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Alleviation of salinity stress in wheat through silicon application

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Abstract

This research was performed to testify positive impact of silicon (Si) in alleviation of salinity and wheat growth and yield. Wheat variety Punjab-2011 was grown under normal and salt affected environments using Randomized Complete Block Design (RCBD) with three treatments and three replicates. Wheat was raised in plots filled with normal soil (EC = 2.32 dS/m) and salty soil (4.93 dS/m). Si as phosphate industry waste was applied @ 0, 50 and 100 µg Si/g soil. Results showed that application of Si reduces the adverse impact of salinity and significantly enhances the growth and yield of wheat plants under normal as well as salt stressed environments. Under salt affected soil environment, Si application at 100 µg Si/g (T_3) resulted in maximum height of wheat plant (97 cm), spike length (13.27 cm), fertile tillers number per spike (5), grains count (39), 1000-grain weight (34.54 g), shoot fresh biomass (20.52 g), shoot dry matter (8.42 g), wheat grain yield (4.3 t/ha), silicon concentration in shoot (2.25 mg/g) and root (3.35 mg/g), total chlorophyll content (27 mg/g of fresh weight) as well as total soluble protein content (93 mg/g dry matter). Likewise, under normal soil environment values for maximum height of wheat plant (100 cm), spike length (13.32 cm), fertile tillers (6), grains count (41), 1000-grain weight (35.22 g), shoot fresh biomass (25.65 g), shoot dry matter (10.12 g), wheat grain yield (5.5 t/ha), silicon concentration in shoot (2 mg/g) and in root (3.18 mg/g), total chlorophyll content (32 mg/g of fresh weight) as well as total soluble protein content (119.3 mg/g dry matter) were obtained with application of T_3. Best results were obtained when maximum concentration of Si (100 µg Si/g) was applied. However, these results required to be testified using different wheat varieties under different salt concentrations in future.

Keywords: Wheat, Silicon, Salinity, Growth parameters, Yield

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Introduction

Pakistan is an agricultural country with massive natural resources. It comprises of a multiple climates and environmental zones. Because of this, it has great prospects to produce all kinds of food supplies. Agriculture is a significant source of our national revenue. Agriculture funds about 60% of all the export remunerations in Pakistan. This sector contributes 21.4% of GDP and has covered 45% of our national workforce (Economic Survey of Pakistan, 2018-19). The irrigated lands of Pakistan which covers an area of about 17 million hectares are the backbone of the country agricultural economy (Salam et al., 2014), out of which an area of about 6.3 million hectares is affected by salinity which requires the best sources of reclamation (Qadir et al., 2001).

Wheat (*Triticum aestivum* L.) is among few of the vital crops in terms of development, production, consumption, export and area under growth (Suleiman et al., 2014). Wheat is an essential crop for approximately half of Earth's inhabitants under rain-fed conditions as well as irrigated conditions, it can be cultivated easily (Mishra et al., 2013). Wheat is an annual cereal crop. It has been portrayed as "Crop's King" because of the maximum area where wheat is cultivated worldwide with enormous production, cost-effectiveness and consumption (Rohani & Marker, 2016). It is known that wheat is the first domestic grain crop in the world. For years, wheat is a staple food in North Africa, Western Asia and Europe and is the most required grain in the world (Sun et al., 2021; Verma et al., 2021).

An extensive variety of products are now prepared by wheat and consumed all over the world. Wheat is utilized primarily to be consumed by people and feeds about thirty five percent of Earth's inhabitants. It is nutritious, easy to stock and transport and can be treated in different sorts of food (Suleiman et al., 2014). Wheat demand is likely to increase quicker than all other chief cultivated harvest. Because of soil constraints, an improved amount of wheat produce should come from advanced absolute produce, which can be accomplished only through determined steps taken by researchers of various agricultural categories (Yadav et al., 2010).

Si is ranked second by its presence in soil (Cui et al., 2021). Plants are categorized into 3 types on the basis of Si, non-accumulating, intermediate and accumulating plant types based on their ability to absorb and accumulate Si (Broadley et al., 2012; Sarah et al., 2020). Even though Si has not yet been classified as a necessary nutrient for plants, it has shown to be useful for plant development, particularly the plants of Gramineae family (Hajiboland, 2012; Saleh et al., 2017). Si in the middle of growth mitigates the effects of several environmental factors such as salinity, chilling, deficiency of water, ultraviolet radiation, freezing and metallic toxicity (Zhu & Gong, 2014; Khan et al., 2019). A number of studies are devoted to Si functions in mitigating salt stress (Verma et al., 2020; Souri et al., 2020; Verma et al., 2021) in Si accumulation types such as wheat (Sattar et al., 2020) rice (Gong et al., 2006; Yan et al., 2020), barley (Liang et al., 1996; Laifa et al., 2020), zucchini (Savvas et al., 2009) as well as in some non-cumulative species such as tomatoes (Al-aghabary et al., 2004), tobacco (Hajiboland & Shiraghvar, 2014), canola (Hashemi et al., 2010) and cucumber (Gou et al., 2020).

