and the data were recorded.

3. 11 Measurement of protein content of sunflower

The Kjeldahl method involves a three-step approach to the quantification of protein: digestion, distillation, and titration. Digestion of organic material is achieved using concentrated H_2SO_4, heat, K_2SO_4 (to raise the boiling point), and a catalyst (e.g., selenium) to speed up the reaction. This process converts any nitrogen in the sample to ammonium sulfate. The digestate is neutralized by the addition of NaOH, which converts the ammonium sulfate to ammonia, which is distilled off and collected in a receiving flask of excess boric acid, forming ammonium borate. The residual boric acid is then titrated with a standard acid with the use of a suitable end-point indicator to estimate the total nitrogen content of the sample. Following determination of the total nitrogen, a specific conversion factor 5.30 was needed to convert the measured nitrogen content to the crude protein content.

3.12 Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant differences among different treatments. The analyses of variance of all the recorded parameters were performed using MSTAT-C software. The difference of the mean values was separated by Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER-IV
RESULTS AND DISCUSSION

Results of the experiment entitled "Effects of Mg, S, Zn, Mn and B on growth, yield and oil content of sunflower", 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 Plant height

Plant height increased significantly due to different treatments of Mg, S, Zn, Mn and B application of sunflower (Table1). The maximum plant height (180.67 cm) was recorded from T_5 treatment followed by T_6 (172.33 cm) treatment and minimum plant height (146.73 cm) was observed from T_8 (control) treatment (Table 1). Similar result was also observed by Ravikumar *et al.* (2021) and Faisal *et al.* (2020).

4.2 Number of seeds per head

Number of seeds per head varied significantly with different treatments of Mg, S, Zn, Mn and B application of sunflower (Table 1). The maximum number of seed per head (645.5) was recorded from T_5 treatment which was statistically identical to T_1 (618.5) treatment, while the minimum number of seed per head (375.9) was obtained from T_8 (control) treatment. Similar Findings Keerio *et al.* (2020) and Saad and Al-Doori (2017) also in agreement with our results.

Table 1: Effect of Mg, S, Zn, Mn and B application on plant height (cm), number of seeds per head and number of leaves per plant of sunflower

Treatments	Plant height(cm)	Number of seeds/heads	Number of leaves
T_1	162.33 cd	545.0 d	17.67 bc
T_2	156.67 de	495.5 e	15.33 cd
T_3	151.33 ef	618.5 b	14.33 cd
T_4	155.67 e	482.3 e	15.00 cd
T_5	180.67 a	645.5 a	23.33 a
T_6	172.33 b	555.9 d	19.67 ab
T_7	165.00 c	597.4 c	17.67 bc
T_8	146.73 f	375.9 f	12.00 d
$LSD_{(0.5)}$	6.1262	17.309	3.8339
$CV_{(\%)}$	9.36	6.85	13.13

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1 =Urea @ 210 g/plot +TSP@ 84g/plot + MoP@ 98g/plot+Spraying 0.2% Borax @ 2g/L of water

T_2 = BARI recommended fertilizers + Borax 7.0 g/plot + $ZnSO_4$ 8.4 g/plot in soil

T_3= BARI recommended fertilizers + Spraying 0.5% Borax + 0.5% $ZnSO_4$ 5g/L of water

T_4= BARI recommended fertilizers + $MgSO_4$ 10 g/ Plot + Spraying MnO_2 @ 2g/L of water

T_5= BARI recommended fertilizers + Spraying Bamper Vitamix @ 2g/L of water

T_6 =BARI recommended fertilizers+Spraying 0.2% Borax 2g/L of water+0.2% $ZnSO_4$ 2gm/L of water

T_7 = BARI recommended fertilizers + Spraying 0.2% $ZnSO_4$ @ 2g/L of water

T_8= control (e.g.: no N, P, K, S, Mg, Zn, Mn and B)

4.3 Number of leaves

Number of leaves per plant is an important parameter for studying the growth of crop plant because of its physiological role in photosynthetic activities. From the result it appears that leaf number of sunflower varied significantly with application of Mg, S, Zn, Mn and B (Table 1). The maximum number of leaves (23.33) was recorded from T_5 treatment which was statistically identical to T_6 (19.67) treatment, while the minimum number of leaves (12.00) was obtained from T_8 (control) treatment. Similar findings were also reported by Faisal *et al.* (2020).

