EFFECT OF Zn AND Mn ON GROWTH AND YIELD OF SUNFLOWER UNDER SALT STRESS CONDITION

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This is to certify that thesis entitled, **"Effect of Zn and Mn on Growth and Yield of Sunflower Under Salt Stress Condition"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science** in **Agronomy,** embodies the result of a piece of bonafide research work carried out by **Mohua Akter,** Registration **No. 15-0744** 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.

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DEDICATED TO

MY

BELOVED PARENTS

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The Author

EFFECT OF Zn AND Mn ON GROWTH AND YIELD OF SUNFLOWER UNDER SALT STRESS CONDITION

ABSTRACT

An experiment was conducted in pot house of Sher-e-Bangla Agricultural University, Dhaka during November 2021 to March 2022 to evaluate the effect of foliar application of Zn and Mn on the growth, yield contributing characters and yield of BARI Sunflower 2 under saline stress conditions. The experiment consisted of two factors as factor A; S_0 = Control, S_1 = 10 ds/m NaCl and S_2 = 20 ds/m NaCl; factor B; T_0 = water spray, T_1 = 0.5% Zn spray, T_2 = 0.5% Mn spray and T_3 = 0.5% Zn spray + 0.5% Mn spray. The experiment was laid out in a Randomized Completely Block Design with three replications. Different growth and yield contributing traits, *viz*. plant height (cm), number of leaf, head diameter (cm), head weight (g), number of seed head^{-1}, 1000 seed weight (g) and yield (t ha^{-1}) were studied. Treatment S_0 (Control) produced the tallest plants at 30, 45 and 60 DAS (36.87, 49.50 and 85.33 cm) compared to other two levels of salinity. The treatment S_2 (20 ds m^{-1} NaCl) produced the shortest plant at 30, 45 and 60 DAS (31.67, 44.70 and 74.33 cm). The reproductive growth in the sunflower was higher for Zn and Mn spray rather water spray. The lowest yield (1.53 t ha^{-1}) was recorded in T_0 treatment. In treatment combination of zero saline and 0.5% Zn spray + 0.5% Mn spray (S_0T_3) gave highest yield (2.93 t ha^{-1}), which was significantly higher than 20 ds/m NaCl and water spray (S_2T_0) (1.20 t ha^{-1}). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly. The results indicated that foliar application of Zn and Mn was significantly improved the yield contributing parameters despite the effect of different level of salinity.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agriculture Organization
et al.	=	And others
DAS	=	Days after Sowing
Mg	=	Milligram
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resource Development Institute
g	=	Gram
cm	=	Centimeter
wt	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Non significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Co-efficient of Varian

CHAPTER I

INTRODUCTION

Sunflower is the fourth annual oil seed crop in the world with high performance under a wide range of environmental conditions (Hatami, 2017) due to its short growing season and adaptability to a wide range of climatic and soil conditions (Thavaprakash *et al.*, 2003). Sunflower produces high-quality oil for human consumption, the oil is also used in the chemical and food industries (El-Bially *et al.*, 2018). Salinity is the main abiotic stress beside the other stresses such as drought and low and high temperature that negatively influences the productivity of biomass, economic yields, and in the end survival of food crops up to the two-third, therefore they are a real threat to global food security (Nawaz *et al.*, 2020). Plant distribution, survival, and productivity are markedly affected by salinity (Ashraf and Harris, 2004). The salt-affected area is increasing day by day because of climate change and it is assumed that 50% of cultivable land will be salt affected by the middle of the twenty-first century (Mahajan and Tuteja, 2005). High salinity affects plant growth through the osmotic effect of the salt in the growth medium and the toxic effect of the salt within the plant. The immediate response of plants to high concentrations of salt is osmotic adjustment by reducing cell expansion, cell division, stomatal closure and gradually reducing leaf area and thus photosynthesis and growth is reduced. In later stages, plants experience ionic stress after accumulating toxic levels of sodium (Na^+) and chloride (Cl^-). Plants exposed to higher salt result in higher Na^+ accumulation and a higher Na^+/potassium (K^+) ratio because Na^+ influx causes K^+ efflux and triggers K^+ leakage from plant cells (Rahman *et al.*, 2016). Higher Na^+ content and a higher Na^+/K^+ ratio in cells cause metabolic toxicity because Na^+ compete with K^+ for binding sites of essential enzymes, and Na^+ cannot be a substitute for K^+ (Rahman *et al.*, 2016).

In general Zinc have main role in synthesis of proteins, enzyme activating, oxidation and revival reactions and metabolism of carbohydrates. Among the essential micronutrients, Zinc (Zn) is reported to have a significant potential to alleviate plant abiotic stress (Weisany *et al.*, 2014). By utilizing of fertilizers contain zinc performance on quality of crops is increasing and with shortage of this elements due to decline in plant photosynthesis and destroy RNA, amount of solution carbohydrates and synthesis of protein decreased and then performance and quality of crop will be decreased (Efe and Yarpuz, 2011). Also, recent studies have suggested that fast uptake of Zn by plants could be the key point of its role against stress (Iqbal *et al.*, 2018). Indeed, several studies on different plants, such as soybeans, cordgrass and tomato, under salinity condition have suggested that Zn increased the tolerance against salt stress, due to this element playing an important role in antioxidant metabolism as a cofactor of main enzymes (Weisany *et al.*, 2014).

Manganese (Mn) is an essential trace element for plants and plays a crucial role in several metabolic processes including photosynthesis, respiration, synthesis of ATP, fatty acid, amino acids, lipids, proteins, flavonoids and hormone activation which helps to reduce the effect of salinity (Lidon *et al.*, 2004; Millaleo *et al.*, 2010). Manganese deficiency is detrimental to plants because it affects the water-splitting step of photosystem II (PS II), which directly provides electrons for photosynthesis. Manganese deficiency also weakens structural resistance against pathogens and reduces tolerance against salinity, drought and heat stress (Millaleo *et al.*, 2010). Several studies also revealed that supplemental Mn plays an important role in the adaptive responses of plants under various environmental stresses. Simultaneous application of Mn improves growth, relative growth rate (RGR), net assimilation rate (NAR), and photosynthetic rate of salinity-stressed barley seedlings (Pandya *et al.*, 2004).

High salt concentrations in soils inhibiting crop growth and productivity are frequent constraint to agriculture in arid and semi-arid regions. Irrigation with poor quality water is one of the main factors resulting in salt accumulation and decrease of agricultural productivity. As saline soils and saline waters are common around the world, great efforts have been devoted to understand physiological aspects of tolerance to salinity in plants. Salinity imposes both ionic and osmotic stresses on plants (Munns *et al.*, 2006). Therefore, salinity affects almost every aspect of the physiology and biochemistry of plants. Survival under these stressful conditions depends on the plant's ability to perceive the stimulus, generates and transmits signals and instigates biochemical changes that adjust the metabolism accordingly (Dolatabadian and Saleh, 2009). Salt stress is a major environmental threat to agriculture, and its adverse impacts are getting more serious problems in regions where saline water is used for irrigation (Türkan and Demiral, 2009). Therefore, efforts to increase the salt tolerance of crop plants are very important to ensure global food security, as well as for water and land conservation. A high salt concentration in the soil or in irrigation water can have a devastating effect on plant metabolism; that is, it can result in the disruption of cellular homeostasis and uncoupling of major physiological and biochemical processes. Plants can respond and adapt to salt stress by altering their cellular metabolism and invoking various defence mechanisms (Ghosh *et al.,* 2011). The survival of plants under this stressful condition depends on their abilities to perceive the stimulus, generate and transmit a signal, and initiate various physiological and biochemical changes (El-Shabrawi *et al.,* 2010).

However, the response of sunflower to salt stress varies among the sunflower varieties and the dose and duration of stress. Moreover, the role of supplemental Mn and Zn is also variable in such conditions. Although there are several studies on the effect of salt stress on sunflower but there are few studies considering the role of supplemental Mn and Zn is in coordinated regulation of growth, metabolism, physiology and yield of sunflower under salinity stress. This study was designed to understand the physiological mechanisms of salt stress tolerance mediated by supplemental Mn and Zn on high yielding and tolerant variety of sunflower such as BARI sunflower-2 which were grown in saline condition. Considering the strategies discussed, our present study will investigate the positive role of supplemental Zn and Mn improving the production of salt-treated sunflower considering the following objectives-

1. To study the effects of foliar spray of Zn and Mn in different concentration on growth and yield of sunflower
2. To determine the effect of foliar spray of Zn and Mn to mitigate saline stress of sunflower.

CHAPTER II

REVIEW OF LITERATURE

Sustainable and equitable global food security is partly dependent on the development of crops and horticultural plants with increased salt tolerance. Increased salt tolerance of perennial species used for fodder or fuel production is also a key component in reducing the spread of secondary salinity in many regions in the world. In the last few years, considerable progress has been made in the analysis of the transcript to study salt stress either alone or in combination with the application of supplemental Mn and Zn. The present review summarizes current research findings for the analysis of sunflower, its salt tolerance and the role of supplemental Mn and Zn.

2.1 Effect of salinity on growth and yield of sunflower

2.1.1 Effect of salinity on growth

Escalante- Estrada *et al.* (2010) conducted an experiment with three salinity levels viz. high salinity (HS) (EC 11 dS m^{-1}), medium salinity (MS) (EC 7 dS m^{-1}) and low salinity (LS) (EC 5 dS m^{-1}). They observed that the highest biomass production, yield and survival were obtained in the LS treatment (5 dS m^{-1}) with 1055 g m^{-2}, 102 g m^{-2} and 100%, followed by MS (7 dS m^{-1}) with 750 g m2, 63 g m^{-2} and 90% and HS (11 dS m^{-1}) with 311 g m^{-2}, 29 g m^{-2} and 62%, respectively. The biomass production and yield variability related to changes in plant population density and survival generated by soil salinity. Biomass accumulation in the organs, yield and survival of sunflower decreased with increasing salinity. The phenology and biomass distribution in sunflower plant organs were not affected by salinity.

Salinity can affect the growth of two very important oil yielding crops, sunflower and safflower at all the developmental stages (Siddiqi *et al.,* 2007). But the response to salinity varies with different sunflower and safflower genotypes. The reduction in growth of the salinized plants may result from the effect of salt on water and nutrient status, physiological and biochemical processes, and ionic imbalance (Hasegawa *et al.,* 2000).

Argentel *et al.* (2008) suggested that the magnitude of the effect of salinity depends on the phenological stage in which it occurs. Flagella *et al.* (2004) observed that salt stress significantly affected oil fatty acid composition. Oleic acid showed an increase from 82.8 to 86.8% in the highest salinity treatment (EC equal to 12 dS m^{-1}) compared to the control (tap water).

Sunflower are classified as being a moderately salt tolerant crop (Maas and Hoffman, 1976); however, there are significant differences in tolerance among cultivars (Ashraf and Tufail, 1995). Sunflower can show signs of salt induced stress despite being classified as a moderately tolerant crop. More salt sensitive lines may show reduction in leaf area, dry matter and ultimately yield (Katerji *et al.,* 1994). Seed oil content can be affected by soil salt concentrations (Flagella *et al.,* 2004).

Helianthus paradoxus is a wild species of sunflower known for its ability to thrive in saline and alkaline environments. Its threatened status is due in part to the damages suffered to its environment caused by highway construction, invasive species encroachment and agriculture disturbance. *H. paradoxus* is believed to be a hybrid that originated between 75,000 and 280,000 years ago (Welch and Rieseberg, 2002) from a cross of two salt sensitive species, *H. annuus* and *H. petiolaris* (Lexer *et al.,* 2003).

Because of this hybridization event and its ability to thrive in soils with high salt concentrations, the Pecos sunflower has been the subject of much sunflower research. Miller *et al.* (1995) believed that salt tolerance in sunflower can be attributed to one major gene along with possible recessive modifier genes. Other studies suggest that genetic regulation is not as simple as Miller proposed.

2.1.2 Effect of salinity on yield

Francois (1996), who found that sunflower was un-affected by soil salinity up to 5 dS m^{-1} and thus it is considered as moderately tolerance species. Also, Katerji *et al.* (2000) classified sunflower as a tolerant crop on the basis of the estimation of the crop water stress index.

Oad *et al.* (2001) recommended that sunflower can be used for saline soils and it should be planted on furrows and water applied at the rate of 50% soil moisture depletion level for maximum water use efficiency and satisfactory sunflower seed yields.

Santos *et al.* (1999) observed that salinity decreased NO_3, P and K content in the whole sunflower plants. Moreover, Decheng and Sheng (2005) showed that the physiological responses of sunflower are not only closely correlated with salinity (the total concentration of stress salt) but also with the pH (i.e. alkalinity).

