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# Role of silicate fertilizer on growth and yield of sunflower (*Helianthus annuus* L.)

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**Abstract**

A pots study was planned at research area of the Department of Soil and Environmental Sciences, College of Agriculture, University of Sargodha, Pakistan during fall, 2020 to ascertain the effect of silicate fertilizer on growth and yield of sunflower. Completely randomized design (CRD) with four replicates and four treatments (control, basal Si application @ 50 mg kg$^{-1}$, basal Si application @ 100 mg kg$^{-1}$ and Foliar Si application @ 1%) were used during this study. Data Regarding crop growth traits like plant height (cm), stem diameter (cm), grain yield (t ha$^{-1}$) and nutrients contents of sunflower plants were recorded using standard procedures. Results of our study directed that a greater plant height (180.50 cm), stem diameter (12.8 mm), green fodder yield (1000.2 g pot$^{-1}$), grain yield (4.62 g plant$^{-1}$), nitrogen contents (3.72 ppm), phosphorus contents (0.59 ppm), potassium contents (2.04 ppm), calcium contents (0.59 ppm) and magnesium contents (0.51 ppm) of sunflower were recorded with 100 mg kg$^{-1}$ application of Si. While, plant height (144.92 cm), stem diameter (8 mm), green fodder yield (800.12 g pot$^{-1}$), achene yield (3.97 g plant$^{-1}$), nitrogen contents (3.17 ppm), phosphorus contents (0.50 ppm), potassium contents (1.96 ppm) calcium contents (0.45 ppm) and magnesium contents (0.38 ppm) of sunflower were observed under control conditions. So, from results of the present experiment it was apparent that application of Si @ 100 mg kg$^{-1}$ helped in obtaining maximum growth and yield of sunflower. However, verification of these results under field conditions is required for making recommendations. 

**Keywords:** Crop growth, Grain yield, Plant height, Silicate fertilizer, Sunflower

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## Introduction

Sunflower (*Helianthus annuus* L.) is short duration oilseed crop (Adeleke & Babalola, 2020) after cotton and soybean (Thavaprakash et al., 2002). Globally, sunflower is ranked as the 4$^{th}$ among almost essential oilseed crops after soybean, sunflower and rapeseed, and it is the most economic and profitable oilseed crop than others (Enebe & Babalola, 2018). Sunflower is an important source of oil and can be grown successfully in both rain-fed and irrigated conditions (Peixoto et al., 2022). By promoting sunflower cultivation in Pakistan, demand and supply of oil could be narrowed down and that would save foreign exchange reserves. The area under sunflower cultivation was 151 thousand acres with 87,000 tons total production and 33,000 tons of oil production, respectively (Pakistan economic survey, 2020-2021). Sunflower seed contains 20-25% protein, 40-50% oil and 80% of unsaturated fatty acids which include linoleic and oleic acids (Ahire et al., 2021; Avni et al., 2016). Its cake or meal represents an exclusive by-product obtained from extract of its seeds containing about 36% of its mass composition and 45 to 50% protein content. Its oil fulfills about 30% of Pakistan's oil requirement (Malik & Siani, 2018). Its seed oil is utilized by heart patients because of having high percentage of unsaturated fat and low degree of cholesterol (Abd El-Gwad & Salem, 2013).

Nutrients are a major need for any crop for its good and sustainable growth in addition to macronutrients (N, P & K) many micronutrients are also required as per crop needs (Gokavi et al., 2021). On earth outside layer Si is the 2nd most abundant component after oxygen (Ahmad et al., 2013). It occupies a total of 29% mean content while in soil its amount ranges from 1% to 45% depending upon the soil type and climatic factors (Zhang et al., 2013). Si content in highly weathered soils can be less than 1% (Amin et al., 2014; Ahire et al., 2021). Silicon is a micronutrient and plant root absorb it in the range between 0.1-0.6 mm as soluble monosilicic acid ($H_4Si_4$) in the soil solution. In the tissues of all plants Si content varies significantly among species with average concentration of 0.1-10% on a dry biomass basis (Keeping et al., 2017). Thakral et al. (2021) reported that silicon encourages the growth of plants and develops tolerance in plants to both types of stresses (biotic and abiotic). Plant growth could be inhibited due to severe shortage of Si (Zargar & Agnihotri, 2013; Manojkumar et al., 2018). Si also helps plant growth, development, photosynthesis, resistance against pests and insects and salinity (Ma, 2004; Schallar & Puppe, 2021). It is a good tool against salinity resistance and plant roots use it as a mono silicate acid (Hussain et al., 2018; Seleiman et al., 2019; Dhiman et al., 2021). Adequate amount of Si also supports the water use efficiency, defence system enzyme activation and removal of antioxidants is regulated by silicon fertilizers (Mohsenzadeh et al., 2007; Luyckx et al., 2017; Boldt et al., 2018). Indeed, the silicon applications alleviate the various harmful effects such as metal toxicity, heat, drought, cold, salinity, heat and nutrient deficiency (Mundada et al., 2021). The application of Si fertilizer increases nitrogen fixation efficiency and also makes the plant tissues hard and strong. In addition to that, the silicon accumulation led to the production of phenolic and phytoalexins that encourage the resistance against various pathogens (Yan et al., 2018).

