



## Research Article

### Effect of Integrating Soil-applied Fertilizers Nitrogen, Zinc and Boron on the Growth and Yield of Sunflower Crops

Asif Ali Kaleri<sup>1</sup>, Nighat Seema Soomro<sup>1</sup>, Ghulam Mustafa Banbhan<sup>2</sup>, Atif Rajput<sup>1</sup>, Asma Kaleri<sup>3</sup>, Bina Khanzada<sup>4</sup>, Naseeruddin<sup>5</sup>, Faisal Naveed Gadahi<sup>1</sup>, Asadullah Azhar<sup>1</sup>, Danish Manzoor<sup>1</sup>

#### Article History

Received: March 20, 2024

Accepted: April 24, 2024

Published: April 30, 2024

<sup>1</sup> Department of Agronomy, Sindh Agriculture University, Tandojam, Pakistan.

<sup>2</sup> Agriculture Research, Government of Sindh, Pakistan.

<sup>3</sup> Department of Plant Breeding and Genetics, Sindh Agriculture University, Tandojam, Pakistan.

<sup>4</sup> Agriculture Research Institute, Plant Protection Government of Sindh, Pakistan.

<sup>5</sup> Department of Agronomy, Baluchistan Agriculture College Quetta, Pakistan.

\*Correspondence: [asifalikaleri2013@gmail.com](mailto:asifalikaleri2013@gmail.com)

#### Abstract

In the case of sunflower production, precision agriculture can be used to determine the optimal fertilizers application rates and timings based on the specific soil and climatic conditions of a particular field. The response of sunflower to macro- and micronutrient applications has been observed. Field conditions were used to assess the effectiveness of applying nitrogen, zinc, and boron alone or in a mixture to improve the growth and production of sunflower HO-1. The experiment followed an RCBD design with a net plot size of 4x5 (20 m<sup>2</sup>). The study examined the impact of different applied soil fertilizers, including NPK. The suggested doses of T1 (control) and T2 (soil) of the applied fertilizer Nitrogen 1000g ha<sup>-1</sup>, T3 soil applied fertilizer Zinc 1000g ha<sup>-1</sup>, T4 soil applied fertilizer Boron 1000g ha<sup>-1</sup>, T5 soil applied fertilizers Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup>; T6 Nitrogen 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>; T7 soil applied fertilizers Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>, T8 soil applied fertilizers Nitrogen 1000g ha<sup>-1</sup> and boron 1000g ha<sup>-1</sup>, T8 were examined. The result indicated that the application of soil-applied fertilizers Nitrogen 1000g ha<sup>-1</sup> Zinc 1000g ha<sup>-1</sup> and Boron 1000g ha<sup>-1</sup> in combination yielded the most significant improvements in Maximum plant height: 181.0 cm; number of levees Plant<sup>-1</sup>: 36.80; stem girth: 12.35; head diameter: 26.30; number of seed head<sup>-1</sup>: 652.0; seed weight ghead<sup>-1</sup>: 40.74; seed index (g): 62.66; and seed yield (kg<sup>-1</sup>): 2230. The findings suggest that the combined application of nitrogen (1000g ha<sup>-1</sup>), zinc (1000 g ha<sup>-1</sup>), and boron (1000g ha<sup>-1</sup>) as soil fertilizers emerged as the most effective treatment for achieving maximum plant growth and seed yield in sunflower crops. As farmers and researchers continue to seek sustainable practices, the insights from this study contribute valuable information to the ongoing dialogue surrounding enhanced crop productivity and quality.