Seed oil content was decreased after salt imposition (El-Khair *et al.* 2000) and Flagella *et al.* (2004), who observed significant reduction in seed oil yield with increasing salt level in sunflower grown in saline conditions

2.2 Effect of Zn and Mn on growth and yield of sunflower

2.2.1 Effect of Zn & Mn on growth

Hellal *et al.* (2021) an experiment was carried out with 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%) and 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 and found a direct relationship on the vegetative growth and yield of the sunflower plants and using maximum of water treatment (80% WHC) and the 3% and 2% mixture of 5 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 and found 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.

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}).

Keerio *et al.* (2020) conducted an experiment at field of oil seeds section, and maximum plant height (203.33 cm), stem girth (11.67 6 cm), head diameter (19.71 cm), number of seeds $head^{-1}$ (1300.0), seeds weight head1 (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) and the foliar application of Zn in 2.0% concentration can be employed to increase the sunflower yield and oil content.

Kawade *et al.* (2018) was conducted a field experiment and found 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} (T10). 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} (T5).

2.2.2 Effect of Zn & Mn on yield

Ravikumar *et al.* (2021) were conducted a study on the effect of sulphur, zinc and boron application on the growth, yield components and yield of hybrid sunflower and found 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 and 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.

Saad and Al-Doori (2017) revelled that 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). 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.

Mirzapour and Khoshgoftar (2006) conducted an experiment with Zn0 (non-Zn fertilized), Zn10, Zn20, Zn30, and Zn60 (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') where addition of 20 kg Zn ha^{-1} significantly increased seed production and shoot dry-matter yield of sunflower. The concentration of Zn in sunflower leaves was increased with an increase in soil-added Zn from 0 to 60 kg Zn ha^{-1} and found 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 Zn20.

2.3 Effect of Zinc on salinity tolerance of sunflower

2.3.1 Effect on growth

Plant zinc-nutritional status is important for increased crop productivity. Its deficiency is regarded as the most restricting factor for plant growth under conditions each of salinity stress (Khoshgoftar *et al.*, 2004) and calcareous soils in arid and semi-arid areas (Chen *et al.*, 2019). The presence of $CaCO_3$ directly or indirectly influences the availability of N, P, K, Mg, Fe, Mn, and Zn (Obreza *et al.*, 1993).

However, the limited availability of Zn in arid and semi-arid regions is particularly common on calcareous and alkaline soils (Alloway, 2006) due to their high $CaCO_3$ content and the lack of organic matter (Kumari *et al.*, 2018). Zinc decreases the harmful effect of salts and reduces the activity of NADPH-bound membrane oxiDate, which may result in a reduction in the production of ROS (Waraich *et al.,* 2011). Also, zinc may be a vital micronutrient for the correct growth of plants and human health (Noulas *et al.*, 2018), and as a co-factor in the enzymatic activity of more than 300 enzymes (Marschner, 1995).

Gitte *et al.* (2005) found that adding 5.25kg Zn/ha to the soil gave the maximum sunflower seed yield, 1000 seed weight, and oil percentage. Therefore, the current investigation aims: (a) to mitigate the adverse impact of salinity, and (b) to improve the productivity of sunflower, using seed priming technique in ASC with the application of Zn under saline stress conditions.

2.3.2 Effect on yield

The good performance of plants with progressive increase the rate of $ZnSO_4$ up to 12kg/ha, may be attributed to the potential role of Zn in promoting salt tolerance in plants with a decreased Na^+ and Cl^- ion uptake (Nadeem *et al.,* 2020). Also, Zn improves salt tolerance in plants and helps the roots absorb more water (Mehrizi *et al.*, 2011).

Moreover, zinc can act as a ROS scavenger and protect the cells (Jan *et al.,* 2019), Zn accelerates the growth of seedlings because of multiplied photosynthesis (Li *et al.,* 2013). Zn considerably improves the activity of antioxidant enzymes such as SOD, APX, and GR in sunflower plants compared with control (Akladious and Mohamed, 2017). Zn applications induce pollen longevity, leading to elevate its fertility and produce more seeds/head (Baniabbasishahri *et al.,* 2012).

However, the higher concentrations of Zn (24kg $ZnSO_4$/ha) had adverse effects and resulted in a decrease in the values due to the excessive rates of Zn that caused a toxicity level and was most inhibitory to plant growth (Dong *et al.,* 2014), which reflected on yield and its attributes.

2.4 Effect of Mn on salinity tolerance of sunflower

2.4.1 Effect on growth

The function of Mn at the cellular level of plant is to bind firmly to lamellae of chloroplast, possibly to the outer surface of thylakoid membranes, affecting the chloroplast structure and photosynthesis (Lidon and Teixeira, 2000).

Mn is required in both lower and high plants for the Hill reaction – the water splitting and oxygen evolving system in photosynthesis. Exogenous application of manganese in adequate amount may result an increase in photosynthetic activity and growth rate of cells in barley under salinity (Cramer and Nowak, 1992).

The general effect of plants to salinity is reduction in growth (Ghoulam *et al.*, 2002). Salt stress limits plant growth by adversely affecting various physiological and biochemical processes including photosynthesis (Ashraf, 2004).

Reduction in reproductive yield under salinity may be due to decrease in number of flowers (Sharma, 1992), resulting in faulty development of pollen grain and ovules which cause improper fertilization and denaturing of embryo, reduction in size of capitulum, number of seeds per capitulum and production of shrivelled seeds (Kumar *et al.*, 1980).

All these problems created by the presence of extra sodium ions in rhizophere can be avoided by providing some sodium antagonistic minerals through foliar spray that function to minimize osmotic stress or ion disequilibrium or alleviate the consequent secondary effects caused by the salt stress (El-Fouly and Abou El- Nour, 1998).

There may be three possible mechanisms for the reduction in growth under saline rooting medium i.e., turgor pressure reduction in expanding tissues, reduction in photosystem activity in leaf cells and direct effects of accumulated salts on metabolic steps in dividing and expanding cells (Neumann, 1997). Foliar applications of Mn mineral partially overcome the negative effects of stress and provide plants balanced nutrients. Spray medium of $MnCl_2$ was found better in all the vegetative growth characteristics as compared to those undergoing with spray of other individual minerals.

Kassab (2005) also observed a significant effect of micronutrients in growth parameters including yield in mung bean plants by foliar application of zinc, manganese and iron under water stress. Such enhancement effect of foliar application might be attributed to the favourable 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 (Michail *et al.,* 2004).

2.4.2 Effect on yield

Bybordi and Mamedov (2010) reported that protein content was increased in canola plants being sprayed by micronutrients i.e., Iron + Mn. Rizk and Abdo (2001) found increased crude protein contents in mung bean with the foliar application of Mg.

Maslenkova *et al.,* (1995) observed that high salinity (100mM NaCl) markedly reduced oxygen evolution in isolated thylakoids of barley seedlings. Foliar application of micronutrients i.e., Mn on sunflower plant partially offset the inhibitory effect of salinity on PSII oxygen-evolving activity and enhanced the Hill activity in plant irrespective to their growth under non saline or saline conditions. Mn was found more stimulating than Boron (alone) in activating the Hill reaction.

Lidon and Teixeira (2000) reported similar result in rice plant (cv.safari) treated with varying concentration of Mn, between 0.125 and 32 mg L^{-1}. They found a significant increase in the photosynthetic electron transport rates coupled to PSII and PSI until the 8-mg L^{-1} Mn treatment. The highest Mn treatment was also observed to be associated to the synthesis of a new thylakoid protein and a Mn protein.

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, Data collection and statistical analysis.

3.1 Location

The experiment was conducted at the Experimental shed of the Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka during October 2021 to March, 2022. The location of the experimental site has been shown in Appendix I.

3.2 Soil

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It was a medium high land with non-calcarious, clay loam and dark grey soil. The pH value of the soil was 5.6. The physical and chemical properties of the experimental soil have been shown in Appendix II.

3.3 Climate

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from October to March. The detailed meteorological Data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the meteorology centre, Dhaka for the period of experimentation have been presented in Appendix III.

3.4 Materials

3.4.1 Plant materials

BARI sunflower 2 was used in the experiment.

3.4.2 Earthen pot

Empty earthen pots with 18-inch depth were used for the experiment. Twelve (12) kilogram sun-dried soils were put in each pot. After that, pots were prepared for seed sowing.

3.5 Salinity treatments

The salinity treatments were applied on 35, 45 and 60 days after sowing. There were 3 salinity levels including control were developed by adding respected amount commercial NaCl (Wako, Japan) salt to the soil pot^{-1} as water dissolved solution. The salinity levels were S_0 (control), S_1 (10 ds/m NaCl) and S_2 (20 ds/m NaCl).

3.6 Treatments

The experiment consisted of two factors as mentioned below:

Factor A

1. S_0 = Control
2. S_1 = 10 ds/m NaCl
3. S_2 = 20 ds/m NaCl

Factor B

1. T_0 = Water spray
2. T_1 = 0.5% Zn spray
3. T_2 = 0.5% Mn spray
4. T_3 = 0.5% Zn+0.5% Mn spray

3.7 Design and layout of the experiment

The experiment was laid out in a Randomized Completely Block Design (RCBD) with three replications. There were 12 number of treatments, 4 number of replications and total 48 number of experimental pots.

3.8 Seed collection

Seeds of BARI sunflower 2 were collected from Oil Seed Research Centre, Bangladesh Agriculture Research Institute (BARI), Joydebpur, Gazipur.

3.9 Soil preparation for pot

Twelve-kilogram sundried soils were put in each pot. After that, pots were prepared for seed sowing. Earthen pots of having 12 inchs diameter, 12 inchs height with a hole at the centre of the bottom were used. Silty soil was used in the experiment. The upper edge diameter of the pots was 30 cm. While filling with soil, the upper one inch of the pot was kept vacant so that irrigation can be provided using a hose pipe. As such the diameter of the upper soil surface was 15 inch (30 cm). The final pot preparation took place on October 8th, 2021.

3.9.1 Fertilizer application in the pot

In this experiment chemical fertilizers and cow dung were applied and it's mixed properly during pot filling with soil. Fertilizers were applied @ 180-200, 160-200, 150-170, 150-170, 8-10, and 10-12 kg/ha of urea, TSP, MP, Gypsum, and Boric acid. A total of 8-10 ton/ha cowdung was also applied. Application of Zn and Mn were done according to treatment requirements.

3.9.2 Induced salinity condition in the pot

By adding different salt concentration as par treatment requirement creating salt stress condition for experiment pots. The salinity treatments were applied on 35, 45 and 60 days after sowing. There were three salinity levels including control which was developed by adding respected amount of commercial NaCl salt to the soil/pot as water dissolved solution. The salinity levels were S_0 (control), S_1 (10 ds/m NaCl) and S_2 (20 ds/m NaCl). In order to spreading homogenously in each pot, the salts were dissolved in 60 litter water and were added to pots for proper salinity imposition.

3.9.3 Seed sowing in the pot

Seeds were sown at the rate of 2-3 seeds to each experimental pot during the last week of November 2021. After sowing light irrigation was given immediately by using watering can. During day time after the newly sprouted young seedlings were shaded by polythene sheet to protect them from scorching sunshine up to a week. After seedling establishment, extra seedling was uprooted leaving one seedling in each pot.

3.10 Irrigation

During the growing stage, irrigation was used to keep 1-2 cm of water in each pot after transplantation. After flower emergence, irrigation water frequency was lowered. Before harvesting, the field was allowed to dry for seven days.

3.10.1 Weeding

During the early stages of crop establishment in the pot, sunflower plants was infected with weeds. To limit weed competition with the crop, three-handed weeding was used. The first weeding took place 20 days after transplanting, followed by the second weeding 15 days later, after that the third weeding was carried out.

3.11 Selfing of flower

Sunflower is highly cross-pollinated crop. In this crop, the cross pollination occurs due to protandry. Cross pollination occurs mainly through insects (Entomophily) and to a limited extent by wind (Anemophily). Opening of flower starts from outer side of the head and proceeds towards centre. The head takes 5-10 days for complete blooming depend on size of head and season. Anthesis occurs between 5 to 8 a.m.

3.12 Harvesting and threshing

Matured heads of sunflower were collected from the experimental pots and carried to the threshing floor and dried under the sun for 2-3 days. Seeds were dried under the sun for 4-5 days and then stored in air tight containers.