Kaya et al. (2006) suggested that in dry conditions under application of Si than its recommended dose result in better stand of crop as compared to control plants. Similarly, results of another study showed that sufficient take-up of Si not only developed resistance against water stress but also enhanced the yield of crops (Ma & Takahashi, 2002). However, due to global climate change the arid and semi-arid regions are facing the water scarcity triggered by salinity. Thus, silicon continuously lost through the process of leaching leading to Si deficiency in soil (Sakr, 2018). Silicon is effective for sustainable crop productivity. The adequate amount of Si would be necessary for temperate as well as the tropical region. Silicon fertilizers can be applied via traditional method (basal application) and modern techniques (foliar application) but it is found more effective when applied by foliar application method (Sivanesan & Park, 2014). The foliar application of silicon fertilizer is a good tool against biotic stress. Its deficiency can lead to wilting of plants, less vegetation, less and short flowering de-shaped and reduced fruiting (Mandlik et al., 2020; Hussain et al., 2021).

Hattori et al. (2007) reported that the application silicon influences stomatal conductance by maintaining plant water status. This might be due to silicon's function in uptake and transport of water into leaves and other parts of plants. Findings of Hattori et al. (2007) implied that silicon application resulted in increment in stomata conductance by modifying plant water eminence. It might be due to silicon enhancing uptake and transportation of water to leaves and other parts of the plant. Furthermore, its deficiency can increase the potential for toxicity of iron, manganese and magnesium. Though the silicon is needed by most plants for optimum growth and development, it's over dose can greatly harm the plants (Mandlik et al., 2020). Excess amounts of silicon fertilizer can compete with the other nutrients and can limit their availability or can cause complete breakdown of their supply (Ahanger et al., 2020). Savic et al. (2013) also reported the positive impact of silicon and boron on sunflower growth response.
This investigation was made to check the impact of silicon nutrition on the growth and yield of sunflower with the intent to investigate the response of sunflower crop to granular silicon augmentation with macro nutrient (N, P, K) and to check out the suitable application method of Si nutrition for sunflower along with its dose optimization under local conditions of Sargodha.

## Materials and Methods

The present study was performed at the Departmental research area of Soil and Environmental Sciences, College of Agriculture, University of Sargodha, Pakistan research area of, during fall, 2020.

### Climate

Sargodha is situated in the semi-arid climatic zone. The climate of Sargodha is highly warm in summer and in winter it is mostly cold. In the summer season the maximum temperature goes up to 50 ˚C while in winter season the lowest temperature is as low as freezing point. The duration of summer falls between April to October while winter from November to March. The average yearly precipitation is about 400 mm (inches) and is highly seasonal with approximately two months in July and August. Mostly, the soils have a sandy clay loam texture.

### Experimental design and layout

Soil was collected from the normal field and collected soil was sieved through 2 mm sieve and air dried for 24 hours. This sieved soil was used to elaborate soil physicochemical properties like EC, pH, nutrients (N, P & K) organic matter, and soil texture. The sieved soil was collected from the same test site and each pot was filled with 10 kg sieved soil. The seeds of sunflower (Hysun 33) were purchased from the market. Three seeds of sunflower were planted in each pot. The recommended agronomic practices including hoeing and weeding were carried out for appropriate crop growth and development. The source of N, P and K fertilizers was urea, single super phosphate (SSP) and muriatic of potash (MOP) respectively. Pre analysis of soil was done to check the properties of soil. The completely randomized design (CRD) was used to analyze this experiment statistically. The study consisted of four treatments along with four replicates.