4.4 Leaf area

It is apparent from the results presented in (Table 2) that Mg, S, Zn, Mn and B application on leaf area of sunflower plants varied significantly. The maximum leaf area (65.33 cm^2) was recorded in T_5 treatment and the minimum leaf area (50.00 cm^2) was observed in T_8 treatment. Similar findings were also reported by Kawade *et al.* (2018); Saad and Al-Doori (2017) and Siddiqui *et al.* (2009).

Table 2: Effect of Mg, S, Zn, Mn and B application on leaf area, leaf length and leaf width of sunflower

Treatments	Leaf area (cm^2)	Leaf length (cm)	Leaf width (cm)
T_1	54.33 bcd	19.76 bc	15.76 b
T_2	59.00 b	16.43 cd	16.67 b
T_3	52.67 cd	17.33 bc	14.00 bc
T_4	54.67 bcd	16.70 cd	14.06 bc
T_5	65.33 a	23.88 a	19.88 a
T_6	55.67 bc	20.73 ab	15.83 b
T_7	59.00 b	19.70 bc	16.50 b
T_8	50.00 d	13.30 d	12.67 c
$LSD_{(0.5)}$	4.8056	3.4661	3.0793
$CV_{(\%)}$	4.93	10.84	11.35

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1 =Urea @ 210 g/plot +TSP@ 84g/plot + MoP@ 98g/plot + Spraying 0.2% Borax @ 2g/L of water

T_2 = BARI recommended fertilizers + Borax 7.0 g/plot + $ZnSO_4$ 8.4 g/plot in soil

T_3= BARI recommended fertilizers + Spraying 0.5% Borax + 0.5% $ZnSO_4$ 5g/L of water

T_4= BARI recommended fertilizers + $MgSO_4$ 10 g/ Plot + Spraying MnO_2 @ 2g/L of water

T_5= BARI recommended fertilizers + Spraying Bamper Vitamix @ 2g/L of water

T_6 =BARI recommended fertilizers + Spraying 0.2% Borax 2g/L of water+0.2% $ZnSO_4$ 2gm/L of water

T_7 = BARI recommended fertilizers + Spraying 0.2% $ZnSO_4$ @ 2g/L of water

T_8= control (e.g.: no N, P, K, S, Mg, Zn, Mn and B)

4.5 Leaf length

Leaf length of sunflower showed statistically significant differences due to application of Mg, S, Zn, Mn and B (Table 2). The maximum length of leaf (23.88 cm) was recorded from T_5 treatment which was statistically identical with T_6 (20.73 cm). The results indicated that spraying Bamper Vitamix 2g/L and 0.2% Borax + 0.2% $ZnSO_4$

had similar effect on production on leaf length of sunflower. while the minimum length of leaf (13.30 cm) was obtained from T_8 (control) treatment.

4.6 Leaf width

The effect of different treatments of Mg, S, Zn, Mn and B application had significant influence on leaf width of sunflower plants (Table 2). The maximum leaf width (19.88 cm) was produced by T_5 treatment followed by T_2 and T_7. From this results it is apparent $ZnSO_4$ either as soil application or as spray had considerable effect of leaf width of sunflower. And the minimum leaf width (12.67 cm) was measured in T_8 (control) treatment.