**Keywords:** *Boron; Nitrogen; Soil Applied; Sunflower; Zinc*



Copyright: © 2024 by the authors.  
Licensee Roots Press, Islamabad  
Pakistan.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

## Introduction

Sunflower is an annual crop native to North America that is now widely cultivated throughout the world. They are commonly known for their large, vibrant yellow flowers, which turn their heads to face the sun throughout the day. However, sunflowers are also an important crop for their seeds, which are rich in oil and protein (Kılıc and Kelkit, 2017). According to Arshad *et al.* (2010), sunflower is the second primary supplier of vegetable oil in Pakistan, following cotton seed. Sunflower oil is a high-quality cooking oil widely used in the food industry, including for frying, baking, and salad dressings. It is also used in the production of biodiesel, a renewable fuel source. Sunflower seeds are a popular snack and ingredient in baked goods, as well as a source of animal feed (Mishra and Singh, 2017).

In addition to their uses in food and fuel production, sunflowers are also used for medicinal purposes. Sunflower oil is believed to have anti-inflammatory and antioxidant properties and may be helpful in treating skin issues such as acne and eczema. Sunflower seeds contain compounds such as phytosterols, which have been shown to help lower cholesterol levels (Yavuz *et al.*, 2017). Sunflower is an important oilseed crop that can be grown in different regions and soils. Fertilizer applications play a major role in the growth and development of sunflower plants. Nitrogen (N), zinc (Zn), and boron (B) are some of the major fertilizers that are important for sunflower production (Kaleri *et al.*, 2019). Nitrogen is a vital element for the growth and development of plants, and it plays a crucial role in sunflower production.

Nitrogen is needed for the formation of amino acids, proteins, and chlorophyll, which are important for photosynthesis and plant growth. Nitrogen is also important for the development of flowers and the production of seeds in sunflowers. Adequate nitrogen supply leads to increased yield and improved seed quality. Sunflower plants treated with higher levels of nitrogen (200 kg ha<sup>-1</sup>) showed increased plant height, leaf area, and seed yield compared to those treated with lower nitrogen levels (150 kg ha<sup>-1</sup>) (Gonzalez-Fontes *et al.*, 2016). Zinc is an essential micronutrient that is required for several physiological processes in plants, including photosynthesis, hormone synthesis, and protein synthesis. Zinc deficiency can lead to stunted growth, chlorosis, and decreased yield in sunflowers. For example, a study by Marques *et al.* (2017) found that zinc fertilization increased sunflower biomass and seed yield compared to non-fertilized plants. Another study by Shereen *et al.* (2015) found that zinc application improved the uptake of other nutrients, such as nitrogen and phosphorus, and led to increased sunflower yield.

Boron is an additional micronutrient that holds considerable importance in fostering plant growth and development. Boron deficiency can lead to weakened cell walls, reduced pollen germination, and decreased seed production in sunflower, Aziz *et al.* (2013) found that boron application led to increased sunflower yield and oil content. Another study by Haddad and Benmoussa (2016) found that boron application increased the level of antioxidant enzymes and improved the oxidative stress tolerance of sunflower plants. The researchers investigated the effects of individual and combined applications of N, Z, and B macro- and micronutrients on the growth and yield of

sunflower (Kaleri *et al.*, 2019).

### Methodology

The field experiment was carried out to determine the impact of soil-applied fertilizers on sunflower growth and yield. The experiment followed a completely randomized block design with a net plot size of 4x5 (20 m<sup>2</sup>). The land preparation methods recommended for sunflower plantations were implemented. The study focused on the local variety HO<sup>-1</sup> and was replicated three times. The soil-applied fertilizers included nitrogen, zinc, and boron at the recommended doses of NPK.

### Culture Practices

The soil was carefully prepared by conducting two rounds of plowing and leveling the surface. Prior to sowing, the appropriate amount of NPK fertilizer was evenly spread across all plots. Throughout this study, during seeding, nitrogen, zinc, and boron were applied to different stages of sunflower. The agronomical traits of the plants were observed by selecting five plants in each plot at five-day intervals during the initial 10 days following crop formation.