### Treatments

Various treatments of the study included $T_1$ = Control, T2= Basal Si application @ 50 mg kg $^{-1}$**,** T3= Basal Si application @ 100 mg kg$^{-1}$ and T4= Foliar Si application @ 1%.

### Soil analysis

Soil analysis was performed before sowing the crop and presented in Table 1. The soil sample was obtained using the soil auger from a depth of 0-30 cm. For all research, the laboratory methods as published in the U.S. Salinity Laboratory Staff (1969) would be adopted. Methods other than these were individually cited. Soil pH, organic matter, texture, saturation percentage, EC, and nutrients (NPK) of soil were determined following methods described in ICARDA manual (Estefan et al., 2013). Pre analysis of soil was done to check the properties of soil.

**Table 1** Pre-sowing analysis of soil

| Sr. No. | Determinations | Unit | Value |
|---|---|---|---|
| 1 | $pH_s$ | - | 8.2 |
| 2 | $EC_e$ | $dSm^{-1}$ | 1.27 |
| 3 | Soil Organic matter | % | 0.28 |
| 4 | Soil Organic Carbon | % | 0.16 |
| 5 | Available potassium | ppm | 280 |
| 6 | Available Phosphorus | ppm | 9 |
| 7 | $Ca^{+2}$+ $Mg^{+2}$ | $mmol_eL^{-1}$ | 3.2 |
| 8 | Textural class | | Sandy clay loam |

### Plant analysis

#### Sample preparation

The dried plant samples at harvest were ground to 40 mesh. For further analysis plant samples after grinding, were stored in air tight polyethylene bags.

#### Digestion of plant samples for the determination of Si in sunflower plant

Plant samples of 0.5 g were transferred into digestion vessel. 10 ml of diacid mixture ($HNO_3$: $HClO_4$= 2:1) was added into the vessel and kept overnight. Next day, samples were digested on the hot plate at 250ºC till the material became transparent. After digestion, material was cooled and diluted up to 50 ml by adding distilled water. The digested samples were filtered with Whatman filter paper # 40 and stored in air tight plastic bottles.

#### Statistical analysis

All collected data were analysed statistically and Statistics 8.1 was applied to make analysis of variance (ANOVA). Significance of treatment means was compared through Tukey's (HSD) test at 5% probability level (Steel et al., 1997).

## Results

#### Plant height (cm)

Height of a plant is an imperative attribute in any crop. Higher the plants result in better crop stand and result in higher crop yield. Silicate fertilizers produce statistically significant influence on plant height of sunflower (Fig. 1). Taller plants (180.50 cm) were examined with Basal Si application @ 100 mg $kg^{-1}$. However, shorter plants (144.92 cm) were recorded under control (where no doses of Silicate fertilizer were applied). Silicate fertilizers enhance the nutrient uptake of plants so this increase in plant height may be due more nutrient uptakes of nutrients of plants.