It is claimed that there are different mechanisms responsible in such improved effects of Silicon under salt pressure such as the stimulation of antioxidant defences and improved plant's water uptake capacity and nutrients present in soil (Currie & Perry, 2007; Othmani et al., 2020; Al-Kahtani et al., 2021). Under salt stress, Si is said to reduce Na^+ absorption but increase K^+: Na^+, which reduces the effect of ion toxicity in various varieties of plant like rice (Yeo et al., 1999) and barley. Another mechanism to improve salt stress by Si is by detecting that Si-facilitated $Mn^{2+}$and Al^{3+} are toxic agents of the cell wall binding (Rogalla & Römheld, 2002). Si was described to lessen the salinity effect upon wheat and on other plants as well. Saqib et al. (2008) reported that reduction in plant uptake of Na+ root distribution of salt-tolerant wheat genotype is due to silicon. Low Na^+ levels in shoot and increased K^+: Na^+ ratio in buds caused enhanced plant development suggesting that Silicon has enhanced the development of buds to resist salinity as well as genotype of saline-sensitive wheat by reducing the Na^+ ion absorption of the plant.

Ali et al. (2009) assessed growing processes of two wheat genotypes (Auqab-2000 and SARC-5) that differ in tolerance to salinity of silicon applied in saline environments. They concluded that the use of silicon resulted in improved dry material and grain production for each genotype grown either in normal conditions or in salt water. The Si concentration in the shoot is mostly associated with the shoot K extent and negative to Na concentration of the shoot. Heightened levels of Potassium and lowered sodium absorption and displacement may be one of the likely mechanisms to increase tolerance of salinity by applying Si in wheat. Therefore, the present research trail was executed in order to justify the effect of exogenous silicon application on salinity in the root zone and on the growth and development of wheat crop.

Materials and Methods

Location

The research was performed in the research area of the Department of Soil and Environmental Science during the summer, 2018 at College of Agriculture (32.04°N, 72.67°E, 188m), University of Sargodha, Sargodha, Pakistan.

Climate of Sargodha

Sargodha is placed within the arid to semi-arid climate region. The maximum summer temperature is 50^{o}C (122^{o}F) till late spring whilst in coldness temperature is low because of the point of solidification. Hotter season lies between April to October and the cooler season from November to March. The average annual rainfall is around 400mm and the monsoon season is in July and August.

Treatments and crop husbandry

In the present study growth established of wheat variety Punjab-2011 was performed in the normal and saline field. The research was carried out in Randomized Complete Block Design (RCBD) under divided plot arrangements having three treatments and each replicated three times. The net plot dimensions were 1m×1m having strips spacing of 75cm and distance between each plant was 25cm. Wheat plants were established in plots with normal soil (EC= 2.32 dS/m) and salt affected soil (4.93 dS/m). Si as phosphate industry waste was applied @ $T_1 = 0$, $T_2 = 50$ and $T_3 = 100$ µg Si/g soil.

Soil and plant analysis

Before and after harvest, soil analysis was done. The soil sample was collected at the depth of 0-30 cm by using a dirt auger. Samples were taken from every plot and were prepped for laboratory examination. The procedures described in handbook 60 of U.S Laboratory Staff (1954) were the inspiration for lab analysis. Procedures apart from these are specified distinctly. Samples of soil dried out in the oven were utilized for all determination. Various physico-chemical traits of soil before cultivation are revealed in Table 1. Data of following traits were noted using standard techniques: The data was noted at the time of development for the following plant traits. For height of the plant of wheat, ten randomly selected plants were selected and height of the main tiller was calculated from the soil crust to the top of the spike of the plant by a meter-rod in centimetres. The length of a spike was calculated with a meter-rod from the bottom of the spike to top of the spike or each genotype within each replicate. No. of fertile tillers of 10 plants were calculated within each genotype within each replicate. Length of spikes of ten randomly selected mother shoots were recorded from the 1st spikelets to the top. Amount of spikelets on each spike was counted manually. 1000-grain weight was recorded from thrashed seed of wheat in grams with the help of electrical balance. Shoot fresh and dry biomass was also recorded.