3.13 Data recording

Collection of data on the following parameters were recorded from the sample plants during the course of experiment. The sampling was done from randomly selected 1 plant in each plot. The data were recorded from the following parameters:

Vegetative parameters:

1. Plant height at 30 DAS, 45 DAS and 60 DAS
2. Number of leaves plant^{-1} 30 DAS, 45 DAS and 60 DAS
3. Leaf length at 30 DAS, 45 DAS and 60 DAS
4. Leaf breadth at 30 DAS, 45 DAS and 60 DAS
5. Leaf area at 30 DAS, 45 DAS and 60 DAS
6. SPAD value at 45 DAS and 60 DAS

Yield and yield contributing parameters:

1. Head diameter at harvesting
2. Head weight after harvesting
3. Weight of seed head^{-1}
4. Number of seed head^{-1}
5. 1000 seed weight
6. Yield (t ha^{-1})
7. Effect of salinity on germination (%)

3.13.1 Detailed procedure of Data collection

Plant height (cm)

At different days after sowing (DAS) the plant length was recorded in centimetres (cm). Data were recorded from plant of each experimental pot. The length from the ground level to the tip of the leaves was assessed.

Number of leaves plant^{-1}

The number of leaves plant^{-1} was counted at different days after sowing from pre-selected plant of each experimental pot. Leaves number plant^{-1} was counted and the mean was calculated.

Leaf length

Different days after sowing (DAS) the leaf length was recorded in centimetres (cm). Data were recorded as the average of five (5) leaves randomly selected from plant. The length from the base to the tip of the leaves was assessed.

Leaf breadth

Different days after sowing (DAS) the leaf breadth was recorded in centimetres (cm). Data were recorded as the average of five (5) leaves from randomly selected plant.

Leaf area (cm^2)

Different days after sowing (DAS) the leaf area was recorded in cm^2 from leaf length and breadth. Data were recorded as the average of five (5) leaves randomly selected plant.

SPAD value

SPAD value was determined from the plant's leaves by using an automatic SPAD meter (KONIKA MINOLTA SPAD-502 plus), a product of Japan. SPAD value was recorded at flowering stage of sunflower.

Head diameter (cm)

Head diameter in centimetre of randomly selected plants was measured from one edge of the head to the other.

Head weight (g)

Head weight in gram of randomly selected plants was measured after harvesting of head from randomly selected plants.

Weight of seed head^{-1} (g)

The weight of seeds per head was recorded from the selected plants in grams on electric balance.

Number of seeds head^{-1}

Individually harvested, dried and threshed heads of some selected plants were subjected to count seeds per head. The fully matured ripen filled achenes were considered as seed whereas shrunken, partially filled and damaged achenes were considered as non-seed.

1000 seed weight (g)

From each randomly selected head, 1000 seeds were counted and weighed using an electrical balance in gram.

Yield (t ha^{-1})

The yield data was calculated at 8% moisture level on plot basis and converted into ton per hector.

Germination (%)

Germination percentage was calculated using the following formula-

$$\text{Germination (\%)} = \frac{\text{Total no.of germinated seeds}}{\text{Total no.of germinated and non-germinated seeds}} \times 100$$

The rate of germination was (estimated by using a modified Timson index of germination velocity) = $\sum G/t$

Where,

G = % seed germination at 2 days interval and

t = germination period.

3.14 Statistical analysis

The recorded Data on various parameters were statistically analysed using STATA-17 (StataCorp, 2021) statistical package program. The mean at the treatments was calculated and analysis of variance at the characters were performed by F-Difference between treatment means were determined by LSD method according to Gomez and Gomez, (1984) at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

The present study was carried out with a view to study the effect salt stress of and its possible effect on growth and yield of sunflower and the mitigation of salt stress either alone or in combination with the application of supplemental Mn and Zn. Data were recorded on different days after sowing on different characters such as plant height (cm), leaf number, leaf length (cm), leaf breadth (cm), dry weight (g), SPAD value, head diameter (cm), head weight (g), weight of seed head^{-1} (g), seed number head^{-1}, 1000 seed weight (g) and yield (t ha^{-1}). The obtained results of the current experiment are discussed in the following paragraphs:

4.1 Vegetative parameters

4.1.1 Plant height (cm)

Effect of salinity

The plant height is one of the most important factors which affect the growth and yield of sunflower. Plant height of sunflower varied in different level of salinity. Analysis of variance showed that the effect of salinity on plant height of sunflower was significant at 30 DAS (Figure 01). Treatment S_0 (Control) produced the tallest plants at 30, 45 and 60 DAS (36.87, 49.50 and 85.33 cm) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) produced the shortest plant at 30, 45 and 60 DAS (31.67, 44.70 and 74.33 cm).

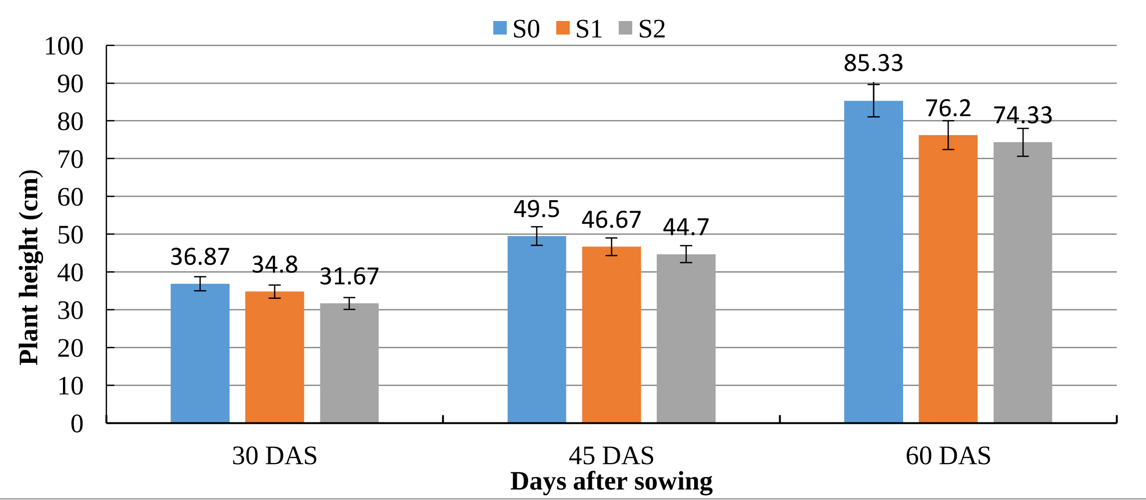

Figure 01. Effect of salinity on plant height at different days after sowing.

[Here, S_0 = Control, S_1 = 10 ds/m NaCl, S_2 = 20 ds/m NaCl]

Effect of micronutrients Zn and Mn

Significant difference was observed in plant height among the treatments at 30 DAS but no significant difference in plant height among the treatments at 45 and 60 DAS (Figure 02). The foliar spray was applied at the time of vegetative growth. The plant height in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray + 0.5% Mn spray (T_3) performed the tallest plant at 30, 45 and 60 DAS (about 38.87, 49.90 and 88.33 cm), which was significantly higher than (31.67 cm) at 30 DAS. The lowest plant height was resulted in all 30, 45 and 60 (31.67, 44.70 and 72.30 cm) from T_0 treatment. Plant height of sunflower showed positive trend in different level of micronutrients. Similar result was also observed by Ravikumar *et al.* (2021) and Faisal *et al.* (2020).

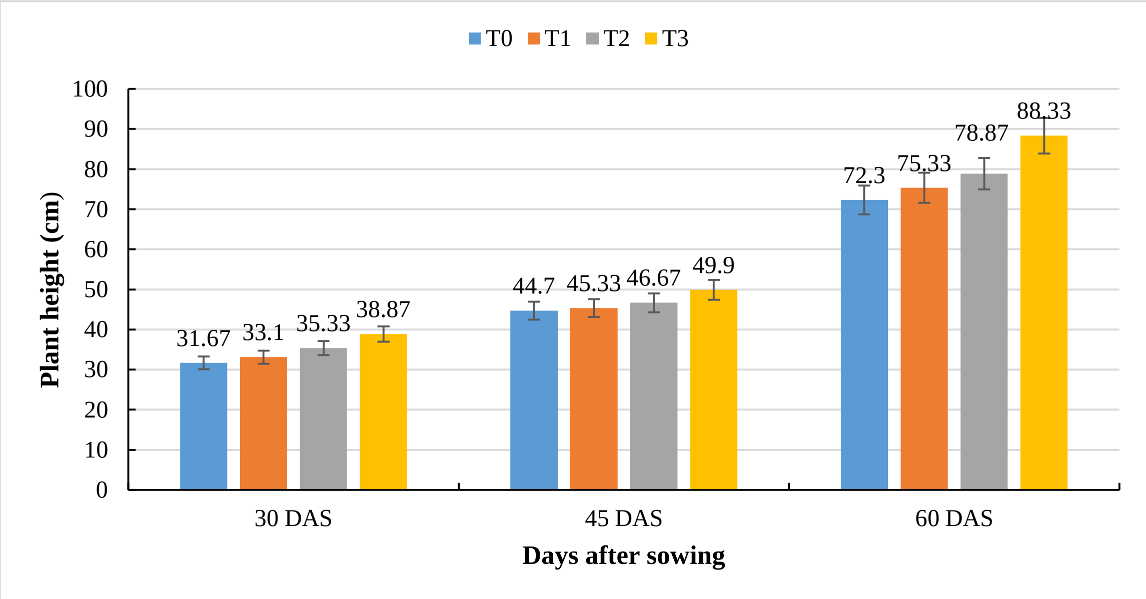

Figure 2. Effect of Zn and Mn on plant height at different days after sowing

[Here, T_0 = Water spray, T_1 = 0.5%, Zn spray, T_2 = 0.5% Mn spray, T_3 = 0.5% Zn spray + 0.5% Mn spray]

Combined effect of salinity, Zn and Mn

Significant difference was observed in plant height among the treatments. The plant height in the sunflower was higher in treatment combination of no salinity and fertilizer foliar spray. In treatment combination of no salinity level and 0.5% Zn spray + 0.5% Mn spray (S_0T_3) gave the tallest plant at 30, 45 and 60 DAS (about 39.80, 49.90 and 86.66 cm), which was significantly higher than S_2 = 20 ds/m NaCl and T_0 = Water spray (S_2T_0) (25.67, 40.80 and 68.67 cm) at 30 45 and 60 DAS (Table 01). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly.

Table 01. Combined effect of salinity, Zn and Mn on plant height

Salinity × Zn and Mn	Plant height (cm)		
	30 DAS	45 DAS	60 DAS
S_0T_0	29.87 f	44.90 e	72.80 g
S_0T_1	31.30 e	45.33 d	74.67 e
S_0T_2	35.67 c	46.87 cd	78.87 d
S_0T_3	39.80 a	49.90 a	86.66 a
S_1T_0	27.33 gh	43.90 f	70.33 i
S_1T_1	29.80 f	44.33 e	72.87 g
S_1T_2	34.67 cd	44.87 e	74.67 e
S_1T_3	36.87 b	47.30 b	82.30 c
S_2T_0	25.67 h	40.80 h	68.67 j
S_2T_1	28.80 g	41.33 g	70.87 hi
S_2T_2	32.66 d	43.67 f	73.66 f
S_2T_3	34.33 cd	45.33 d	81.33 b
LSD (0.05)	1.98	1.91	1.03
CV (%)	6.93	7.22	9.84

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl; T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray; 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]

4.1.2 Leaf number

Effect of salinity

Significant changes of leaf number of the sunflower for different level of salinity at 30, 45 and 60 DAS (Figure 03). Treatment S_0 (Control) showed the highest leaf number at 30, 45 and 60 DAS (8.00, 12.33 and 19.00) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) showed the lowest leaf number at 30, 45 and 60 DAS (4.67, 8.33 and 14.67). Reduction in leaf number under salinity stress has been also demonstrated in sunflower (Mehmet and Ahmet, 2003).