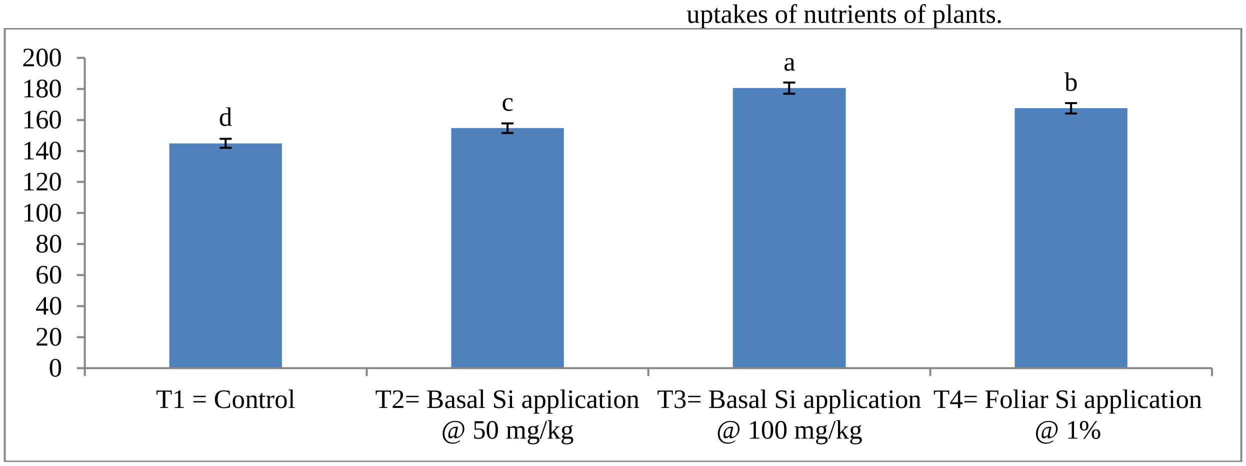


**Fig. 1** Effect of silicate fertilizer on plant height (cm) of sunflower

#### Stem diameter (mm)

Stem diameter is an important attribute in any crop. More the diameter of stem of sunflower result in more plant ability to bear a head, more head of sunflower ensued in higher the final yield of sunflower. Stem diameter of sunflower is statistically influenced by application of silicate fertilizers. Maximum stem diameters of sunflower plant (5.40 mm) were examined with Basal Si application @ 100 mg $kg^{-1}$ (Fig. 2). However, minimum (4.16 mm) stem diameters of sunflower plant (3.62 mm) were recorded under control (where no doses of Silicate fertilizer were applied). Silicate fertilizers enhance the nutrient uptake of plants so this increase in stem diameter may be due more nutrient uptakes of nutrients of plants.

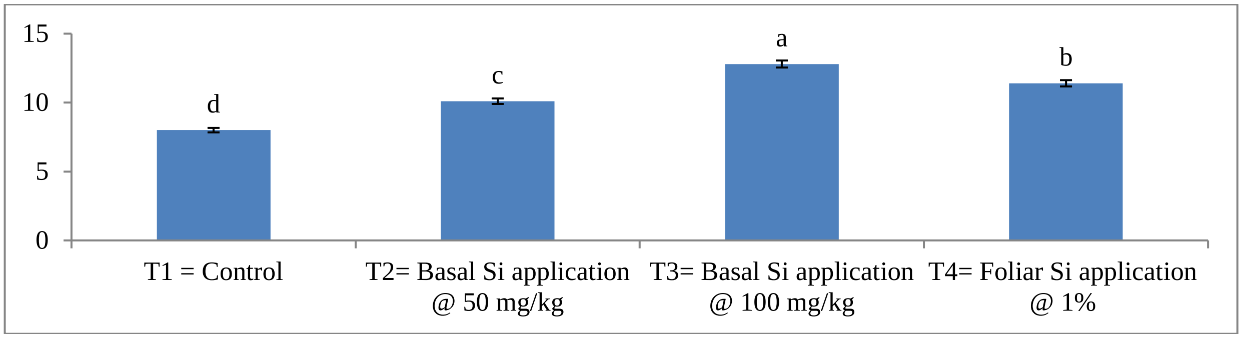


**Fig. 2** Effect of silicate fertilizer on stem diameter (mm) of plants of sunflower

**Green fodder yield (g pot$^{-1}$)**

Green fodder yield is an important trait in any crop. More the green fodder yield crop means more the productivity of the crop. Green fodder yield was statistically significantly influenced by application of silicate fertilizers. Effect of silicate fertilizer on green fodder yield of sunflower was presented in Fig. 3. Maximum green fodder yield (1000.2 g pot$^{-1}$) was examined with Basal Si application @ 100 mg kg$^{-1}$. However minimum green fodder yields (800.12 g pot$^{-1}$) of sunflower were recorded under control (where no doses of silicate fertilizer were applied).