1. T1 =(Control)
2. T2=Nitrogen 1000g ha<sup>-1</sup>
3. T3 = Zinc 1000g ha<sup>-1</sup>
4. T4 = Boron 1000g ha<sup>-1</sup>
5. T5 = Nitrogen 1000g ha<sup>-1</sup>+ Zinc 1000g ha<sup>-1</sup>
6. T6 = Nitrogen 1000g ha<sup>-1</sup>+ Boron 1000g ha<sup>-1</sup>
7. T7 = Zinc 1000g ha<sup>-1</sup>+ Boron 1000g ha<sup>-1</sup>
8. T8 = Nitrogen 1000g ha<sup>-1</sup>+ Zinc 1000g ha<sup>-1</sup>+ boron 1000g ha<sup>-1</sup>

During the maturity stage, 15 plants were sampled from each experimental unit to measure their height (in centimeters), number of leaves, and stem girth (in centimeters). The seed heads were separated from each plant, threshed, and used to calculate the number of seeds per head, head weight, weight of 1000 seeds (seed index), and seed yield, all of which were recorded.

### Statistical analysis

The data were subjected to ANOVA using MSTAT-C statistical package. The LSD test was applied to compare means superiority, where ever necessary (Russel and Eisensmith, 1983).

### Results

#### Plant height (cm)

The use of nitrogen, zinc, and boron on the plants of sunflower substantially and positively influenced numerous physiological yields and yield constituent characteristics (Table 1). The plant height (cm) of sunflower is affected by different levels of nitrogen, zinc, and boron. The treatments T<sub>8</sub> = Nitrogen 1000g ha<sup>-1</sup>+ Zinc 1000g ha<sup>-1</sup>+ Boron 1000g ha<sup>-1</sup> produced a maximum plant height of 181.0 cm, while the crops receiving T<sub>7</sub> Zinc 1000g ha<sup>-1</sup>+ Boron 1000g ha<sup>-1</sup>, T<sub>6</sub> = Nitrogen 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>, and T<sub>5</sub> = Nitrogen 1000g ha<sup>-1</sup>+ Zinc 1000g ha<sup>-1</sup> resulted in mean plant heights of 150.3 cm, 172.0 cm, and 168.0 cm, respectively. Similarly, the following mean plant heights (58.1cm, 59.5 cm,

and 58.8 cm) were observed when crop treatments with  $T_4$  = Boron 1000g ha<sup>-1</sup>,  $T_3$  = Zinc 1000g ha<sup>-1</sup>, and  $T_2$  = Nitrogen 1000g ha<sup>-1</sup> were applied. Further, the lowest mean plant height (155 cm) was noted with  $T_1$  = Control, no fertilizer, 00 kg ha<sup>-1</sup>.

#### **Number of leaves Plant<sup>-1</sup>**

Table 1 showed that the number of levees in plant<sup>-1</sup> of sunflower is affected by different levels of nitrogen, zinc, and boron. The treatments  $T_8$  = Nitrogen 1000g ha<sup>-1</sup>+ Zinc 1000g ha<sup>-1</sup>+ Boron 1000g ha<sup>-1</sup> produced a maximum number of levees plant<sup>-1</sup> of 36.80, while the crops receiving  $T_7$  Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>,  $T_6$  = Nitrogen 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup> and  $T_5$  = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> resulted in a mean number of levees plant<sup>-1</sup> of 33.55, 31.90, and 30.90, respectively. Similarly, the following mean number of levees per plant (27.33, 27.00, and 28.74) were observed when crop treatments with  $T_4$  = Boron 1000g ha<sup>-1</sup>,  $T_3$  = Zinc 1000g ha<sup>-1</sup>, and  $T_2$  = Nitrogen 1000g ha<sup>-1</sup> were applied. Further, the lowest mean number of levees per plant (22.38) was noted with  $T_1$  = control, no fertilizer, 00 kg ha<sup>-1</sup>.