4.7 Diameter of capitulum of sunflower

The diameter of capitulum of sunflower showed statistically significant variation due to the application of Mg, S, Zn, Mn and B (Table 3). The highest capitulum diameter (11.67 cm) was recorded in T_5 treatment. The second highest capitulum diameter (10.00 cm) was found in T_2 treatment which was statistically similar to T_6 treatment. And the lowest capitulem diameter (5.67 cm) was recorded in T_8 treatment. Similar findings were also reported by Keerio *et al.* (2020) and Faysal *et al.* (2020).

Table 3: Effect of Mg, S, Zn, Mn and B application on capitulum diameter and diameter of inflorescence with petals of sunflower

Treatments	Capitulum diameter (cm)	Diameter of inflorescence with petals
T_1	8.97 bc	19.10 bc
T_2	10.60 ab	20.60 b
T_3	6.50 de	21.07 b
T_4	7.57 cde	21.23 b
T_5	11.67 a	22.00 a
T_6	10.00 ab	17.50 cd
T_7	7.67 cd	17.20 cd
T_8	5.67 e	15.80 d
LSD $_{(0.5)}$	1.9122	2.3741
CV $_{(\%)}$	12.88	7.00

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1 =Urea @ 210 g/plot +TSP@ 84g/plot + MoP@ 98g/plot+Spraying 0.2% Borax @ 2g/L of water

T_2 = BARI recommended fertilizers + Borax 7.0 g/plot + $ZnSO_4$ 8.4 g/plot in soil

T_3= BARI recommended fertilizers + Spraying 0.5% Borax + 0.5% $ZnSO_4$ 5g/L of water

T_4= BARI recommended fertilizers + $MgSO_4$ 10 g/ Plot + Spraying MnO_2 @ 2g/L of water

T_5= BARI recommended fertilizers + Spraying Bamper Vitamix @ 2g/L of water

T_6 =BARI recommended fertilizers + Spraying 0.2% Borax 2g/L of water+0.2% $ZnSO_4$ 2gm/L of water

T_7 = BARI recommended fertilizers + Spraying 0.2% $ZnSO_4$ @ 2g/L of water

T_8= control (e.g.: no N, P, K, S, Mg, Zn, Mn and B)

4.8 Diameter of inflorescence with petal

Diameter of inflorescence with petal varied significantly due to Mg, S, Zn, Mn and B application of sunflower (Table 3). The maximum diameter of flower with petal (22.00 cm) was recorded from T_5 treatment, while it was minimum (15.80 cm) in T_8 (control) treatment.

4.9 Number of petals

Number of petals varied due to Mg, S, Zn, Mn and B application of sunflower (Table 4). The maximum number of petal (44.67) was recorded from T_5 treatment followed by T_6 (40.67) treatment, while the minimum number of petals (30.33) was obtained from T_8 (control) treatment.

Table 4: Effect of Mg, S, Zn, Mn and B application on number of petals, number of calyx and number of total head/plots of sunflower

Treatments	Number of petals	Number of calyx	Number total head/plot
T_1	38.00 bc	47.67 c	37 c
T_2	35.67 cd	54.00 b	38 bc
T_3	39.33 bc	52.00 b	38 bc
T_4	33.67 de	51.67 b	42 ab
T_5	44.67 a	59.00 a	39 bc
T_6	40.67 ab	54.33 b	39 bc
T_7	37.67 bcd	51.00 bc	40 bc
T_8	30.33 e	43.00 d	45 a
$LSD_{(0.5)}$	4.2545	3.8339	4.3272
CV (%)	6.25	4.29	9.65

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

T_1 =Urea @ 210 g/plot +TSP@ 84g/plot + MoP@ 98g/plot+Spraying 0.2% Borax @ 2g/L of water

T_2 = BARI recommended fertilizers + Borax 7.0 g/plot + $ZnSO_4$ 8.4 g/plot in soil

T_3= BARI recommended fertilizers + Spraying 0.5% Borax + 0.5% $ZnSO_4$ 5g/L of water

T_4= BARI recommended fertilizers + $MgSO_4$ 10 g/ Plot + Spraying MnO_2 @ 2g/L of water