To compute the root & shoot Si concentration initially random samples were collected and oven-dried and after this with help of pestle and mortal ground to make powdery form. In a Teflon glass beaker 50% of H_2O_2 and NaOH with a fine powder of sample was digested for 2 hours at 150^o C on a hot plate. With the help of a procedure named as colorimetric molybdenum blue was used for estimation of available Si content in the plant. To 1mL of supernatant filtrate liquid, 25 mL of 20% acetic acid, 10 mL of ammonium molybdate (54 g/L) solution was added in 50 mL of polypropylene volumetric flask. After 5 minutes, 5 ml of 20% tartaric acid and 1 mL of reducing solution was added in flask and volume was made with 20% citric acid. After half an hour, the absorbance was measured at 650 nm with a spectrophotometer. The reducing agent was prepared by dissolving 1 g Na_2SO_3, 0.5 g 1 amino-2-naphthol-4-sulfonic acid and 30 g $NaHSO_3$ in 200 mL water (Elliot & Synder, 1991). Method suggested by Arnon (1949) was employed for determination of total chlorophylls a & b using spectrophotometer at 647 and 665 nm. Protein content was estimated using a spectrophotometer at 595 nm wavelength following the protocol suggested by Bradford (1976).

Table 1 Physiochemical characteristics of soil used in the experiments

Determinants	Unit	Normal soil	Saline soil
EC_e	dSm^{-1}	2.32	4.93
pH_s	-	7.9	8.62
Soil organic matter	%	0.5	0.3
Soil organic carbon	%	0.04	0.02
Available P	ppm	7.75	5.6
Available K	ppm	130.5	110.5
Available Si	(mg/kg soil)	30	25
Total Si	(mg/kg soil)	229	205

Statistical analysis

The noted data were statistically analyzed using statistix 8.1 analysis of variance (ANOVA) procedure and significant of treatments means were compared using Tukey's (HSD) test at 5% probability level (Steel et al., 1997).

Results and Discussion

Plant height (cm)

The data pertaining in Fig.1 showed the impact of silicon amendment on plant height of wheat crop under normal and salt affected soil. A significant impact of silicon nutrition was observed on plant height of wheat. The peak plant height (100 cm) of wheat was observed at high silicon level (T_3 = 100 µg Si/g) under normal soil conditions while the lowest plant height (88 cm) was observed where no silicon (T_1 = 0 µg Si/g) was applied under salt affected soil. The medium silicon level (T_2 = 50 µg Si/g) was able to produce 94 and 91 (cm) plant height of wheat under normal and salt stressed situations respectively. Notably, among all the tested levels of silicon, the 100 µg Si/g was found more effective in producing higher plant height of wheat. Results of this study were in line with the experimental outcomes of Rohanipoor et al. (2013) whose results showed that the plant height of maize was considerably reduced by salinity but it was also increased by applying Si. In addition, Ibrahim et al. (2016) also reported for wheat crop that the height of plants was increased through the Si application.

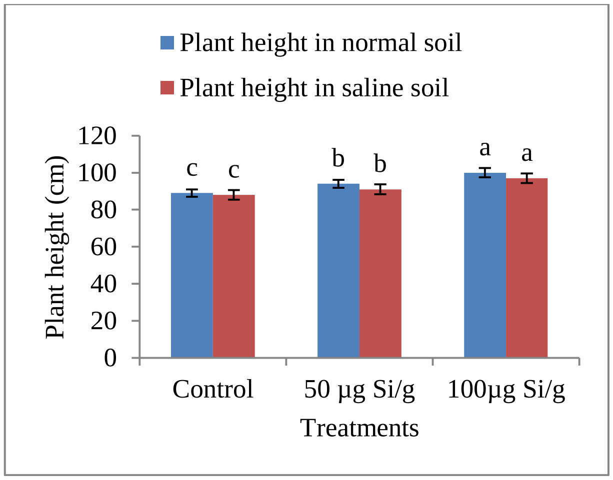

Fig. 1 Impact of various silicon concentrations on plant height (cm/plant) of wheat plants under normal and salt affected soils

Spike length (cm/spike)

Impact of different silicon concentrations on spike length of wheat sown in normal and salt affected soil conditions was presented in Fig. 2. The data indicated that various concentrations of silicon expressively influence the spike length of wheat crop. Among all the silicon concentrations the highest spike length (13.32 cm) was noted with 100 µg Si/g under normal soil conditions. Whereas, the minimum spike length (11.41 cm) was noted within plots where silicon was applied at 0 µg Si/g under salt affected soil. The medium treatment levels (T_2 = 50 µg Si/g) of silicon produced 13.09 and 13.07 cm of spike length under normal and salt affected soil respectively. It is also shown that application of 100 µg Si/g was highly efficient in producing the greater spike length of wheat under both soil conditions. Ali et al. (2012) reported that morphological characteristics of wheat crop like length of spike, height of plant and number of seeds per spike was increased through the application of Si under saline environment.