#### **Stem Girth (cm)**

The stem girth (cm) of sunflower is affected by different levels of nitrogen, zinc, and boron. The treatments  $T_8$  = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup> produced a maximum stem girth (cm) of 12.35, while the crops receiving  $T_7$  Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>,  $T_6$  = Nitrogen 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>, and  $T_5$  = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> resulted in mean stem girth (cm) of 10.06, 12.05, and 11.10, respectively (Table 1). Similarly, the following mean stem girth (cm) values (11.00, 11.95, and 10.05) were observed when crop treatments with  $T_4$  = Boron 1000g ha<sup>-1</sup>,  $T_3$  = Zinc 1000g ha<sup>-1</sup>, and  $T_2$  = Nitrogen 1000g ha<sup>-1</sup> were applied. Further, the lowest mean stem girth (cm) (7.44) was noted with  $T_1$  = control, no fertilizer, 00 kg ha<sup>-1</sup>.

#### **Head diameter (cm)**

Head diameter (cm) of sunflower is affected by different levels of nitrogen, zinc, and boron. The treatments  $T_8$  = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup> produced a maximum head diameter (cm) of 26.30, while the crops receiving  $T_7$  Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>,  $T_6$  = Nitrogen 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>, and  $T_5$  = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> resulted in mean head diameters (cm) of 23.50, 23.05, and 22.44, respectively (Table 1). Similarly, the following mean head diameter (cm) (20.05, 21.25, and 18.75) were observed when crop treatments with  $T_4$  = Boron 1000g ha<sup>-1</sup>,  $T_3$  = Zinc 1000g ha<sup>-1</sup>, and  $T_2$  = Nitrogen 1000g ha<sup>-1</sup> were applied. Further, the lowest mean head diameter (cm) (16.00) was noted with  $T_1$  = control, no fertilizer, 00 kg ha<sup>-1</sup>.

#### **Number of seed head<sup>-1</sup>**

The number of seed head<sup>-1</sup> per sunflower is affected by different levels of nitrogen, zinc, and boron. The treatments  $T_8$  = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup> produced a maximum number of seed head<sup>-1</sup> of 652.0, while the crops receiving  $T_7$  Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>,  $T_6$  = Nitrogen 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>, and  $T_5$  = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> resulted in a mean number of seed head<sup>-1</sup> of 620.2, 613.5, and 614.1, respectively (Table 2). Similarly, the following mean numbers of seed head<sup>-1</sup> (590.7, 575.1, and 520.2) were observed when crop treatments with  $T_4$  = Boron 1000g ha<sup>-1</sup>,  $T_3$  = Zinc 1000g ha<sup>-1</sup>, and  $T_2$  = Nitrogen 1000g ha<sup>-1</sup> were applied. Further, the

lowest mean number of seed head<sup>-1</sup> (420.7) was noted with T1 = control, no fertilizer, 00 kg ha<sup>-1</sup>.

Table 1. Agronomic traits of sunflower are affected by sole and integrated applied soil fertilizers.

Treatment	Plant height (cm)	Number of levees Plant <sup>-1</sup>	Stem Girth (cm)	Head diameter (cm)
T <sub>1</sub> =(Control)	155.0c	22.38	7.44c	16.00d
T <sub>2</sub> =Nitrogen 1000g ha <sup>-1</sup>	160.0bc	28.74ab	10.05b	18.75cd
T <sub>3</sub> =Zinc 1000g ha <sup>-1</sup>	175.3a	27.00a	11.95a	21.25bc
T <sub>4</sub> =Boron 1000g ha <sup>-1</sup>	176.0a	27.33ab	11.00ab	20.05bc
T <sub>5</sub> =Nitrogen 1000g ha <sup>-1</sup> ha+ Zinc 1000g ha <sup>-1</sup>	168.0ab	30.90ab	11.10ab	22.44bc
T <sub>6</sub> =Nitrogen 1000g ha <sup>-1</sup> + Boron 1000g ha <sup>-1</sup>	172.0ab	31.90a	12.05a	23.05ab
T <sub>7</sub> =Zinc 1000g ha <sup>-1</sup> + Boron 1000g ha <sup>-1</sup>	150.3c	33.55ab	11.06b	23.50ab
T <sub>8</sub> =Nitrogen 1000g ha <sup>-1</sup> + Zinc 1000g ha <sup>-1</sup> + boron 1000g ha <sup>-1</sup>	181.0a	36.80a	12.35a	26.30a
S.E	3.920	2.160	0.4435	1.130
LSD	11.88	6.569	1.340	3.430
CV %	4.00	11.50	6.72	9.13

Table 2. Agronomic traits of sunflower are affected by sole and integrated applied soil fertilizers.