T_5= BARI recommended fertilizers + Spraying Bamper Vitamix @ 2g/L of water

T_6 =BARI recommended fertilizers + Spraying 0.2% Borax 2g/L of water+0.2% $ZnSO_4$ 2gm/L of water

T_7 = BARI recommended fertilizers + Spraying 0.2% $ZnSO_4$ @ 2g/L of water

T_8= control (e.g.: no N, P, K, S, Mg, Zn, Mn and B)

4.10 Number of calyx

Number of calyx of sunflower varied significantly due to application of Mg, S, Zn, Mn and B (Table 4). The maximum number of calyx (59.00) was recorded from T_5 treatment, while the minimum number of calyx (43.00) was obtained from T_8 (control) treatment. From the results it appears that Bamper Vitamix had positive impact on the formation of sunflower calyx as compared to other fertilizer sources applied.

4.11 Number of total head per plot

Number of total head per plot varied significantly due to different treatments of Mg, S, Zn, Mn and B application of sunflower (Table 4). The maximum number of total head per plot (45.00) was recorded from T_8 treatment. The number of total head per plot was identical in T_2, T_3 and T_6 treatments while the minimum number of leaves (37.00) was obtained from T_1 treatment.

4.12 Weight of total seed per plot

Weight (kg) of total seed per plot varied significantly due to application of fertilizers containing elements like Mg, S, Zn, Mn and B (Table 5). The maximum weight of total seed per plot (2.51 kg) was recorded from T_5 treatment, while the minimum weight of total seed per plot (1.18 kg) was obtained from T_8 (control) treatment. Similar findings were also reported by Sher *et al.* (2021).

4.13 Weight of seed per head

Weight of seed per head varied significantly due to application of fertilizers containing elements like Mg, S, Zn, Mn and B (Table 5). The maximum weight of seed per head (64.55 gm) was recorded from T_5 treatment and second highest in T_3

(55.63 gm) treatment, while the minimum weight of seed per head (26.31 gm) was obtained from T_8 (control) treatment.

Table 5: Effect of Mg, S, Zn, Mn and B application on weight of total seed per plot, weight of seed per head, weight of single seed & yield of sunflower

Treatments	Weight of total seed/plot (kg)	Weight of seed per head (gm)	Weight of single seed	Yield (t/ha)
T_1	1.82 d	49.09 c	0.09 ab	1.30 d
T_2	1.70 e	44.57 cd	0.09 ab	1.21 e
T_3	2.12 b	55.63 b	0.09 ab	1.52 b
T_4	1.63 f	38.60 d	0.08 bc	1.16 f
T_5	2.51 a	64.55 a	0.10 a	1.70 a
T_6	1.73 e	47.40 c	0.08 bc	1.23 e
T_7	1.91 c	26.31 e	0.08 bc	1.36 c
T_8	1.18 g	26.31 e	0.07 c	0.85 g
LSD $_{(0.5)}$	0.0665	6.0973	0.0142	0.0470
CV $_{(\%)}$	7.10	8.00	9.65	6.45

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1 =Urea @ 210 g/plot +TSP@ 84g/plot + MoP@ 98g/plot+Spraying 0.2% Borax @ 2g/L of water

T_2 = BARI recommended fertilizers + Borax 7.0 g/plot + $ZnSO_4$ 8.4 g/plot in soil

T_3= BARI recommended fertilizers + Spraying 0.5% Borax + 0.5% $ZnSO_4$ 5g/L of water

T_4= BARI recommended fertilizers + $MgSO_4$ 10 g/ Plot + Spraying MnO_2 @ 2g/L of water

T_5= BARI recommended fertilizers + Spraying Bamper Vitamix @ 2g/L of water

T_6 =BARI recommended fertilizers + Spraying 0.2% Borax 2g/L of water+0.2% $ZnSO_4$ 2gm/L of water

T_7 = BARI recommended fertilizers + Spraying 0.2% $ZnSO_4$ @ 2g/L of water

T_8= control (e.g.: no N, P, K, S, Mg, Zn, Mn and B)

4.14 Weight of single seed

Effects of Mg, S, Zn, Mn and B 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 (0.10 g) was found from the treatment T_5 and it was lowest (0.07 g) was in treatment T_8 (Control). The results obtained by Saha *et al.* (2018) and Rahman *et al.* (2015), which supported the present findings.