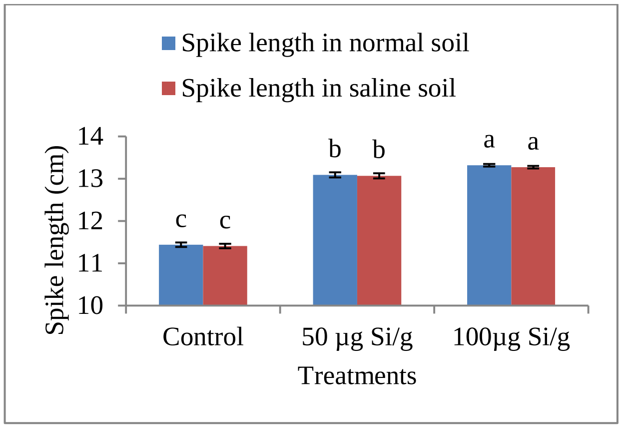

Fig. 2 Impact of various silicon concentrations on spike length (cm/plant) of wheat plants under normal and salt affected soils

Number of fertile tillers per plant

It was apparent from the data shown in Fig. 3 that various concentrations of silicon have varying impacts on the number of fertile tillers of wheat crop. Results revealed substantial response to different concentrations of silicon under normal and salt affected soil. Maximum number of fertile tillers (06) was detected with 100 µg Si/g silicon concentration under normal conditions. However, the minimum number of fertile tillers (03) was recorded with 0 µg Si/g silicon concentration under salt affected soil conditions. The application of 50 µg Si/g silicon concentration produced 05 fertile tillers under both normal and salt affected soil conditions. It was also revealed from the data that 100 µg Si/g silicon concentration was much better than 50 and 0 µg Si/g concentrations in case of fertile tillers of wheat. Parallel outcomes were also indicated by Ahmed et al. (2007) who revealed that foliar application of silicon and boron pointedly affect the number of fertile tillers in wheat and highest number of fertile tillers were perceived with silicon and boron use under saline conditions.

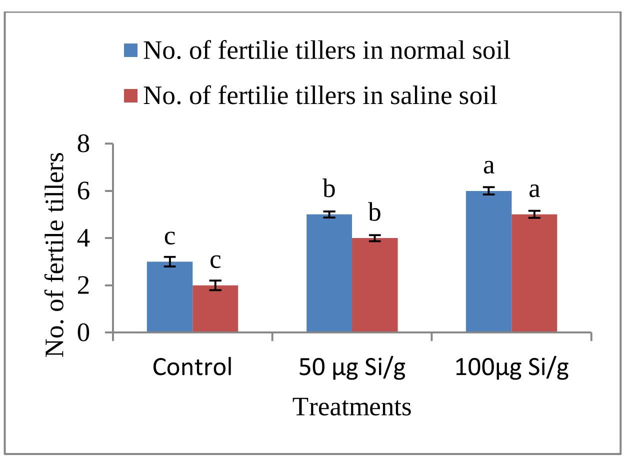

Fig. 3 Impact of various silicon concentrations on number of fertile tillers of wheat plants under normal and salt affected soils

Number of grains/spike

The data presented in Fig. 4 exhibited the influence of silicon amendment on number of grains per spike of wheat crop under normal and salt affected soil. A significant impact of silicon nutrition was detected on number of grains per spike of wheat. The highest number of grains per spike (41) of wheat was observed at high silicon level (T_3 = 100 µg Si/g) under normal soil conditions while the lowest number of grains/spike (32) was observed where no silicon (T_4 = 0 µg Si/g) was applied under salt affected soil conditions. The medium silicon treatment level (T_2 = 50 µg Si/g produced 39 and 35 grains per spike of wheat under normal and salt affected soil conditions respectively. However, among all the tested levels of silicon, the 100 µg Si/g was found more effective in producing a higher number of grains/spike of wheat. Tahir et al. (2006); Ali et al. (2012) also reported supporting outcomes that morphological characteristics of wheat crop like length of spike, height of plant and number of seeds per spike was increased through the application of Si under salinity condition.