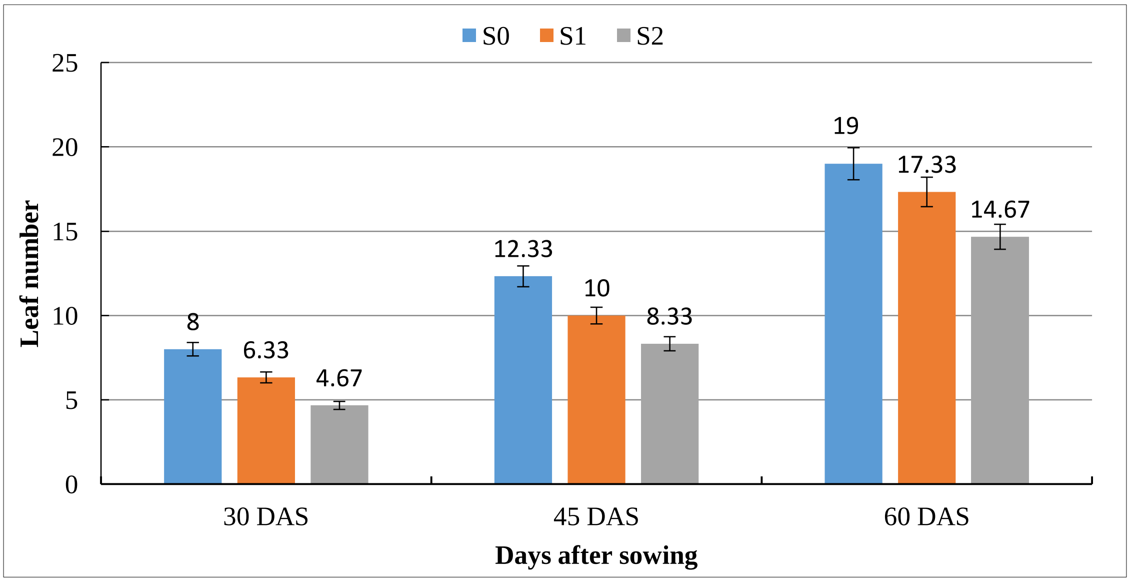

Figure 03. Effect of salinity on leaf number at different days after sowing

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl]

Effect of micronutrients Zn and Mn

Significant difference was observed in leaf number among the treatments at 30, 45 and 60 DAS (Figure 04). The foliar spray was given at the time of vegetative growth. The leaf number in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray + 0.5% Mn spray (T_3) demonstrated the highest leaf number at 30, 45 and 60 DAS (about 10.00, 13.67 and 18.33). The lowest leaf number was found all 30, 45 and 60 (5.00, 9.67 and 13.65) for T_0 treatment. Similar result was also found from the study by Ravikumar *et al.* (2021) and Faisal *et al.* (2020).

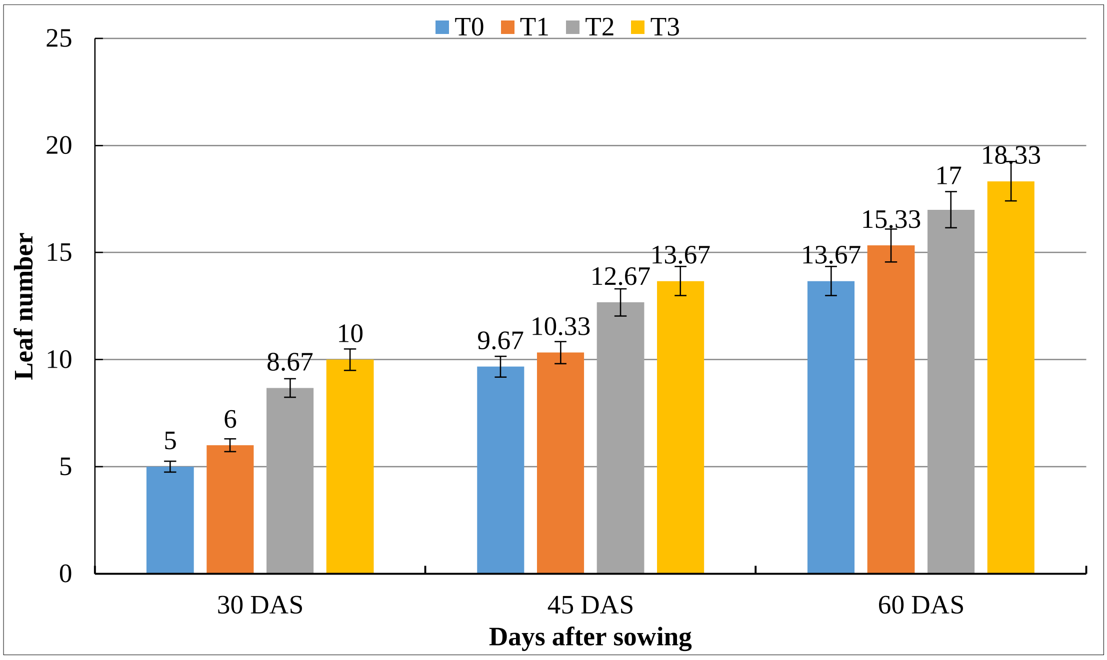

Figure 04. Effect of Zn and Mn on leaf number at different days after sowing

[Here, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray]

Combined effect of salinity, Zn and Mn

Significant difference was observed in leaf number among the treatments and variety at 30, 45 and 60 DAS. The leaf number in the sunflower was higher in treatment combination of no salinity and fertilizer foliar spray. In treatment combination of no salinity level and 0.5% Zn spray + 0.5% Mn spray (S_0T_3) enlisted the highest leaf number at 30, 45 and 60 DAS 10.33, 14.00 and 19.67 respectively, and lowest leaf number found in 20 ds/m NaCl and water spray (S_2T_0) 4.00, 7.33 and 10.00 respectively at 30, 45 and 60 DAS (Table 02). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly.

Table 02. Combined effect of salinity, Zn and Mn on leaf number

Salinity × Zn and Mn	Leaf number		
	30 DAS	45 DAS	60 DAS
S_0T_0	4.67 g	8.67 f	13.00 f
S_0T_1	7.33 d	11.33 d	15.67 d
S_0T_2	8.67 c	13.33 b	17.33 b
S_0T_3	10.33 a	14.00 a	19.67 a
S_1T_0	4.33 g	7.35 g	12.00 g
S_1T_1	6.33 e	10.00 e	14.33 e
S_1T_2	7.67 d	12.33 c	15.33 d
S_1T_3	9.33 b	13.00 b	16.67 c
S_2T_0	4.00 h	7.33 g	10.00 h
S_2T_1	5.33 f	10.00 e	12.33 g
S_2T_2	6.67 e	11.33 d	14.67 e
S_2T_3	8.33 c	12.67 c	15.33 d
LSD (0.05)	0.88	0.86	0.92
CV (%)	10.54	10.09	8.31

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray; 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]

4.1.3 Leaf length

Effect of salinity

Changes of leaf length of the sunflower for different level of salinity and found significant only at 30, 45 DAS (Figure 05). Treatment S_0 (Control) produced the highest leaf length at 30, 45 and 60 DAS (3.33, 8.33 and 11.00 cm) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) gave the lowest leaf length at 30, 45 and 60 DAS (1.86, 5.90 and 7.33 cm). Although sunflower plants are moderately saline tolerant but medium to hight level of salinity decrease plants vegetative growth as observed in the study of Katerji *et al.* (2000).

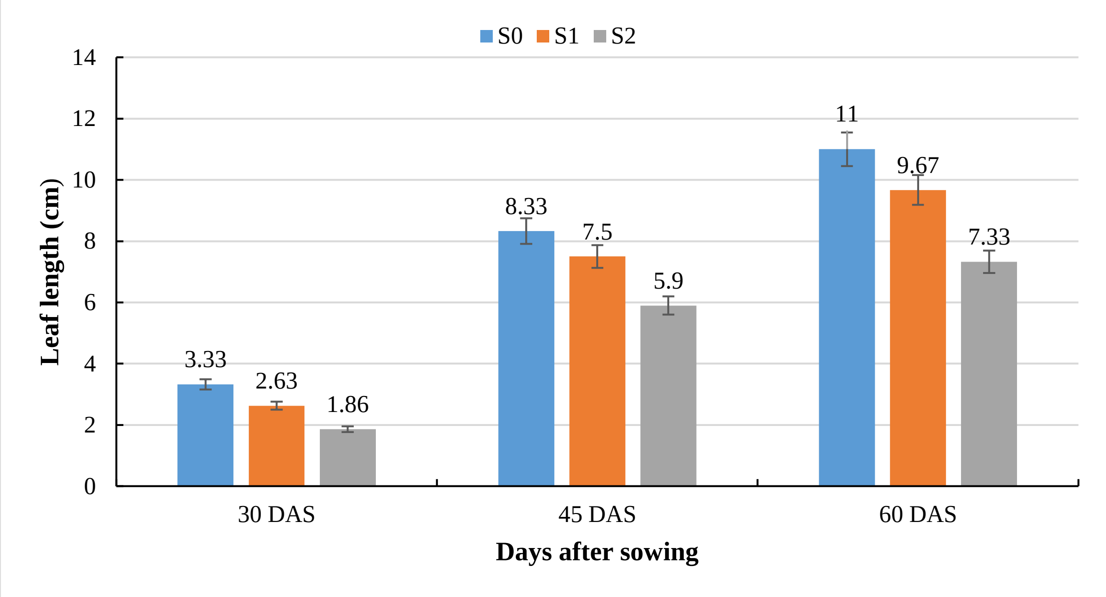

Figure 05. Effect of salinity on leaf length at different days after sowing

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl]

Effect of micronutrients Zn and Mn

Significant difference in leaf length among the treatments at 30 DAS but no significant difference in leaf length among the treatments at 45 and 60 DAS (Figure 06). The foliar spray of the micronutrients was applied at the time of vegetative growth. The leaf length in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray+ 0.5% Mn spray (T_3) found the highest leaf length at 30, 45 and 60 DAS 3.87, 9.00 and 11.86 cm respectively. The lowest leaf length was resulted in all 30, 45 and 60 (1.76, 5.90 and 8.33 cm) from T_0 treatment. Similar result was also observed by Faisal *et al.* (2020).

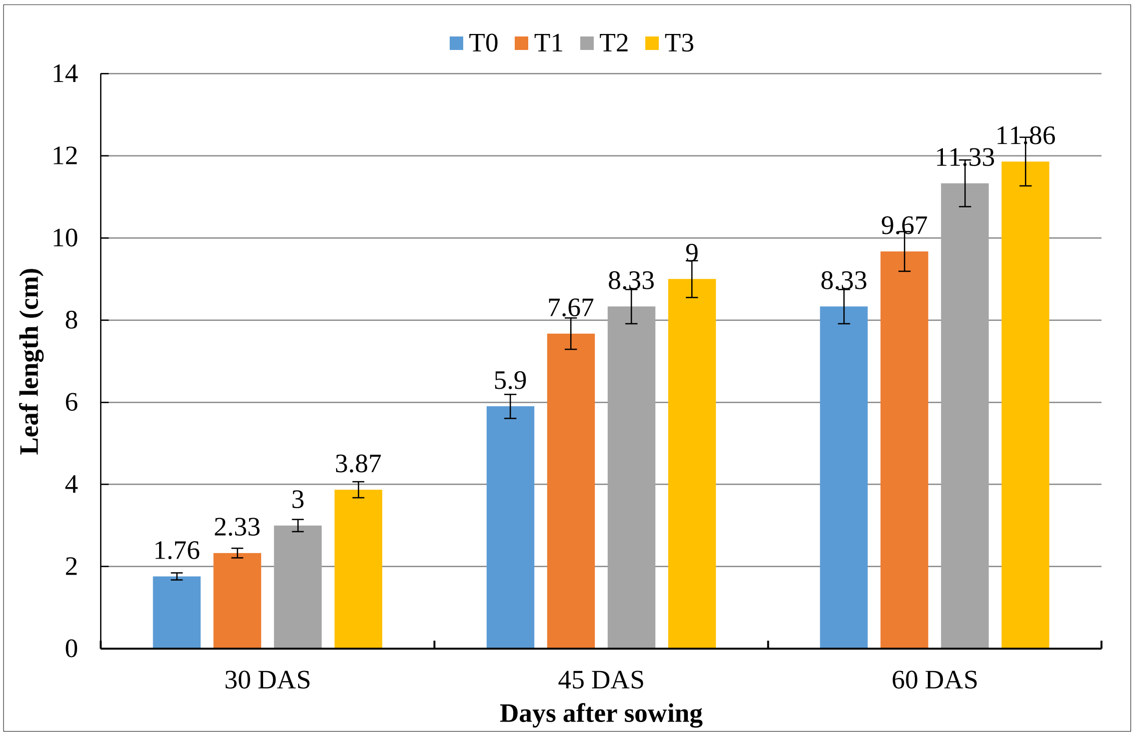

Figure 06. Effect of Zn and Mn on leaf length at different days after sowing

[Here, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray]

Combined effect of salinity, Zn and Mn

Significant difference was observed in leaf length among the treatments. The leaf length in the sunflower was higher in treatment combination of no salinity and fertilizer foliar spray (Table 03). In treatment combination of no salinity level and 0.5% Zn spray+ 0.5% Mn spray (S_0T_3) gave the highest leaf length at 30, 45 and 60 DAS 4.00, 9.33 and 12.33 cm respectively, and lowest leaf length found in S_2 = 20 ds/m NaCl and T_0 = water spray (S_2T_0) (1.10, 5.33 and 7.00 cm) at 30 45 and 60 DAS (Table 03). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly.