Treatment	Number of seed head <sup>-1</sup>	Seed weight g head <sup>-1</sup>	Seed index (g)	Seed yield (kg <sup>-1</sup> )
T <sub>1</sub> =(Control)	420.7e	26.05d	41.05d	1638c
T <sub>2</sub> =Nitrogen 1000g ha <sup>-1</sup>	520.2d	29.40cd	50.70c	1828bc
T <sub>3</sub> =Zinc 1000g ha <sup>-1</sup>	575.1bcd	34.02ab	60.92ab	2225a
T <sub>4</sub> =Boron 1000g ha <sup>-1</sup>	590.7abc	35.15abc	55.15bc	1975abc
T <sub>5</sub> =Nitrogen 1000g ha <sup>-1</sup> ha+ Zinc 1000g ha <sup>-1</sup>	614.1ab	35.01abc	53.10c	1936abc
T <sub>6</sub> =Nitrogen 1000g ha <sup>-1</sup> + Boron 1000g ha <sup>-1</sup>	613.5ab	36.25ab	60.15ab	2111ab
T <sub>7</sub> =Zinc 1000g ha <sup>-1</sup> + Boron 1000g ha <sup>-1</sup>	620.2cd	32.75bc	50.70c	1991abc
T <sub>8</sub> =Nitrogen 1000g ha <sup>-1</sup> + Zinc 1000g ha <sup>-1</sup> + boron 1000g ha <sup>-1</sup>	652.0a	40.74a	62.66a	2230a
S.E	20.00	1.950	2.070	105.1
LSD	60.70	5.919	6.310	290.08
CV %	6.10	9.90	6.632	9.228

#### Seed weight (g Head<sup>-1</sup>)

Seed weight g Head<sup>-1</sup> of sunflower is affected by different levels of nitrogen, zinc, and boron. The treatments T<sub>8</sub> = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup> produced a maximum seed weight g Head<sup>-1</sup> of 40.74, while the crops receiving T<sub>7</sub> Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>, T<sub>6</sub> = Nitrogen 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>, and T<sub>5</sub> = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> resulted in mean seed weight g Head<sup>-1</sup> of 32.75, 36.25, and 35.01, respectively (Table 2). Similarly, the following mean seed weight g Head<sup>-1</sup> (35.15, 34.02, and 29.40) were observed when crop treatments with T<sub>4</sub> = Boron

1000g ha<sup>-1</sup>, T3 = Zinc 1000g ha<sup>-1</sup>, and T2 = Nitrogen 1000g ha<sup>-1</sup> were applied. Further, the lowest mean seed weight g Head<sup>-1</sup> (26.05) was noted with T1 = control, no fertilizer, 00 kg ha<sup>-1</sup>.

#### **Seed index (g)**

The seed index (g) of sunflower is affected by different levels of nitrogen, zinc, and boron. The treatments T<sub>8</sub> = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup> produced a maximum seed index (g) of 62.66, while the crops receiving T<sub>7</sub> Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>, T<sub>6</sub> = Nitrogen 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>, and T<sub>5</sub> = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> resulted in mean seed index (g) of 50.70, 60.15, and 53.10, respectively (Table 2). Similarly, the following mean seed index (g) values (55.15, 60.92, and 50.70) were observed when crop treatments with T<sub>4</sub> = Boron 1000g ha<sup>-1</sup>, T<sub>3</sub> = Zinc 1000g ha<sup>-1</sup>, and T<sub>2</sub> = Nitrogen 1000g ha<sup>-1</sup> were applied. Further, the lowest mean seed index (g) (41.05) was noted with T<sub>1</sub> = control, no fertilizer, 00 kg ha<sup>-1</sup>.