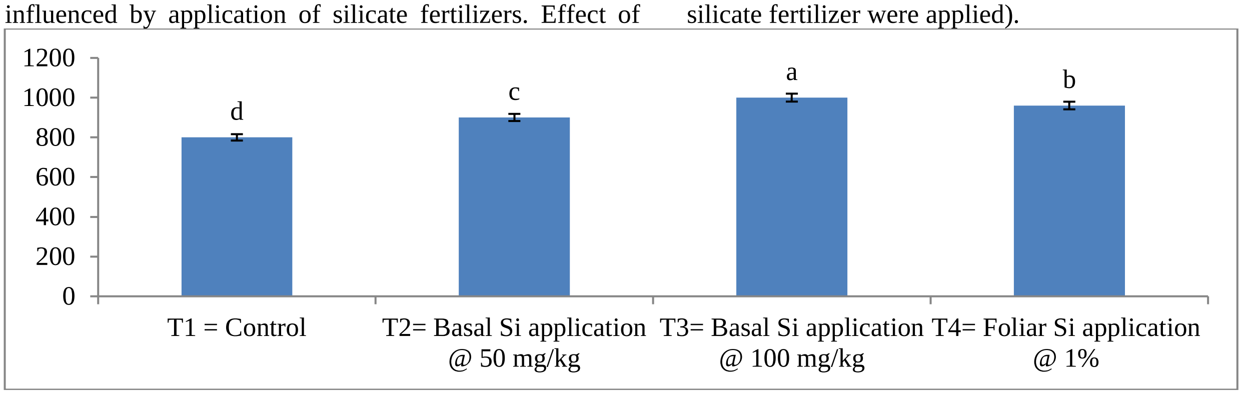


**Fig. 3** Effect of silicate fertilizer on green fodder yield (g pot$^{-1}$) of sunflower

**Achene yield (g plant$^{-1}$)**

Achene yield is an important trait as more the achene yield more the productivity of sunflower crop. Achene yield of sunflower was statistically non-significantly affected by silicate fertilizers presented in Fig. 4. Maximum achene yield (4.62 g plant$^{-1}$) was examined with Basal Si application @ 100 mg kg$^{-1}$. On the other hand, minimum achene yield (3.97 g plant$^{-1}$) of sunflower was recorded under control (where no dose of silicate fertilizer was applied).

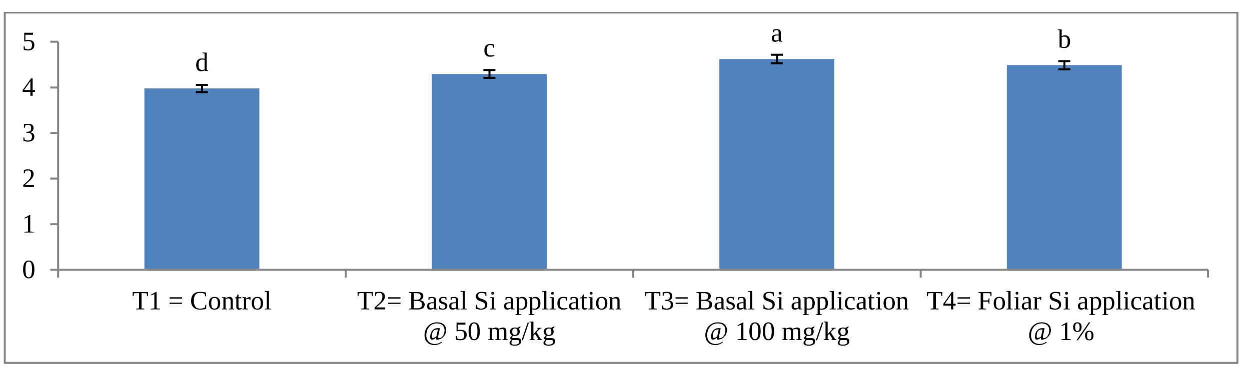


**Fig. 4** Effect of silicate fertilizer on achene yield (g plant$^{-1}$) of sunflower

**Plants analysis**

**Nitrogen contents (ppm)**

Analysis of variance of effect of silicate fertilizer on Nitrogen contents of plants of sunflower directed that there was statistically non-significant effect on nitrogen contents of plants of sunflower (Fig. 5). Maximum nitrogen contents of plants of sunflower (3.72 ppm) were examined with Basal Si application @ 100 mg kg$^{-1}$. Conversely, minimum nitrogen contents (3.17 ppm) of plants of sunflower plant were recorded under control (where no dose of silicate fertilizer was applied).