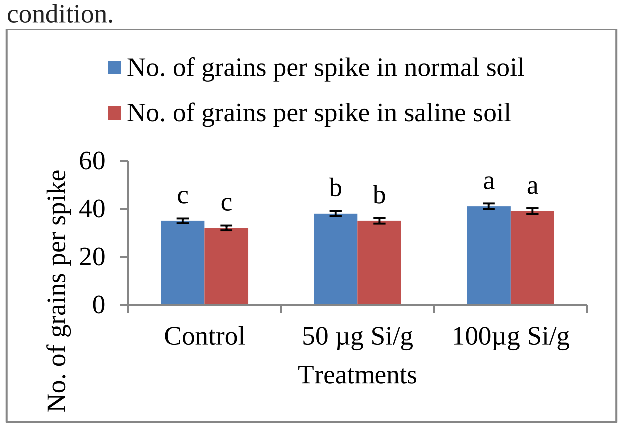

Fig. 4 Impact of various silicon concentrations on number of grains per spike of wheat plants under normal and salt affected soils

1000-grain weight (g)

Influence of different silicon concentrations on 1000-grain weight of wheat sown under normal and salt affected soil conditions was depicted in Fig. 5. The data indicated that various concentrations of silicon considerably influence the 1000-grain weight of wheat. Among all the silicon concentrations the peak 1000-grain weight (35.22 g) was noted with 100 µg Si/g under normal soil conditions. The minimum 1000-grain weight (33.21 g) was noted in plots where silicon was applied at 0 µg Si/g under salt affected soil conditions. The medium treatment level (T_2 = 50 µg Si/g) of silicon was able to produce 34.56 and 34.09 g of 1000-grain weight under normal and salt affected soil respectively. It is also observed that application of 100 µg Si/g was highly efficient in producing the greater 1000-grain weight of wheat under both soil conditions (normal and salt affected). Tahir et al. (2006); Ibrahim et al. (2016); Sattar et al. (2020) revealed that in wheat crop applying Si amended salinity stress and augmented biomass, 1000 grain weight, yield, nutrient extent. Further, application of silicon amplified Si levels in wheat straw and it was proportionate to the increase in Silicon amended growth medium.

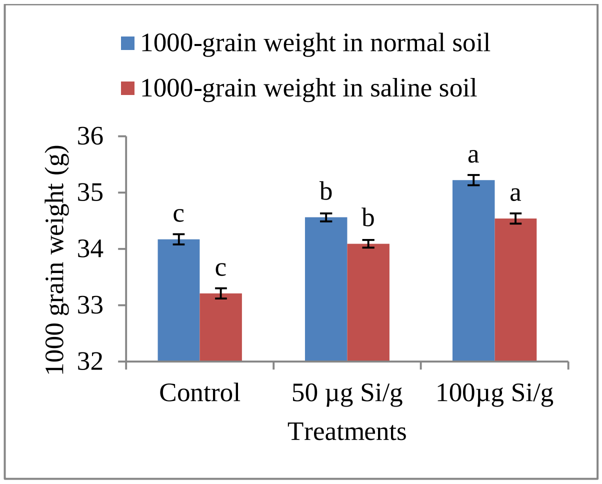

Fig. 5 Impact of various silicon concentrations on 1000-grain weight (g) of wheat plants under normal and salt affected soils

Shoot fresh biomass (g/plant)

The data presented in Fig. 6 reflected that various concentrations of silicon have varying effects on the fresh biomass of wheat crop. Data suggested a substantial response to different concentrations of silicon under normal and salt affected soil. Maximum shoot fresh biomass (25.65 g) was perceived with 100 µg Si/g silicon concentration under normal soil conditions. However, the minimum shoot fresh biomass (14.32 g) was recorded with 0 µg Si/g silicon concentration under salt affected soil conditions. The application of 50 µg Si/g silicon concentration produced 24.71 and 18.60 g of shoot fresh biomass under normal and salt affected soil conditions respectively. It is also revealed from the data that 100 µg Si/g silicon concentration was much better than 50 and controlled Silicon treatment concentrations in case of shoot fresh biomass of wheat. This research also approved by the exploration of Tahir et al. (2006); Hajiboland et al. (2017) whose verdicts denotes that Si supplementation resulted in higher shoot and root fresh biomass in the control plants of rice while a bit of such effect was observed in the salt-stressed ones.