#### **Seed yield (kg<sup>-1</sup>)**

Seed yield (kg<sup>-1</sup>) of sunflower is affected by different levels of nitrogen, zinc, and boron. The treatments T<sub>8</sub> = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup> produced a maximum seed yield (kg<sup>-1</sup>) of 2230, while the crops receiving T<sub>7</sub> Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>, T<sub>6</sub> = Nitrogen 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup>, and T<sub>5</sub> = Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> resulted in mean seed yields (kg<sup>-1</sup>) of 1991, 2111, and 1936, respectively (Table 2). Similarly, the following mean seed yield (kg<sup>-1</sup>) (1975, 2225, and 1828) were observed when crop treatments with T<sub>4</sub> = Boron 1000g ha<sup>-1</sup>, T<sub>3</sub> = Zinc 1000g ha<sup>-1</sup>, and T<sub>2</sub> = Nitrogen 1000g ha<sup>-1</sup> were applied. Further, the lowest mean seed yield (kg<sup>-1</sup>) (1638) was noted with T<sub>1</sub> = control, no fertilizer, 00 kg ha<sup>-1</sup>.

### **Discussion**

#### **Discussion**

The utilization of soil-applied fertilizers in sunflower cultivation proved highly effective, particularly in enhancing physiological characteristics and yield. The utilization of nitrogen (N), zinc (Zn), and boron (B) in Treatment 8 led to a notable rise in the maximum plant height when compared to alternative treatments (Control). This underscores the favorable impact of the integrated fertilization method on the overall growth of the plants. Notably, the combined application of nitrogen with zinc and boron in Treatment 8 exhibited greater effectiveness. The result indicated that the application of soil-applied fertilizers Nitrogen 1000g ha<sup>-1</sup> + Zinc 1000g ha<sup>-1</sup> + Boron 1000g ha<sup>-1</sup> in combination yielded the most significant improvements in Maximum plant height: 181.0 cm; number of leaves per plant: 36.80; stem girth: 12.35; head diameter: 26.30; number of seeds head<sup>-1</sup> 652.0; seed weight g head<sup>-1</sup> 40.74; seed index 62.66; and seed yield (kg<sup>-1</sup>) 2230. These findings imply that sunflower plants readily absorb certain nutrients, particularly nitrogen, zinc, and boron, immediately after their application, as demonstrated in this study. While all nutrients are crucial for the growth and development of sunflower crops, nitrogen, zinc, and boron stand out as particularly essential for their improvement, in addition to the recommended NPK fertilizer dosage. Sunflower crops have been found to require boron as a vital micronutrient, alongside zinc, according to the International

Fertilizer Association (Oad *et al.*, 2018; Kaleri *et al.*, 2023). Recent research studies have indicated the presence of zinc deficiency in soils (Maqsood *et al.*, 2009; Kaleri *et al.*, 2019) emphasizing the importance of boron in enzymatic and biochemical reactions, as highlighted by Zahoor *et al.* (2011), Gitte *et al.* (2005), and Koutroubas *et al.* (2008), who obtained similar findings. The role of nitrogen in promoting plant growth stages is well-established, attributed to its involvement in providing structural support to the cell membrane and facilitating the integration of non-structural components such as enzymes, nucleic acids, amino acids, and chlorophyll pigments (Sadras and Angus, 2006; Mohsen and Majid, 2011). Ravikumar *et al.* (2021) and Jalilian *et al.* (2012) reported that the application of N fertilizer also increases protein concentration. The growth spurt observed in the plant's height could be attributed to the suitable quantity of boron administered, given its crucial function in activating various enzymatic and biochemical processes. Corresponding findings were previously documented by Gitte *et al.* (2005) and Zahoor *et al.* (2011). The influence of micronutrients on growth and yield components has been noted to significantly enhance the seed setting percentage in sunflower, as reported by Rahul *et al.* (2021). The enhanced growth of the stem can be credited to the functions of boron and nitrogen in processes such as chlorophyll and nucleic acid synthesis, cell differentiation, elongation, turgidity, and lignin biosynthesis. Adequate nitrogen nutrition resulted in the efficient translocation of photosynthates, leading to improved seed filling, thereby increasing both the number of filled seeds per head and the seed weight per head, as indicated by Mehmood *et al.* (2018). The findings of Ceyhan *et al.* (2008) corroborate these results, noting significant variations in 1000-achene weight among different sunflower varieties. Additionally, Sadiq *et al.* (2000) documented an increase in 1000-achene weight with the application of higher levels of nitrogen. The application of N, Zn, and B in Treatment 8 resulted in a substantial increase in maximum plant height compared to other treatments. This indicates the positive influence of the combined fertilization approach on overall plant growth.