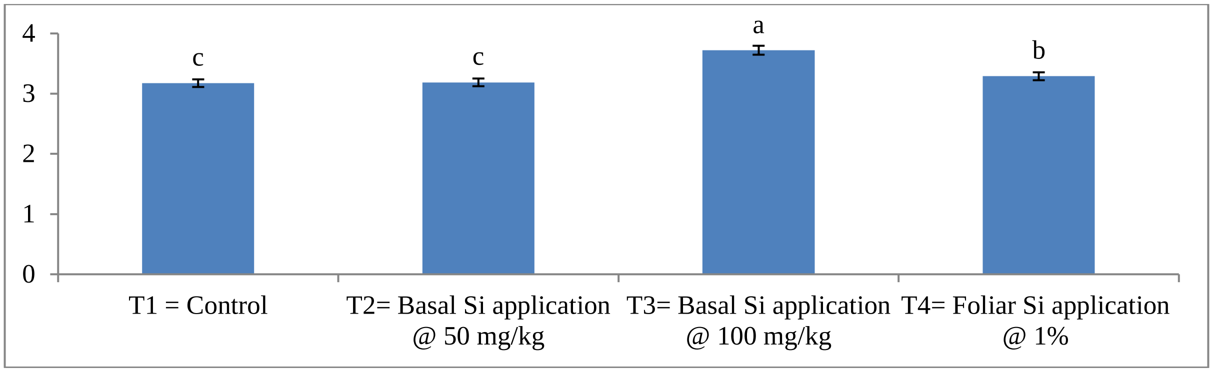


**Fig. 5** Effect of silicate fertilizer on nitrogen contents (ppm) of plants of sunflower

**Phosphorus contents (ppm)**

Analysis of variance of effect of silicate fertilizer on phosphorus contents of plants of sunflower directed that there was statistically significant effect on phosphorus contents of plants of sunflower (Fig. 6). Maximum phosphorus contents of plants of sunflower (0.59 ppm) were examined with Basal Si application @ 100 mg kg$^{-1}$. On the other hand, minimum phosphorus contents (0.50 ppm) of sunflower plants were recorded under control (where no dose of silicate fertilizer was applied).

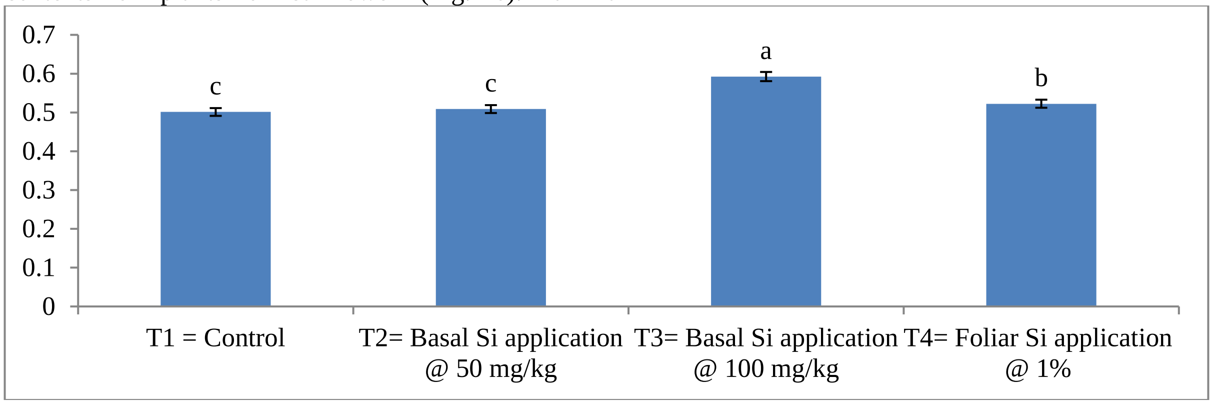


**Fig. 6** Effect of silicate fertilizer on phosphorus contents (ppm) of plants of sunflower

**Potassium contents (ppm)**

Analysis of variance of effect of silicate fertilizer on potassium contents of plants of sunflower directed that there was statistically non-significant effect on potassium contents of plants of sunflower (Fig. 7). Maximum potassium contents of plants of sunflower (2.04 ppm) were examined with Basal Si application @ 100 mg kg$^{-1}$. However, minimum potassium contents (1.96 ppm) of sunflower plants were recorded under control (where no dose of silicate fertilizer was applied).

**Calcium contents (ppm)**

Analysis of variance of effect of silicate fertilizer on calcium contents of plants of sunflower directed that there was statistically significant effect on calcium contents of plants of sunflower (Fig. 8). Maximum calcium contents of plants of sunflower (0.59 ppm) were examined with Basal Si application @ 100 mg kg$^{-1}$. Conversely, minimum calcium contents of plants of sunflower (0.46 ppm) were recorded under control (where no dose of silicate fertilizer was applied).