4.15 Yield (t/ha)

Yield of sunflower seeds varied due to application of Mg, S, Zn, Mn and B fertilizers under study (Table 5). The maximum yield (1.70 t ha^{-1}) was recorded from T_5 treatment, while the minimum yield (0.85 ton per ha) was obtained from T_8 (control) treatment. Keerio *et al.* (2020); Khan *et al.* (2029) and Kawade *et al.* (2028) also reported similar results.

4.16 Oil content of sunflower

Remarkable variation was observed on oil content of sunflower when Bamper Vitamix was sprayed @ 2g/L along with recommended treatments of fertilizers (Table 6).Other sources of secondary micronutrient elements like Mg, S, Zn, Mn and B also enhanced oil content of sunflower as compared to control. The highest oil content (46.53 %) was found from the treatment of T_5 followed by T_3 (43 %) treatment. It was lowest (21.28 %) achieved from the treatment of T_8 (control).Our results are in agreement with those of Sher *et al.* (2021) and Galavi *et al*. (2012).

Table 6: Effect of Mg, S, Zn, Mn and B application on oil content of sunflower

Treatments	Oil content (%)
T_1	40.50 c
T_2	38.00 d
T_3	43.00 b
T_4	37.50 d
T_5	46.53 a
T_6	36.10 e
T_7	40.06 c
T_8	21.28 f
LSD $_{(0.5)}$	0.9314
CV $_{(\%)}$	5.35

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1 =Urea @ 210 g/plot +TSP@ 84g/plot + MoP@ 98g/plot+Spraying 0.2% Borax @ 2g/L of water

T_2 = BARI recommended fertilizers + Borax 7.0 g/plot + $ZnSO_4$ 8.4 g/plot in soil

T_3= BARI recommended fertilizers + Spraying 0.5% Borax + 0.5% $ZnSO_4$ 5g/L of water

T_4= BARI recommended fertilizers + $MgSO_4$ 10 g/ Plot + Spraying MnO_2 @ 2g/L of water

T_5= BARI recommended fertilizers + Spraying Bamper Vitamix @ 2g/L of water

T_6 =BARI recommended fertilizers + Spraying 0.2% Borax 2g/L of water+0.2% $ZnSO_4$ 2gm/L of water

T_7 = BARI recommended fertilizers + Spraying 0.2% $ZnSO_4$ @ 2g/L of water

T_8= control (e.g.: no N, P, K, S, Mg, Zn, Mn and B)

4.17 Protein content of sunflower

Remarkable variation was observed on protein content of sunflower due to the Mg, S, Zn, Mn and B containing fertilizers (Figure 2). The highest protein content (22.25 %) was found from the treatment of T_5 followed by T_1 (17.50 %) treatment. The lowest protein content (13.97 %) was achieved from the treatment of T_8 (control). It is therefore informed that application of Bamper Vitamix at 2g/L was most effective in producing highest protein content in sunflower while comparing the reslts attained with Mg, S, Zn, Mn and B containing fertilizers. Kawade *et al.* (2028) also reported similar results.