Table 03. Combined effect of salinity, Zn and Mn on leaf length

Salinity × Zn and Mn	Leaf length (cm)		
	30 DAS	**45 DAS**	**60 DAS**
S_0T_0	1.90 d	5.95 e	8.67 e
S_0T_1	2.78 c	7.87 c	9.88 d
S_0T_2	3.33 b	8.67 b	11.50 b
S_0T_3	4.00 a	9.33 a	12.33 a
S_1T_0	1.50 de	5.66 ef	8.00 f
S_1T_1	2.67 c	7.67 c	9.35 d
S_1T_2	3.00 b	8.33 b	11.18 b
S_1T_3	3.87 ab	9.15 ab	11.67 b
S_2T_0	1.10 e	5.33 f	7.00 g
S_2T_1	2.33 c	7.00 d	8.33 e
S_2T_2	2.87 c	8.10 bc	9.50 d
S_2T_3	3.25 b	8.58 b	10.24 c
LSD (0.05)	0.41	0.37	0.61
CV(%)	10.29	5.73	12.15

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray; 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]

4.1.4 Leaf breadth

Effect of salinity

leaf breadth of the sunflower for different level of salinity and found significantly influenced only at 60 DAS (Figure 07). Treatment S_0 (Control) produced the highest leaf breadth at 30, 45 and 60 DAS (1.13, 3.80 and 4.55 cm) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) gave the lowest leaf breadth at 30, 45 and 60 DAS (0.78, 3.25 and 3.80 cm), which is consistent with the findings of Flagella *et al.* (2004), who observed significant reduction in vegetative growth with increasing salt level in sunflower grown in saline conditions.

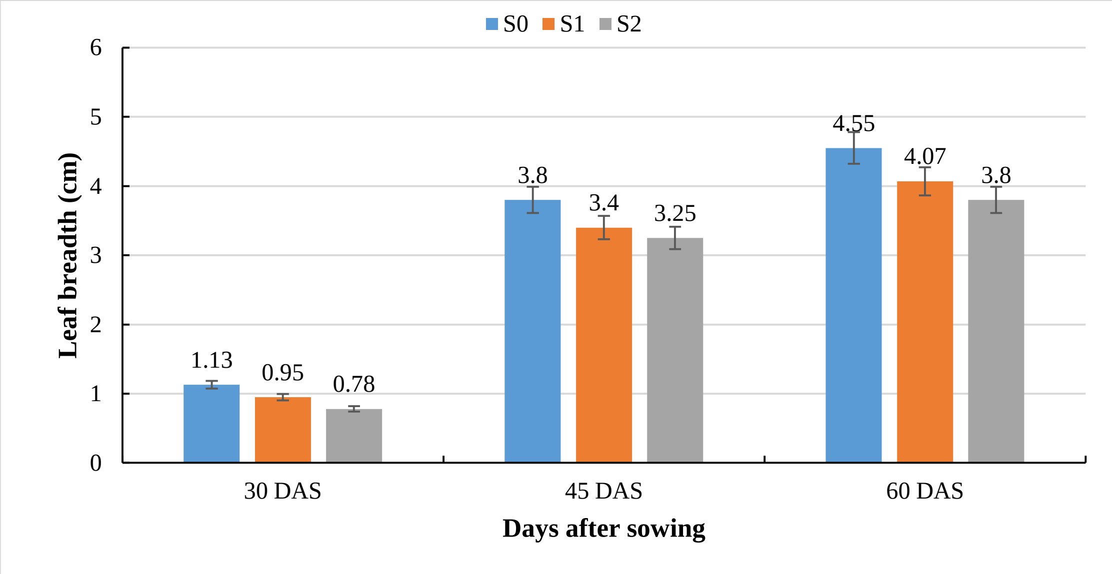

Figure 07. Effect of salinity on leaf breadth at different days after sowing

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl]

Effect of micronutrients Zn and Mn

Non-significant difference in leaf breadth among the treatments at 30 DAS but significant difference in leaf breadth among the treatments at 45 and 60 DAS (Figure 08). The foliar spray of micronutrients was given at the time of vegetative growth. The leaf breadth in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray + 0.5% Mn spray (T_3) resulted the highest leaf breadth at 30, 45 and 60 DAS 1.25, 4.00 and 4.67 cm respectively. The lowest leaf breadth was resulted in all 30, 45 and 60 DAS (1.25, 4.00 and 4.67 cm) from T_0 treatment. Similar findings were also observed by Ravikumar *et al.* (2021).

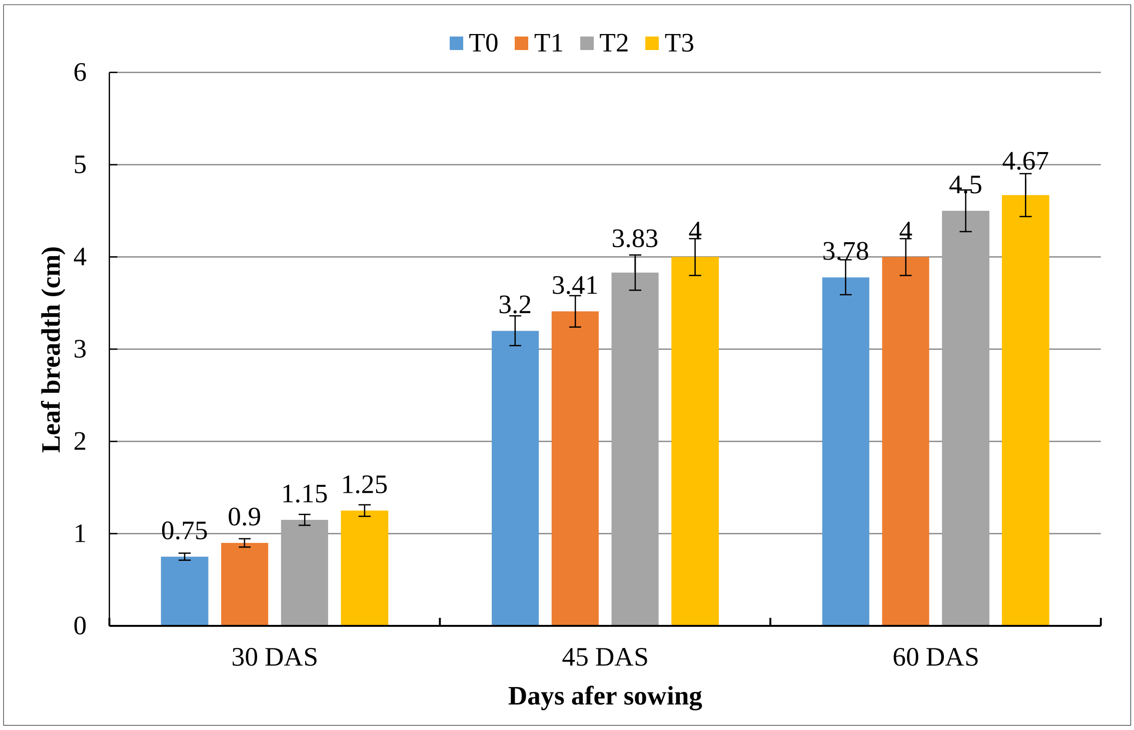

Figure 08. Effect of Zn and Mn on leaf breadth at different days after sowing

[Here, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray]

Combined effect of salinity, Zn and Mn

Significant difference was observed in leaf breadth for the combined effect of salinity and treatments (Table 04). The leaf breadth in the sunflower was higher in treatment combination of no salinity and 0.5% Zn + 0.5% Mn foliar spray. In treatment combination of no salinity level and 0.5% Zn spray + 0.5% Mn spray (S_0T_3) produced the highest leaf breadth at 30, 45 and 60 DAS (about 1.28, 4.67 and 4.91 cm), and lowest leaf breadth found in 20 ds/m NaCl and water spray (S_2T_0) (0.67, 3.10 and 3.50 cm) at 30 45 and 60 DAS (Table 04). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly**.** Findings Keerio *et al.* (2020) and Saad and Al-Doori (2017) also in agreement with our results.

Table 04. Combined effect of salinity, Zn and Mn on leaf breadth

Salinity × Zn and Mn	Leaf breadth (cm)		
	30 DAS	**45 DAS**	**60 DAS**
S_0T_0	0.79 b	3.25 c	3.87 b
S_0T_1	0.98 b	3.43 b	4.33 ab
S_0T_2	1.21 ab	3.87 b	4.70 ab
S_0T_3	1.28 a	4.67 a	4.91 a
S_1T_0	0.70 b	3.15 c	3.70 b
S_1T_1	0.95 b	3.35 b	4.15 ab
S_1T_2	1.01 ab	3.70 b	4.30 ab
S_1T_3	1.12 ab	4.20 ab	4.77 ab
S_2T_0	0.67 c	3.10 d	3.50 c
S_2T_1	0.90 b	3.25 c	4.02 b
S_2T_2	1.00 ab	3.50 b	4.11 ab
S_2T_3	1.10 ab	4.03 ab	4.67 ab
LSD (0.05)	0.47	0.71	0.68
CV(%)	7.19	5.33	4.20

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray; 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]

4.1.5 Leaf area

Effect of salinity

Significant changes in leaf area of the sunflower for different level of salinity was found only for 60 DAS (Figure 09). Treatment S_0 (Control) produced the highest leaf area at 30, 45 and 60 DAS (3.76, 31.65 and 50.05 cm^2) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) produced the lowest leaf area at 30, 45 and 60 DAS (1.45, 19.18 and 27.85cm^2). The one of the well-known negative effects of abiotic stresses is decrease in photosynthesizing leaf area. In view of some recent reports, salt stress reduced photosynthesis (Khan *et al.*, 2009).

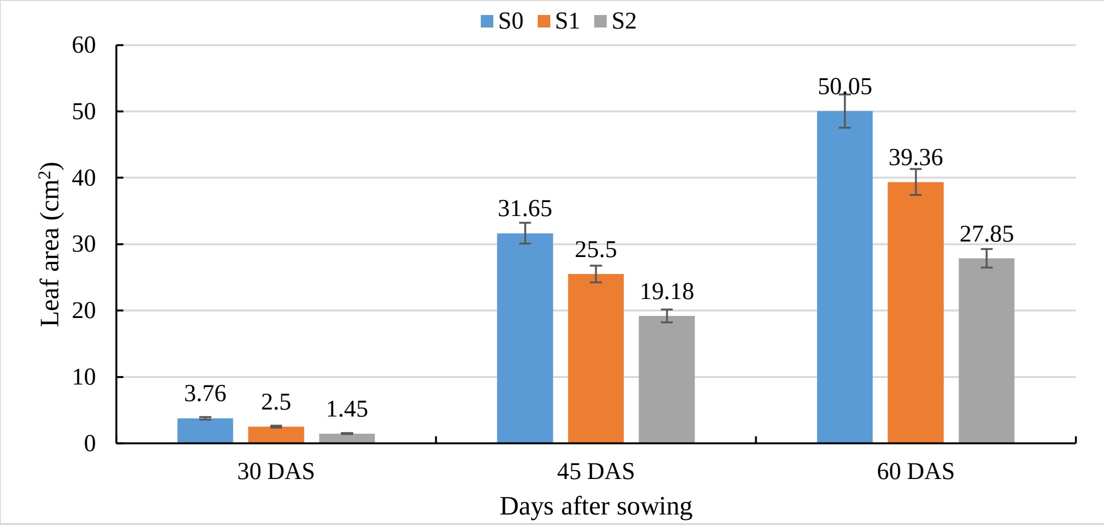

Figure 09. Effect of salinity on leaf area at different days after sowing

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl]

Effect of micronutrients Zn and Mn

Non-significant difference was observed in leaf area among the treatments at 30 DAS but significant difference in leaf area among the treatments at 45 and 60 DAS (Figure 10). The foliar spray was given at the time of vegetative growth. The leaf area in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray+ 0.5% Mn spray (T_3) gave the highest leaf area at 30, 45 and 60 DAS (4.84, 36.00 and 55.39 cm^2). The lowest leaf area was resulted in all 30, 45 and 60 (1.32, 18.88 and 31.49 cm^2) from T_0 treatment. Similar findings were also observed from the study of Saad and Al-Doori (2017).