### Conclusion

The findings suggest that the combined application of nitrogen ( $1000\text{g ha}^{-1}$ ), zinc ( $1000\text{g ha}^{-1}$ ), and boron ( $1000\text{g ha}^{-1}$ ) as soil fertilizers emerged as the most effective treatment for achieving maximum plant growth and seed yield in sunflower crops. The comprehensive improvements across various growth and yield parameters highlight the significance of a holistic approach to nutrient management in agriculture. As farmers and researchers continue to seek sustainable practices, the insights from this study contribute valuable information to the ongoing dialogue surrounding enhanced crop productivity and quality.

### Conflict of Interest

The authors have not declared any conflict of interest.

### Authors Contributions

All the authors contributed equally in the manuscript.

## References

- Arshad, M., M. A. Khan, S. Jadoon and A. S. Mohmand. 2010. Factor analysis in sunflower (*Helianthus annuus* L.) to investigate desirable hybrids. *Pakistan Journal of Botany*, 42: 4393-402.
- Aziz, M., T. Haq, M. A. Sultan, A. Hameed and R. N. Shabbir. 2013. Response of sunflower (*Helianthus annuus* L.) to varying levels of boron. *Journal of Animal and Plant Sciences*, 23: 977-81.
- Ceyhan, E., M. Önder, Ö. Öztürk, M. Harmankaya, M. Hamurcu and S. Gezgin. 2008. Effects of application boron on yields, yield component and oil content of sunflower in boron-deficient calcareous soils. *African Journal of Biotechnology*, 7: 2854-61.
- Gitte, A., S. Patil and M. Tike. 2005. Influence of zinc and boron on biochemical and yield characteristics of sunflower. *Indian Journal of Plant Physiology*, 10: 400-03.
- Gonzalez-Fontes, A., M. T. Navarro-Gochicoa, J. M. Maldonado and J. Rexach. 2016. Nitrogen in sunflower: Uptake, assimilation and remobilization. *Frontiers in Plant Science*, 7: 1675.
- Haddad, A. and H. Benmoussa. 2016. Boron application affects growth, yield and antioxidant enzyme activities in sunflower (*Helianthus annuus* L.). *Journal of Applied Horticulture*, 18: 23-26.
- Jalilian, J., S. A. M. Modarres-Sanavy, S. F. Saberali and K. Sadat-Asilan. 2012. Effects of the combination of beneficial microbes and nitrogen on sunflower seed yields and seed quality traits under different irrigation regimes. *Field Crops Research*, 127: 26-34.
- Kaleri, A., G. Laghari, A. Gandahi, A. Kaleri and M. Nizamani. 2019. Integrated foliar fertilizer effects on growth and yield of sunflower. *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences*, 35: 25-28.
- Kaleri, A. A., M. A. Ansari, H. Rajper, D. Manzoor, G. M. Banbhan, A. Shakoor, I. Shahzadi, M. Faizan, M. M. Ahmed and M. U. Javed. 2023. The impact of nitrogen potassium and zinc concentrations on the development and productivity of safflower (*Carthamus tinctorius* L.). *Jammu Kashmir Journal of Agriculture*, 3: 259-64.
- Kılıç, S. and A. Kelkit. 2017. A review on the medical potential of *Helianthus annuus* L. *Journal of Medicinal Plants Research*, 11: 366-79.
- Koutroubas, S. D., D. K. Papakosta and A. Doitsinis. 2008. Nitrogen utilization efficiency of safflower hybrids and open-pollinated varieties under Mediterranean conditions. *Field Crops Research*, 107: 56-61.
- Maqsood, M. A., S. Rahmatullah, T. Kanwal, A. M. Aziz and M. Ashraf. 2009. Evaluation of Zn distribution among grain and straw of twelve indigenous wheat (*Triticum aestivum* L.) genotypes. *Pakistan Journal of Botany*, 41: 225-31.
- Marques, L., E. Duarte, B. Gonçalves and R. J. Carbas. 2017. Sunflower response to zinc fertilization. *Communications in Soil Science and Plant Analysis*, 48: 1433-44.
- Mehmood, A., M. Saleem, M. Tahir, M. Sarwar, T. Abbas, A. Zohaib and H. Abbas. 2018. Sunflower (*Helianthus annuus* L.) growth, yield and oil quality response to combined application of nitrogen and boron. *Pakistan Journal of Agricultural Research*, 31: 86-97.
- Mishra, S. and V. P. Singh. 2017. Sunflower (*Helianthus annuus* L.): A multipurpose plant. *International Journal of Agricultural Sciences and Veterinary Medicine*, 5: 84-91.