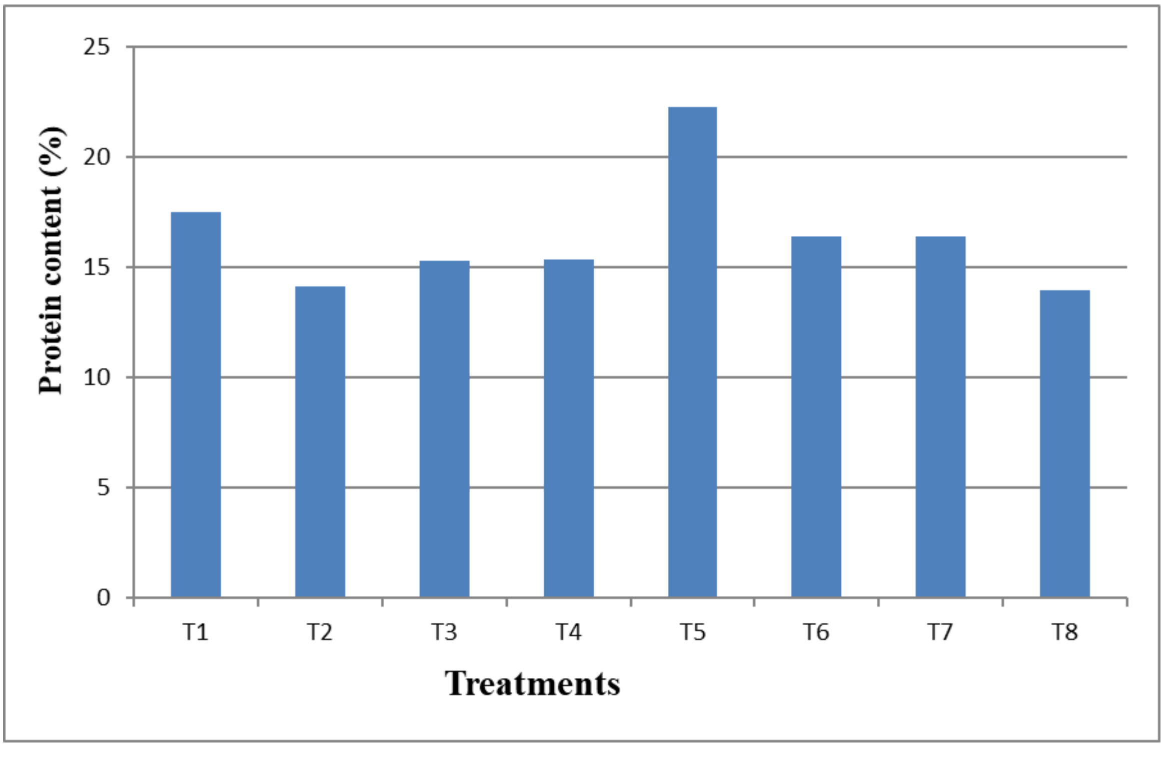

Figure 2: Effect of Mg, S, Zn, Mn and B application on protein content of sunflower

T_1 =Urea @ 210 g/plot +TSP@ 84g/plot + MoP@ 98g/plot+Spraying 0.2% Borax @ 2g/L of water

T_2 = BARI recommended fertilizers + Borax 7.0 g/plot + $ZnSO_4$ 8.4 g/plot in soil

T_3= BARI recommended fertilizers + Spraying 0.5% Borax + 0.5% $ZnSO_4$ 5g/L of water

T_4= BARI recommended fertilizers + $MgSO_4$ 10 g/ Plot + Spraying MnO_2 @ 2g/L of water

T_5= BARI recommended fertilizers + Spraying Bamper Vitamix @ 2g/L of water

T_6 =BARI recommended fertilizers + Spraying 0.2% Borax 2g/L of water+0.2% $ZnSO_4$ 2gm/L of water

T_7 = BARI recommended fertilizers + Spraying 0.2% $ZnSO_4$ @ 2g/L of water

T_8= control (e.g.: no N, P, K, S, Mg, Zn, Mn and B)