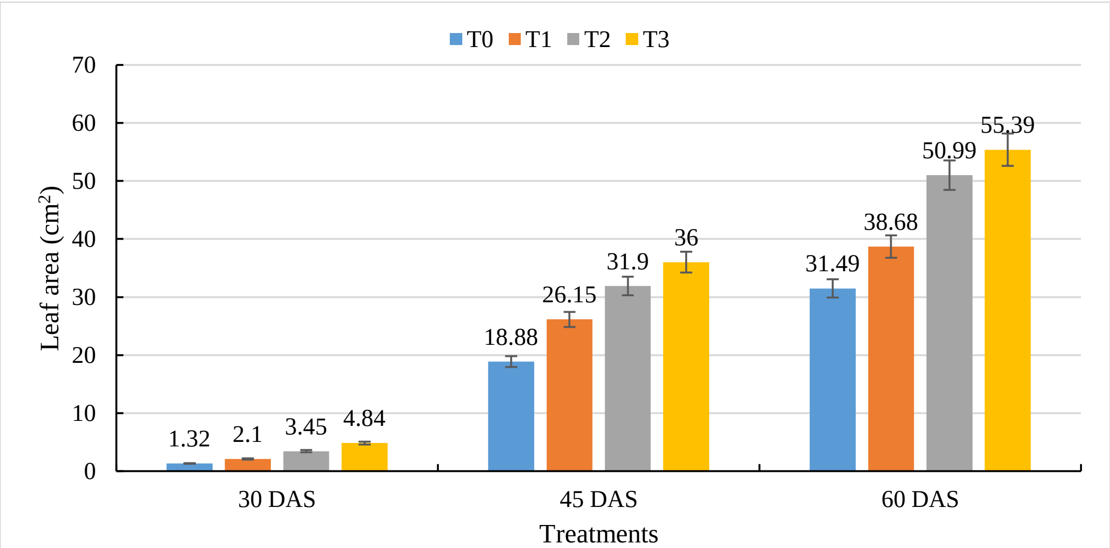

Figure 10. Effect of Zn and Mn on leaf area at different days after sowing

[Here, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray]

Combined effect of salinity, Zn and Mn

Significant difference was observed in leaf area among the treatments (Table 05). The leaf area in the sunflower was higher in treatment combination of no salinity and fertilizer foliar spray. In treatment combination of no salinity level and 0.5% Zn spray + 0.5% Mn spray (S_0T_3) produced the highest leaf area at 30, 45 and 60 DAS (5.12, 43.57 and 60.54 cm^2), and lowest leaf area found in S_2 = 20 ds/m NaCl and T_0 = water spray (S_2T_0) (0.74, 16.52 and 24.50 cm^2) at 30 45 and 60 DAS (Table 05). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly**.**

Table 05. Combined effect of salinity, Zn and Mn on leaf area

Salinity × Zn and Mn	**Leaf area (cm^2)**		
	30 DAS	**45 DAS**	**60 DAS**
S_0T_0	1.50 e	19.34 g	33.55 f
S_0T_1	2.72 d	26.99 e	42.78 d
S_0T_2	4.03 b	33.55 c	54.05 b
S_0T_3	5.12 a	43.57 a	60.54 a
S_1T_0	1.05 e	17.83 hi	29.60 g
S_1T_1	2.54 d	25.69 e	38.80 e
S_1T_2	3.03 c	30.82 cd	48.07 c
S_1T_3	4.33 b	38.43 b	55.67 b
S_2T_0	0.74 f	16.52 i	24.50 h
S_2T_1	2.10 d	22.75 f	33.49 f
S_2T_2	2.87 d	28.35 d	39.05 e
S_2T_3	3.58 c	34.58 c	47.82 c
LSD (0.05)	0.68	2.93	2.65
CV(%)	9.14	8.05	8.33

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray; 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]

4.1.6 SPAD value

Effect of salinity

SPAD value of the sunflower for different level of salinity found significant only at 30 and 60 DAS (Figure 11). Treatment S_0 (Control) produced the highest SPAD value at 30and 60 DAS (38.20 and 41.10) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) produced the lowest SPAD value at 30 and 60 DAS (36.50 and 35.20). Higher salinity caused a marked reduction in chlorophyll content of sunflower, these results support the findings of Mohamedin *et al.*, (2006).

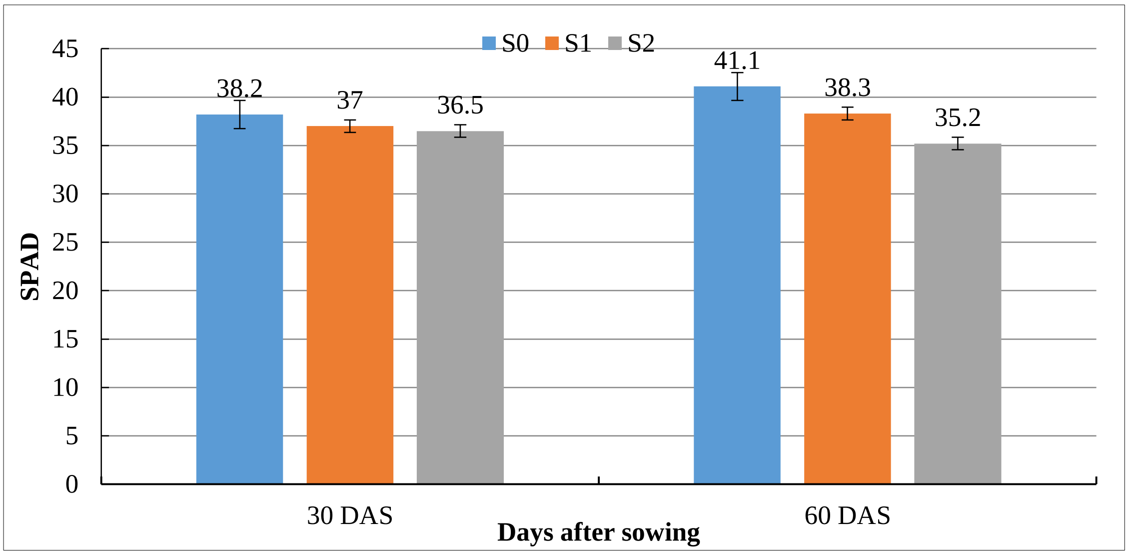

Figure 11. Effect of salinity on SPAD value at different days after sowing

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl]

Effect of micronutrients Zn and Mn

Significant difference in SPAD value among the treatments at 30 and 60 DAS can be observed (Figure 12). The foliar spray was applied at the time of vegetative growth according to treatment requirements. The SPAD value in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray + 0.5% Mn spray (T_3) produced the highest SPAD value at 30 and 60 DAS (41.20 and 41.50). The lowest SPAD value was resulted in all 30 and 60 (38.50 and 40.20) from T_0 treatment. Similar findings were also reported by Siddiqui *et al.* (2014).

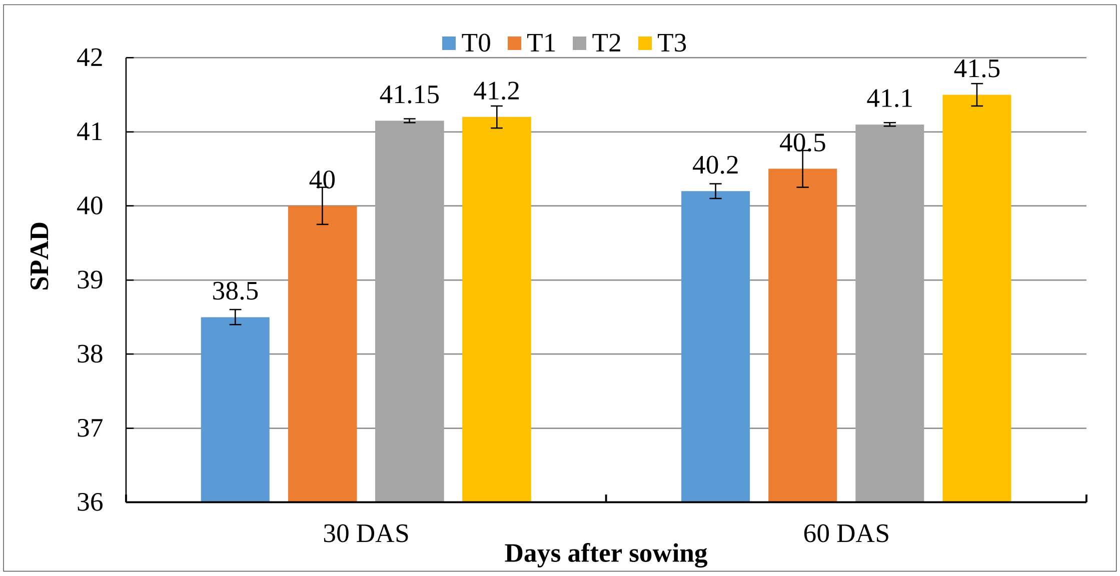

Figure 12. Effect of Zn and Mn on SPAD value at different days after sowing

[Here, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray]

Combined effect of salinity, Zn and Mn

Significant difference was observed in SPAD value among the treatments (Table 06). The SPAD value in the sunflower was higher in treatment combination of no salinity and fertilizer foliar spray. In treatment combination of no salinity level and 0.5% Zn spray + 0.5% Mn spray (S_0T_3) demonstrated the highest SPAD value at 30 and 60 DAS (41.80 and 42.00), and lowest SPAD value found in S_2 = 20 ds/m NaCl and T_0 = water spray (S_2T_0) (28.30 and 32.30) at 30 and 60 DAS (Table 06). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly. The salinity caused a marked reduction in chlorophyll content of sunflower. These results are in agreement with Rivelli and Gherbin (2006) who showed that leaf area and total shoot dry weight of Romsun HS90 sunflower cultivar decline 85% and 77% by 150 mM salinity, respectively.

Table 06. Combined effect of salinity, Zn and Mn on SPAD value

Salinity ×Zn and Mn	SPAD value	
	30 DAS	60 DAS
S_0T_0	38.60 c	40.05 c
S_0T_1	40.10 b	40.70 c
S_0T_2	41.10 ab	41.50 b
S_0T_3	41.80 a	42.00 a
S_1T_0	33.90 f	32.80 gh
S_1T_1	34.80 f	34.60 f
S_1T_2	35.00 e	35.40 e
S_1T_3	36.10 d	35.70 e
S_2T_0	28.30 g	32.30 h
S_2T_1	34.70 f	32.80 gh
S_2T_2	35.00 e	34.70 f
S_2T_3	35.10 e	38.80 d
LSD (0.05)	1.70	1.81
CV (%)	10.51	10.80

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray; 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]

4.2 Yield and yield contributing parameters

4.2.1 Head diameter at harvesting

Effect of salinity

Changes of head diameter at harvesting of the sunflower for different level of salinity was found significant. Treatment S_0 (Control) produced the highest head diameter at harvesting (17.10 cm) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) produced the lowest head diameter at harvesting (14.15 cm) (Table 07). which is consistent with the findings of Flagella *et al.* (2004), who observed significant reduction in yield with increasing salt level in sunflower grown in saline conditions.

Effect of treatments Zn and Mn

There was significant difference observed in head diameter at harvesting among the treatments. The foliar spray was given at the time of vegetative growth with two instalments. The reproductive growth in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray + 0.5% Mn spray (T_3) produced the highest head diameter at harvesting (17.40 cm), which was significantly higher than T_0 (14.10 cm). The lowest head diameter at harvesting was resulted in (14.10 cm) T_0 treatment (Table 08). Similar findings were also reported by Sher *et al.* (2021).

Combined effect of salinity, Zn and Mn

Significant difference was observed in head diameter at harvesting among the treatments. The head diameter at harvesting in the sunflower was higher in treatment combination of no salinity and fertilizer foliar spray. In treatment combination of no salinity level and 0.5% Zn spray+ 0.5% Mn spray (S_0T_3) resulted highest head diameter at harvesting (about 17.50 cm), which was significantly higher than S_2 = 20 ds/m NaCl and T_0 = water spray (S_2T_0) (12.05 cm) (Table 09). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly.

4.2.2 Head weight after harvesting

Effect of salinity

Head weight at harvesting of the sunflower for different level of salinity found significant. Treatment S_0 (Control) produced the highest head weight at harvesting (107.50 g) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) produced the lowest head weight at harvesting (70.75 g) (Table 07). Which is consistent with the findings of Flagella *et al.* (2004).