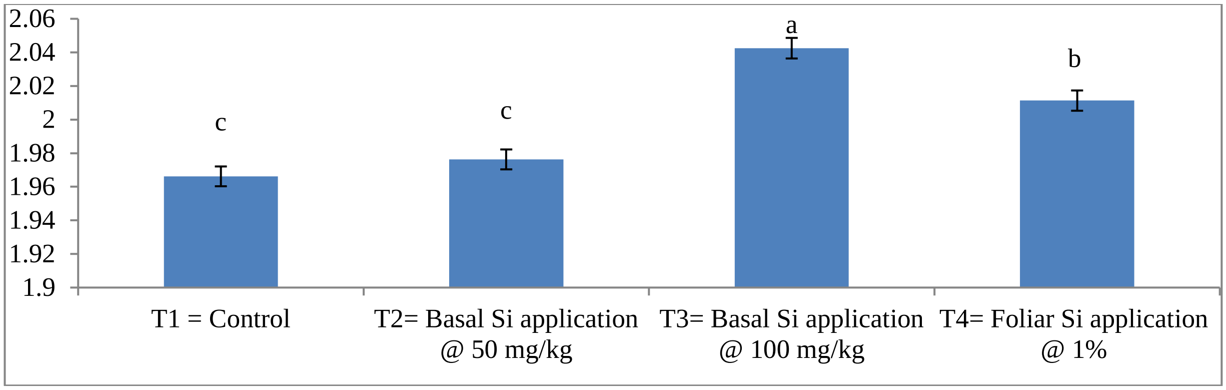


**Fig. 7** Effect of silicate fertilizer on potassium contents (ppm) of plants sunflower

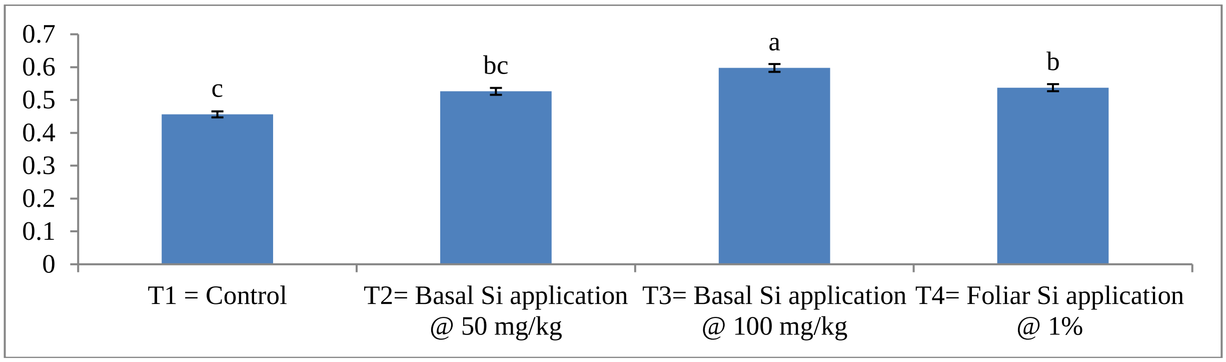


**Fig.8** Effect of silicate fertilizer on calcium contents (ppm) of plants sunflower

**Magnesium contents (ppm)**

Analysis of the effect of silicate fertilizer on magnesium contents of plants of sunflower dictated that there was statistically significant impact on Mg contents of plants of sunflower (Fig. 9). Maximum Mg contents of plants of sunflower (0.51 ppm) were examined with Basal Si application @ 100 mg $kg^{-1}$. But, minimum Mg contents of plants of sunflower (0.38 ppm) were recorded under control (where no dose of silicate fertilizer was applied).