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Research Farm and laboratory of Agro-Environmental Lab, Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the period from November 2021 to March 2022 to study the effect of Mg, S, Zn, Mn and B on growth, yield & oil content of sunflower. The experiment comprised of eight treatments viz., T_1 =Urea @ 210 g/plot +TSP@ 84g/plot + MoP@ 98g/plot + Spraying 0.2% Borax @ 2g/L of water, T_2 = BARI recommended fertilizers + Borax 7.0 g/plot + $ZnSO_4$ 8.4 g/plot in soil, T_3= BARI recommended fertilizers + Spraying 0.5% Borax + 0.5% $ZnSO_4$ 5g/L of water, T_4= BARI recommended fertilizers + $MgSO_4$ 10 g/ Plot + Spraying MnO_2 @ 2g/L of water, T_5= BARI recommended fertilizers + Spraying Bamper Vitamix @ 2g/L of water, T_6 =BARI recommended fertilizers + Spraying 0.2% Borax 2g/L of water+0.2% $ZnSO_4$ 2gm/L of water, T_7 = BARI recommended fertilizers + Spraying 0.2% $ZnSO_4$ @ 2g/L of water and T_8= control (e.g.: no N, P, K, S, Mg, Zn, Mn and B). 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, leaf length, leaf width, oil content, number of seed per head, leaf area, length of leaf, capitulum diameter, diameter of flower with petal, 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 were studied. All the parameters varied significantly due to application of Mg, S, Zn, Mn, B, and Bamper vitamix.

The maximum plant height (180.67 cm), number of seed per head (645.5), number of leaves (23.33), leaf area (65.33 cm), length of leaf (23.88 cm) per plant, leaf width (19.88 cm), capitulum diameter (11.67 cm), diameter of flower with petal (22.00 cm), number of petal (44.67), number of calex (59.00), number of total head per plot (45), weight of total seed per plot (2.51 kg), weight of seed per head (64.55 gm), weight of single seed (0.1 g), yield (1.7 t/ha), oil content (46.53 %) and protein content (22.25 %) were observed from T_5 treatment. While the minimum plant height (146.73 cm), number of seed per head (375.9), number of leaves (12.00), leaf area (50.00 cm), length of leaf (13.30 cm), leaf width (12.67 cm), capitulem diameter (5.67 cm), diameter of flower with petal (15.80 cm), number of petal (30.33), number of calex (43.00), number of total head per plot (37), weight of total seed per plot (1.18 kg), yield (0.85 ton per ha), weight of single seed (0.07 g), weight of seed per head (26.31 gm), oil content (21.28 %) and protein content (13.97 %) were observed from T_8 (control) treatment respectively. Application of BARI recommended fertilizers + spraying Bamper Vitamix @ 2gm/ L of water showed better performance for maximum parameters of sunflower. So, it can be concluded that combination of BARI recommended fertilizers + spraying Bamper Vitamix @ 2gm/ L of water 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