Effect of treatments Zn and Mn

For head weight at harvesting among the treatments there was significant difference was observed (Table 8). The foliar spray was given at the time of vegetative growth with two instalments. The reproductive growth in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray + 0.5% Mn spray (T_3)

produced the highest head weight at harvesting (110.03 g), which was significantly higher than T_0 (70.51 cm). The lowest head weight at harvesting was resulted in (70.51g) T_0 treatment (Table 8). Application of micronutrients promoted photosynthetic activities, which lead to an increase in cell division and as a result increasing biomass production. Alloway (2004) observed the reduction of photosynthesis plants in Zinc deficient.

Combined effect of salinity, Zn and Mn

Significant difference was observed in head weight at harvesting among the treatments. The head weight at harvesting in the sunflower was higher in treatment combination of no salinity and fertilizer foliar spray. In treatment combination of no salinity level and 0.5% Zn spray+ 0.5% Mn spray (S_0T_3) resulted highest head weight at harvesting (110.30 g), which was significantly higher than S_2 = 20 ds/m NaCl and T_0 = water spray (S_2T_0) (65.70 g) (Table 09). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly.

4.2.3 Weight of seed head^{-1}

Effect of salinity

Weight of seed head^{-1} of the sunflower for different level of salinity found significant. Treatment S_0 (Control) produced the highest weight of seed head^{-1} (70.05 g) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) produced the lowest weight of seed head^{-1} (61.48 g) (Table 07).

Effect of treatments Zn and Mn

There was significant difference observed in weight of seed head^{-1} among the treatments. The foliar spray was given at the time of vegetative growth with two instalments. The reproductive growth in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray + 0.5% Mn spray (T_3) produced the highest weight of seed head^{-1}(74.13 g), which was significantly higher than T_0 (61.45 g). The lowest weight of seed head^{-1} at was resulted in (61.45 g) T_0 treatment (Table 08). Similar results were also observed by Alloway (2004).

Combined effect of salinity, Zn and Mn

Significant difference was observed in weight of seed head^{-1} among the treatments. The weight of seed head^{-1} in the sunflower was higher in treatment combination of no salinity and fertilizer foliar spray. In treatment combination of no salinity level and 0.5% Zn spray + 0.5% Mn spray (S_0T_3) resulted highest weight of seed head^{-1} (75.33 g), which was significantly higher than S_2 = 20 ds/m NaCl and T_0 = water spray (S_2T_0) (56.95 g) (Table 09). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly.

Table 07. Effect of salinity on head diameter, weight of head and weight of seed head^{-1} at harvest

Salinity	Head diameter at harvesting (cm)	Head weight after harvesting (g)	weight of seed head^{-1} (g)
S_0	17.10 a	107.50 a	70.05 a
S_1	15.03 b	98.85 b	66.35 b
S_2	14.15 c	70.75 c	61.48 c
LSD (0.05)	1.03	7.01	4.95
CV(%)	9.03	11.44	13.15

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl, 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]

Table 08. Effect of Zn and Mn on head diameter, weight of head and weight of seed head^{-1} at harvest

Treatments	Head diameter at harvesting (cm)	Head weight after harvesting (g)	weight of seed head^{-1} (g)
T_0	14.10 d	70.51 d	61.45 d
T_1	15.33 cd	98.80 c	66.33 cd
T_2	17.25 ab	107.55 b	70.50 b
T_3	17.40 a	110.03 a	74.13 a
LSD (0.05)	1.05	7.01	4.04
CV(%)	8.04	3.06	7.88

[Here, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray; 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]

Table 09. Combined effect of salinity and Zn and Mn on head diameter, weight of head and weight of seed head^{-1} at harvest

Salinity × Zn and Mn	Head diameter at harvesting (cm)	Head weight after harvesting (g)	weight of seed head $^{-1}$(g)
S_0T_0	14.12 d	70.51 d	62.50 de
S_0T_1	15.50 c	97.83 c	67.14 c
S_0T_2	17.35 ab	105.25 ab	70.74 b
S_0T_3	17.50 a	110.30 a	75.33 a
S_1T_0	13.10 e	67.30 ef	60.45 e
S_1T_1	14.51 d	95.85 c	65.25 c
S_1T_2	15.30 c	103.20 b	69.70 bc
S_1T_3	16.66 b	109.35 ab	73.67 ab
S_2T_0	12.05 f	65.20 f	56.95 f
S_2T_1	13.76 e	90.81 cd	63.25 c
S_2T_2	14.88 d	101.15 b	68.73 c
S_2T_3	16.61 b	104.55 ab	71.75 ab
LSD (0.05)	2.77	6.13	4.85
CV(%)	1.25	9.01	4.79

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray; 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]

4.2.4 Seed number head^{-1}

Effect of salinity

Depicts the changes of seed number head^{-1} of the sunflower for different level of salinity and found significant. Treatment S_0 (Control) produced the highest seed number head^{-1} (940.30) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) produced the lowest seed number head^{-1} (765.33) (Table 10). similar findings were also observed from El-Khair *et al.* (2000).

Effect of micronutrients Zn and Mn

There was significant difference observed in seed number head^{-1} among the treatments. The foliar spray was given at the time of vegetative growth with two instalments. The reproductive growth in the sunflower was higher for Zn and Mn spray rather water spray. In treatment Zn spray + Mn spray) (T_3) produced the highest seed number/head (955.07), which was significantly higher than T_0 (763.30 g). The lowest seed number head^{-1} was resulted in (763.30) T_0 treatment (Table 11). The results obtained by Saha *et al.* (2018), which supported the present findings.

Combined effect of salinity, Zn and Mn

Significant difference was observed in seed number head^{-1} among the treatments. The seed number head^{-1} in the sunflower was higher in treatment combination of no salinity and fertilizer foliar spray. In treatment combination of no salinity level and Zn spray + Mn spray) (S_0T_3) resulted highest seed number head^{-1} (956.67), which was significantly higher than 20 ds/m NaCl and water spray (S_2T_0) (750.81) (Table 12). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly. Similar result was also observed by Prasad *et al.,* (2012) by Zn foliar application.

4.2.5 1000 seed weight

Effect of salinity

Significant variation was observed for 1000 seed weight of the sunflower for different level of salinity and found Treatment S_0 (Control) produced the highest 1000 seed weight (79.67 g) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) produced the lowest 1000 seed weight (58.58 g) (Table 10).

Effect of micronutrients Zn and Mn

Considering 1000 seed weight among the treatments there was significant difference can be observed (Table 11). The reproductive growth in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray + 0.5% Mn spray (T_3) produced the highest 1000 seed weight (81.24 g), which was significantly higher than

T_0 (56.50 g). The lowest 1000 seed weight at was resulted in (56.50 g) T_0 treatment (Table 11).

Combined effect of salinity, Zn and Mn

Significant difference was observed in 1000 seed weight among the treatments. The 1000 seed weight in the sunflower was higher in treatment combination of no salinity and fertilizer foliar spray. In treatment combination of no salinity level and 0.5% Zn spray + 0.5% Mn spray (S_0T_3) resulted highest 1000 seed weight (82.50 g), which was significantly higher than S_2 = 20 ds/m NaCl and T_0 = water spray (S_2T_0) (51.50 g) (Table 12). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly. Similar result was also observed by Prasad *et al.*, (2012) by Zn foliar application.

4.2.6 Yield (t ha^{-1})

Effect of salinity

Yield of the sunflower for different level of salinity found significant. Treatment S_0 (Control) produced the highest yield (2.37 t ha^{-1}) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) produced the lowest yield (1.73 t ha^{-1}) (Table 10). Similar results were also observed by Flagella *et al.* (2004).

Effect of micronutrients Zn and Mn

There was significant difference observed in yield among the treatments. The foliar spray was given at the time of vegetative growth with two instalments. The reproductive growth in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray + 0.5% Mn spray (T_3) produced the highest yield (2.91 t ha^{-1}). The lowest yield ton/ha at was resulted in (1.53 t ha^{-1}) T_0 treatment (Table 11).

Combined effect of salinity, Zn and Mn

Significant difference was observed in yield among the treatments. The yield of sunflower was higher in treatment combination of no salinity and fertilizer foliar spray. In treatment combination of S_0T_3 resulted highest yield (2.93 t ha^{-1}), which was significantly higher than S_2 = 20 ds/m NaCl and T_0 = water spray (S_2T_0) (1.20 t ha^{-1}) (Table 12). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly. Similar result was also observed by Prasad *et al.* (2012) by Zn foliar application.

4.2.7 Germination (%)

Effect of salinity

Germination (%) of the sunflower for different level of salinity found significant. Treatment S_0 (Control) produced the highest germination (95%) compared to other two level of salinity. The treatment S_2 (20 ds/m NaCl) produced the lowest germination (68.66%) (Table 10).

Effect of treatments Zn and Mn

There was significant difference observed in germination (%) among the treatments. The foliar spray was given at the time of vegetative growth with two instalments. The reproductive growth in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray + 0.5% Mn spray (T_3) produced the highest germination (96.33%). The lowest germination (%) at was resulted in (72%) T_0 treatment (Table 11).

Combined effect of salinity and treatments

Significant difference was observed in germination (%) among the combination of salinity and treatments. The germination (%) in the sunflower was higher in treatment combination of no salinity and fertilizer foliar spray. In treatment combination of no salinity level and 0.5% Zn spray+ 0.5% Mn spray (S_0T_3) resulted highest germination (96.33%) which was significantly higher than S_2 = 20 ds/m NaCl and T_0 = water spray (S_2T_0) (62.50%) (Table 12). Higher salinity level leads to the reduction of plant vegetative growth whereas, foliar spray of Zn and Mn compensate this trend significantly.

Table 10. Effect of salinity on seed number head^{-1}, 1000 seed weight and yield of sunflower

Salinity	Seed number head^{-1}	1000 seed weight (g)	Yield (t ha^{-1})	Germination (%)
S_0	940.30 a	79.67 a	2.37 a	95.00 a
S_1	845.00 b	71.50 b	2.01 ab	80.00 b
S_2	765.33 c	58.58 c	1.73 b	68.66 c
LSD (0.05)	23.11	10.19	0.43	5.90
CV(%)	12.44	9.29	10.03	8.05

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl, 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]

Table 11. Effect of Zn and Mn on seed number head^{-1}, 1000 seed weight and yield of sunflower

Treatments	Seed number head^{-1}	1000 seed weight (g)	Yield (t ha^{-1})	Germination (%)
T_0	763.30 d	56.50 d	1.53 d	72.00 d
T_1	841.50 c	72.50 c	2.10 c	83.50 c
T_2	942.66 b	79.87 b	2.67 b	90.00 b
T_3	955.07 a	81.24 a	2.91 a	96.33 a
LSD (0.05)	20.17	5.48	0.83	2.95
CV(%)	10.04	12.55	10.56	7.98

[Here, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray; 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]

Table 12. Combined effect of salinity, Zn and Mn on seed number head^{-1}, 1000 seed weight and yield of sunflower

Salinity × Treatments	Seed number head^{-1}	1000 seed weight (g)	Yield (t ha^{-1})	Germination (%)
S_0T_0	765.10 g	55.50 g	1.45 e	92.00 b
S_0T_1	840.50 d	71.80 e	2.13 cd	93.80 ab
S_0T_2	940.66 bc	78.87 b	2.66 b	95.00 ab
S_0T_3	956.67 a	82.25 a	2.93 a	96.33 a
S_1T_0	755.20 hi	53.50 h	1.25 ef	87.75 c
S_1T_1	831.50 ef	70.90 e	2.10 d	88.00 bc
S_1T_2	937.67 bc	75.87 c	2.46 cd	89.50 bc
S_1T_3	950.50 ab	80.50 ab	2.75 b	90.00 bc
S_2T_0	750.81 i	51.50 h	1.20 f	62.50 f
S_2T_1	827.50 f	67.98 f	2.03 d	66.00 ef
S_2T_2	931.67 c	73.75 d	2.31 cd	68.33 ef
S_2T_3	947.80 b	78.50 b	2.48 cd	70.00 d
LSD (0.05)	9.34	2.16	0.31	3.55
CV(%)	10.41	12.93	11.48	8.91

[Here, S_0= Control, S_1= 10 ds/m NaCl, S_2= 20 ds/m NaCl, T_0= Water spray, T_1= 0.5%, Zn spray, T_2= 0.5% Mn spray, T_3= 0.5% Zn spray+ 0.5% Mn spray; 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]

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

In this present study, sunflower variety BARI Sunflower 2 was evaluated for yield and yield contributing characters under pot house condition in research field of Sher-e-Bangla Agricultural University, Dhaka from November 2021 to March 2022. The objective of this study was the effect of Zn and Mn foliar spray to reduce the effect of salinity on sunflower. Yield attributing traits such as plant height (cm), number of leaf, head diameter (cm), head weight (g), number of seed head^{-1}, 1000 seed weight (g) and yield (t ha^{-1}) were studied. The experiment consisted of two factors as factor A; S_0 = Control, S_1 = 10 ds/m NaCl and S_2 = 20 ds/m NaCl with factor B; T_0 = water spray, T_1 = 0.5% Zn spray, T_2 = 0.5% Mn spray and T_3 = 0.5% Zn spray+ 0.5% Mn spray. The experiment was laid out in a Randomized Completely Block Design (RCBD) with three replications. There were 12 number of treatments, 4 number of replications and total number of pots: 48 altogether.