- Mohsen, S. and R. Majid. 2011. Effect of different application rates of nitrogen on yield and quality of cotton (*Gossypium hirsutum*). American-Eurasian Journal of Agricultural and Environmental Sciences, 10: 366-70.
- Oad, R. K., M. A. Ansari, J. Kumar and D. R. Menghwar. 2018. Effect of foliar applied urea on growth and yield of sunflower (*Helianthus annuus* L.). Open Access Library Journal, 5: 1-13.
- Rahul, G., R. Singh and E. Singh. 2021. Influence of sulphur and boron on yield and economics of sunflower (*Helianthus annuus* L.). Biological Forum–An International Journal, 13: 229-32.
- Ravikumar, C., A. Karthikeyan, P. Senthilvalavan and R. Manivannan. 2021. Effect of sulphur, zinc and boron on the growth and yield enhancement of sunflower (*Helianthus annuus* L.). Journal of Applied and Natural Science, 13: 295-300.
- Russel, D. and S. Eisensmith. 1983. MSTAT-C. Crop and Soil Science Department, Michigan State University: USA.
- Sadiq, S. A., M. Shahid and A. Jan. 2000. Effect of various levels of nitrogen, phosphorus and potassium (NPK) on growth, yield and yield components of sunflower. Pakistan Journal of Biological Sciences, 3: 338-39.
- Sadras, V. O. and J. F. Angus. 2006. Benchmarking water-use efficiency of rainfed wheat in dry environments. Australian journal of agricultural research, 57: 847-56.
- Shereen, A., M. Yaseen, M. Ahmed, M. Y. Ashraf and M. Hussain. 2015. Effect of zinc fertilization on growth, yield and nutrient concentration in sunflower (*Helianthus annuus* L.) under arid conditions. Communications in Soil Science and Plant Analysis, 46: 733-48.
- Yavuz, O., İ. Demirezen Yılmaz and H. Şuleyman. 2017. The potential use of sunflowers in phytoremediation of heavy metals. International Journal of Phytoremediation, 19: 1018-22.
- Zahoor, R., S. A. Basra, H. Munir, M. A. Nadeem and S. Yousaf. 2011. Role of boron in improving assimilate partitioning and achene yield in sunflower. Journal of Agriculture and Social Sciences, 7: 49-55.