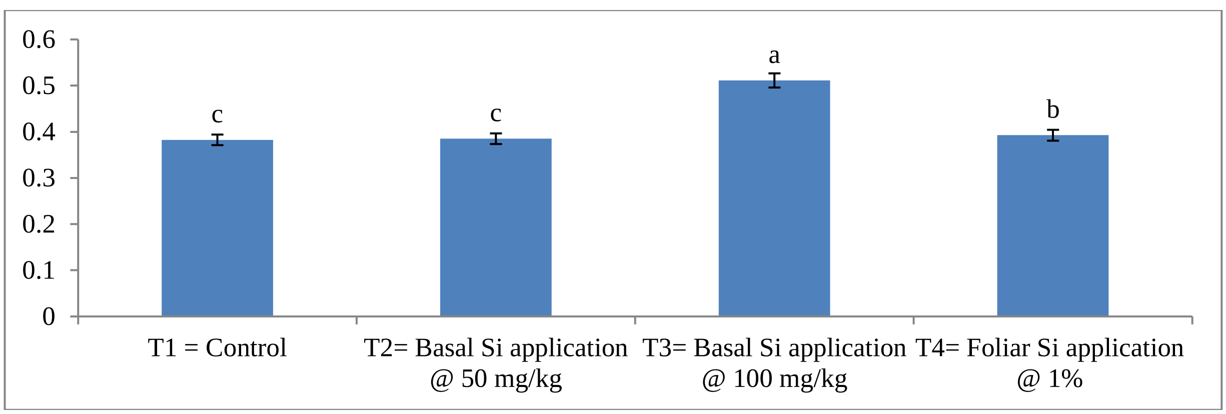


**Fig. 9** Effect of silicate fertilizer on magnesium contents (ppm) of plants sunflower

## Discussion

Micronutrients for example, silicon application is vital for proper growth and yield of crops. Silicon is a significant micronutrient for sustainable cultivation of all cereals and oil seed crops particularly in Asia (Brunings et al., 2009). In crop plants the functions of silicon are well reported for the wellbeing, growth, development and yields (Jinab et al., 2008). It has been reported that the adequate take-up of silicon (Si) can expand the agronomic yields principally due to better crop stand against both biotic and abiotic stresses (Ma & Takahashi, 2002). In crop plants developing under salt-stress conditions silicon helps in keeping a sufficient uptake of fundamental nutrition and diminishes sodium take-up.

Present study exposed that addition of Si @ 100 mg $kg^{-1}$resulted in maximum crop growth (plant height (cm), stem diameter (cm), yield components (grain yield) and nutrients contents of plants which were followed by Foliar Si application

@ 1% and Basal Si application @ 50 mg $kg^{-1}$ respectively. On the other hand, minimum crop growth (number of plants per square meter, plant height (cm), stem diameter (mm), yield components (achene yield) and nutrients contents of plants was observed under control receiving no Si. Findings of current research implied that application of silicate fertilizer improved all growth parameters and nutritional content of sunflower. Such an improvement in growth and yield of sunflower is attributed to the role of silicon in photosynthesis and improved absorption of nutrients by plants. It has been documented that Silicate fertilizers enhance the nutrient uptake of plants so this increase in green fodder yield is may be due more nutrient uptakes of nutrients of plants result in higher green fodder yield (Wang et al., 2010).

Peixoto et al. (2022) also reported that silicon being involved in resistance toward infections and stresses thus, responsible for better quality of produce. In spite of the fact that silicon has not been considered significant for vegetative development yet it helps the plant in sound advancement under anxieties in various crops. Through plant tissue examination it has been revealed that silicon is a vital component for improvement of the cell wall (Liang et al., 2005). Adequate amount of Si also supports the water use efficiency, defence system enzyme activation and removal of antioxidants is regulated by silicon fertilizers (Mohsenzadeh et al., 2007). Its applications alleviate the various harmful effects such as metal toxicity, heat, drought, cold, salinity, heat and nutrient deficiency. The application of Si fertilizer increased nitrogen fixation efficiency and also made the plant tissues hard and strong, in addition to that the silicon accumulation led to the production of phenolic and phytoalexins that encourage the resistance against various pathogens (Yan et al., 2018).

Silicon fertilizers can be applied via traditional method (basal application) and modern techniques (foliar application) but it is found more effective when applied by foliar application method (Sivanesan & Park, 2014). The foliar application of silicon fertilizer is a good tool against biotic stress. Its deficiency can lead to wilting of plants, less vegetation, less and short flowering de-shaped and reduced fruiting (Mandlik et al., 2020). Similarly, Flores et al. (2021), Jeer et al. (2021) and Aurangzaib et al. (2021) also supported the positive role of silicon application in improved growth and yield of plants including sunflower (Ahire et al., 2021). Our outcomes were also supported by Ahmad et al. (2007), Abd El-Gwad and Salem (2013), Peixoto et al. (2022) as well as Jeer et al. (2021) who revealed that silicon play vital role in photosynthesis, controlling movement stomata and effective use of water which eventually brings about healthier vegetative development and straw produce crops.

## Conclusion

This research study clearly showed that use of silicon as an exogenous source in the growth environment improved the yield and yield attributes parameter of sunflower crop. Provision of Si was made from the basic and foliar nutrition source. In performance, the chemical basal source proved a good indication in growth and yield. The foliar silicon source may be performed well on a long term basis but on immediate effect not proved a good silicon nutrition source. The interaction also observed between basal and foliar source, and interaction not proved positive. From the result of the experiment, it was concluded that the application of Si @ 100 mg $kg^{-1}$helped in obtaining maximum growth and yield of sunflower.

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