Treatment S_0 (Control) produced the tallest plants at 30, 45 and 60 DAS (36.87, 49.50 and 85.33 cm) compared to other two level of salinity, highest leaf number at 30, 45 and 60 DAS (8.00, 12.33 and 19.00), highest leaf length at 30, 45 and 60 DAS (3.33, 8.33 and 11.00 cm), highest leaf breadth at 30, 45 and 60 DAS (1.13, 3.80 and 4.55cm), highest leaf area at 30, 45 and 60 DAS (3.76, 31.65 and 50.05 cm^2), highest SPAD value at 30 and 60 DAS (38.20 and 41.10), highest head diameter at harvesting (17.10 cm), highest head weight at harvesting (107.50 g), highest weight of seed head^{-1} (70.05 g), highest seed number head^{-1} (940.30), highest 1000 seed weight (79.67 g), highest yield (2.37 t ha^{-1}) and highest germination (95%).

The treatment S_2 (20 ds/m NaCl) produced the shortest plant at 30, 45 and 60 DAS (31.67, 44.70 and 74.33 cm), lowest leaf number at 30, 45 and 60 DAS 4.67, 8.33 and 14.67 respectively, lowest leaf length at 30, 45 and 60 DAS (1.86, 5.90 and 7.33 cm), lowest leaf breadth at 30, 45 and 60 DAS (0.78, 3.25 and 3.80cm), lowest leaf area at 30, 45 and 60 DAS (1.45, 19.18 and 27.85 cm^2), lowest SPAD value at 30 and 60 DAS (36.50 and 35.20), lowest head diameter at harvesting (14.15 cm), lowest head weight at harvesting (70.75 g), the lowest weight of seed head^{-1} (61.48 g), lowest seed number head^{-1} (765.33), lowest 1000 seed weight (58.58 g), lowest yield (1.73 t ha^{-1}) and lowest germination (68.66%).

The plant height in the sunflower was higher for Zn and Mn spray rather water spray. In treatment 0.5% Zn spray + 0.5% Mn spray (T_3) gave the tallest plant at 30, 45 and 60 DAS (38.87, 49.90 and 88.33 cm), highest leaf number at 30, 45 and 60 DAS (10.00, 13.67 and 19.67), highest leaf length at 30, 45 and 60 DAS (3.87, 9.00 and 11.86 cm), highest leaf breadth at 30, 45 and 60 DAS (1.25, 4.00 and 4.67 cm), highest leaf area at 30, 45 and 60 DAS (4.84, 36.00 and 55.39 cm^2), highest SPAD value at 30 and 60 DAS (41.20 and 41.50), highest head diameter at harvesting (17.40 cm), highest head weight at harvesting (110.03 g), highest weight of seed head^{-1} (74.13 g), highest seed number head^{-1} (955.07), highest 1000 seed weight (81.24), highest yield (2.91 t ha^{-1}) and highest germination (96.33%).

The lowest plant height was resulted from T_0 treatment in all 30, 45 and 60 (31.67, 44.70 and 72.30 cm), lowest leaf number was resulted in all 30, 45 and 60 (10.00, 13.67 and 19.67), lowest leaf length was resulted in all 30, 45 and 60 (1.76, 5.90 and 8.33 cm), lowest leaf breadth was resulted in all 30, 45 and 60 DAS (1.25, 4.00 and 4.67 cm), lowest leaf area was resulted in all 30, 45 and 60 (1.32, 18.88 and 31.49 cm^2), lowest SPAD value was resulted in all 30 and 60 (38.50 and 40.20), lowest head diameter at harvesting was resulted in (14.10 cm), lowest head weight at harvesting was resulted in (70.51 g), lowest weight of seed head^{-1} at was resulted in (61.45 g), lowest seed number head^{-1} was resulted in (763.30), lowest 1000 seed weight at was resulted in (56.50 g), lowest yield at was resulted in (1.53 t ha^{-1}) and lowest germination (%) at was resulted in (72%).

The plant height in the sunflower was higher in treatment combination of without salinity and fertilizer foliar spray. In treatment combination of without salinity and 0.5% Zn spray + 0.5% Mn spray (S_0T_3) produced the tallest plant at 30, 45 and 60 DAS (39.80, 49.90 and 86.66 cm), highest leaf number at 30, 45 and 60 DAS (10.33, 14.00 and 19.67), highest leaf length at 30, 45 and 60 DAS (4.00, 9.33 and 12.33 cm), highest leaf breadth at 30, 45 and 60 DAS (1.28, 4.67 and 4.91 cm), highest leaf area at 30, 45 and 60 DAS (5.12, 43.57 and 60.54 cm^2), highest SPAD value at 30 and 60 DAS (41.80 and 42.00), highest head diameter at harvesting (17.50 cm), highest head weight at harvesting (110.30 g), highest weight of seed head^{-1} (75.33 g), highest seed number head^{-1}(956.67) and highest 1000 seed weight (82.50 g). On the other hand, lowest leaf number found in S_2 (20 ds/m NaCl) and T_0 (water spray) (S_2T_0) (4.00, 7.33 and 10.00) at 30 45 and 60 DAS, lowest leaf length found in S_2 = 20 ds/m NaCl and T_0 = water spray (S_2T_0) (1.10, 5.33 and 7.00 cm) at 30 45 and 60 DAS, and lowest leaf breadth (0.67, 3.10 and 3.50 cm) at 30, 45 and 60 DAS, lowest leaf area (0.74, 16.52 and 24.50cm^2) at 30 45 and 60 DAS, lowest SPAD value (28.30 and 32.30) at 30 and 60 DAS.

The yield t ha^{-1} in the sunflower was higher in treatment combination of without salinity and fertilizer foliar spray. In treatment combination of S_0T_3 resulted highest yield (2.93 t ha^{-1}), which was significantly higher than S_2 = 20 ds/m NaCl and T_0 = water spray (S_2T_0) (1.20 t ha^{-1}). The germination (%) in the sunflower was higher in treatment combination of without salinity and fertilizer foliar spray. In treatment combination of no salinity level and 0.5% Zn spray + 0.5% Mn spray (S_0T_3) resulted highest germination (96.33%) which was significantly higher than S_2 = 20 ds/m NaCl and T_0 = water spray (S_2T_0) (62.50%).

5.2 Conclusion

- The result indicated that, plant micronutrients, Zn and Mn significantly improved the yield contributing parameters despite the effect of different level of salinity.
- Foliar application of Zn and Mn decreased the effect of salinity up-to 15% in comparison ordinary form.
- This increasing may be due to the implementation of micronutrients (Zn and Mn) in smaller particles, which cause to faster absorb and transfer. Selection of appropriate dose of Zn and Mn is very importance because high concentration of these particles can damage plant issues in salinity condition.

5.3 Recommendations

- The results of this study suggest that foliar application of Zn and Mn may increase qualitative yield of sunflower under experimental saline soil, but the amount of Zn and Mn fertilizer needed must be carefully determined.
- Research on the major challenges in the application of foliar spray of fertilizers and its impact on the environment and human health is needed.
- Research should be conducted in the coastal saline regions of Bangladesh.

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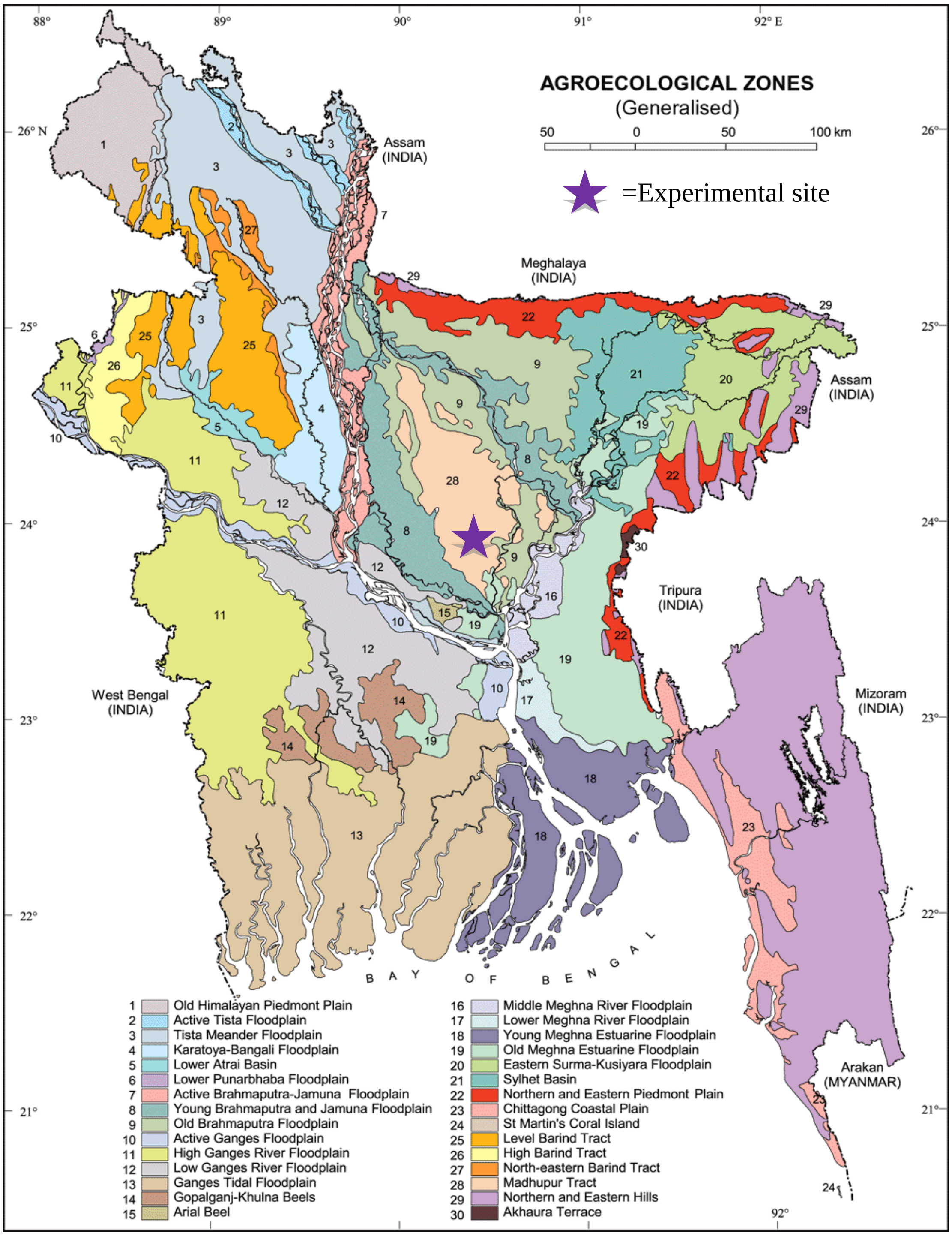
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Agronomy research shade, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

Appendix III. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	5.9
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Appendix IV. Monthly meteorological information from November, 2021 to March, 2022

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2021	November	28.10	11.83	58.18	47.00
	December	25.00	9.46	69.53	00.00
2022	January	25.20	12.80	69.00	00.00
	February	27.30	16.90	66.00	39.00
	March	31.70	19.20	57.00	23.00

Source : Meteorological Centre, Agargaon, Dhaka (Climate Division)

PLATE

Plate 1. Preparation of the experimental pots for sunflower

Plate 2. Germination of sunflower seedlings

Plate 3. Tagging of the sunflower plants

Plate 4. Salinity treatments application

Plate 5. Data collection from sunflower plants

Plate 6. Sunflower head at flowering stage

Plate 7. Effect of salinity on sunflower seed germination

Plate 8. Experimental field visit