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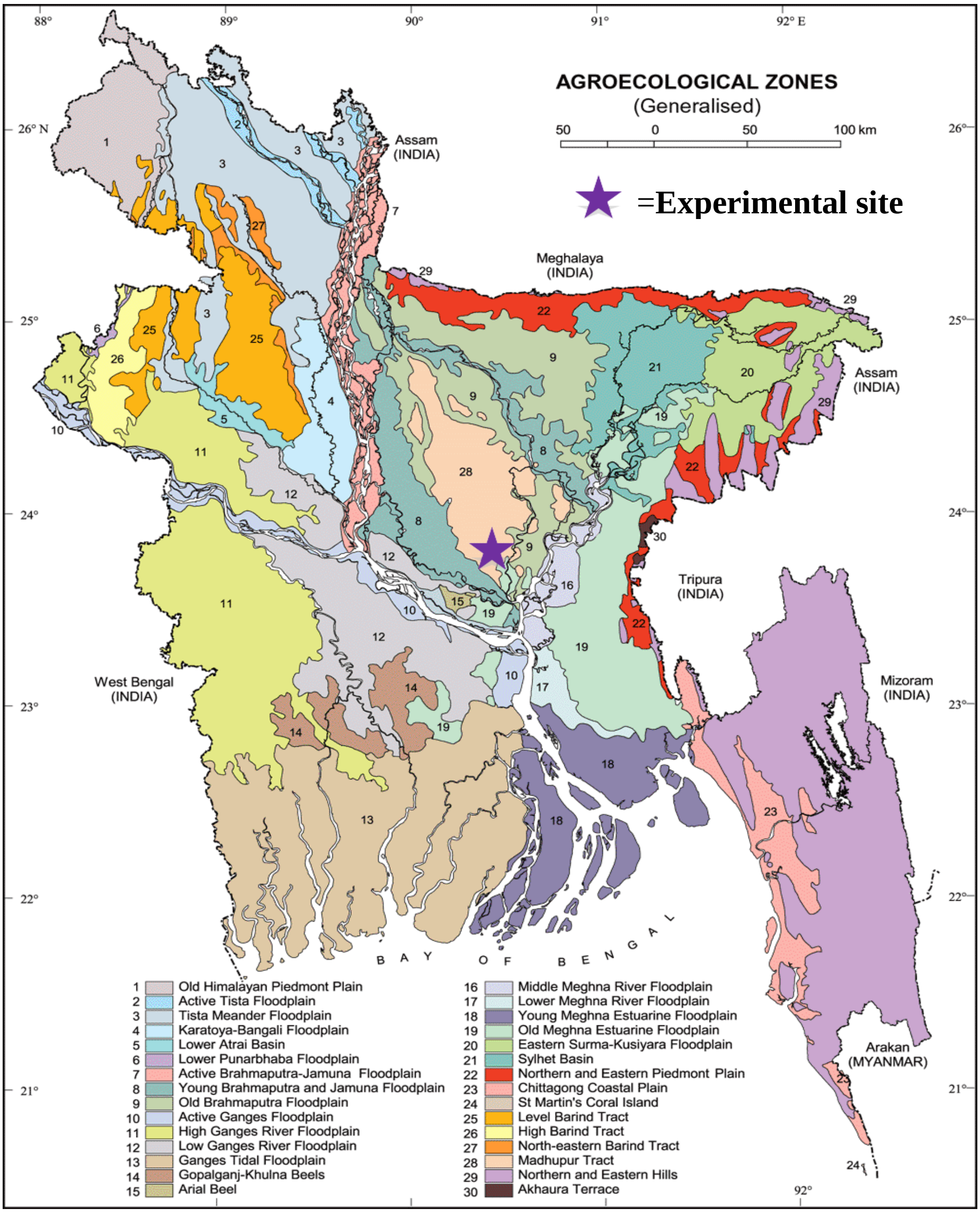
APPENDICES

Appendix I. Experimental location on the map of agro-ecological zones of bangladesh



Appendix II. Monthly average of air temperature, relative humidity and total rainfall of the experimental site during the period from November, 2021 to March, 2022

Month	*Air temperature (°C)		*Relative humidity (%)	*Rainfall (mm) (total)
	Maximum	Minimum		
November, 2021	25.8	16.0	78	00
December, 2021	22.4	13.5	74	00
January, 2022	25.2	12.8	69	00
February, 2022	27.3	16.9	66	39
March, 2022	31.7	19.2	57	23

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka - 1212

Appendix III. Characteristics of horticulture farm soil as analyzed by Soil resources development institute (SRDI), khamar bari, farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Horticulture Garden, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land t}pe	High land
Soil scries	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Fallow - Broccoli

Appendix III. (contd.)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Particle size analysis	
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (mc/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI

Appendix IV. Some pictorial documents of the research experiment during the study period

Plate no. 1: Experimental research field sunflower during the study period.

Plate no. 2: Healthy sunflower with flower bud during the study period.

Plate no. 3: Healthy sunflower pollinated by honey bee.

Plate no. 4: Healthy capitulem sunflower.

Plate no. 5: Healthy capitulem sunflower after harvesting.

Plate no. 6: Healthy sunflower seeds after harvesting.