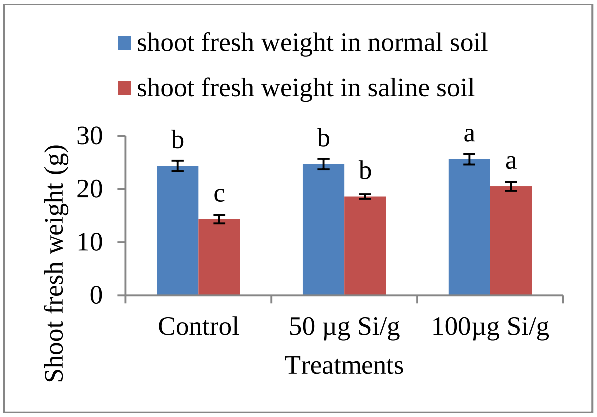

Fig. 6 Impact of various silicon concentrations on shoot fresh weight (g) of wheat plants under normal and salt affected soils

Shoot dry matter (g/plant)

The information concerning Fig. 7 exhibited the influence of silicon amendment on shoot dry matter of wheat crop in normal and salt affected soil. A significant impact of silicon nutrition was detected on dry matter of shoot in wheat. The maximum shoot dry matter (10.12 g) of wheat was observed at high silicon level (T_3 = 100 µg Si/g) under normal soil conditions while the lowest shoot dry matter (6.36 g) was observed where no silicon (T_4 = 0 µg Si/g) was applied under salt affected soil conditions. The medium silicon treatment level (T_2 = 50 µg Si/g) produced 9.12 and 7.16 g shoot dry matter of wheat under normal and salt affected soil conditions respectively. Conversely, amongst all the tested levels of silicon, the 100 µg Si/g was found more effective in producing higher shoot dry matter of wheat. Ahmad et al. (2007), Tahir et al. (2006) and Sattar et al. (2020) also stated a similar outcome, which indicated that application of silicon augmented dry matter production of wheat at all soil types and water contents levels. Dry matter reduction was expressively increased in plants when silicon was applied where they have low water contents, signifying increased tolerance of wheat plants to drought.

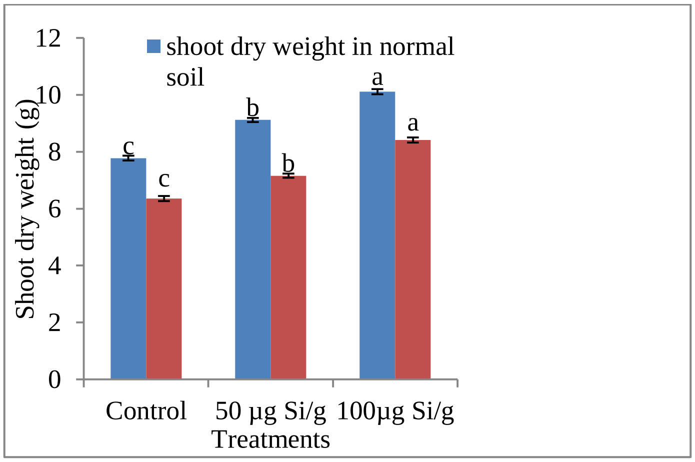

Fig. 7 Impact of various silicon concentrations on shoot dry weight (g) of wheat plants under normal and salt affected soils

Wheat grain yield (t/ha)

Influence of different silicon concentrations on wheat grain yield under normal and salt affected soil conditions was presented in Fig. 8. The data indicated that various concentrations of silicon considerably influence the grain yield of wheat. Among all the silicon concentrations the peak grain yield (5.5 t/ha) was noted with 100 µg Si/g under normal soil conditions. The minimum grain yield (2.4 t/ha) was noted in plots where silicon was applied at 0 µg Si/g under normal soil conditions. Likewise, under saline environments highest grain yield (4.3 t/ha) was noted with 100 µg Si/g with lowest grain yield of 1.3 t/ha was noted in plots where silicon was applied at 0 µg Si/g. It is also observed that application of 100 µg Si/g was highly efficient in producing the greater 1000-grain weight of wheat under both soil conditions (normal and salt affected). Tahir et al. (2006); Saleh et al. (2017); Sattar et al. (2020) also concluded similar outcomes about betterment in yield of wheat achieved by the application of Si under a salt stressed environment. They attributed this betterment in growth and yield of wheat to better water uptake by plant roots, improvement in plant defence system and selective uptake of Na and K ions by roots.

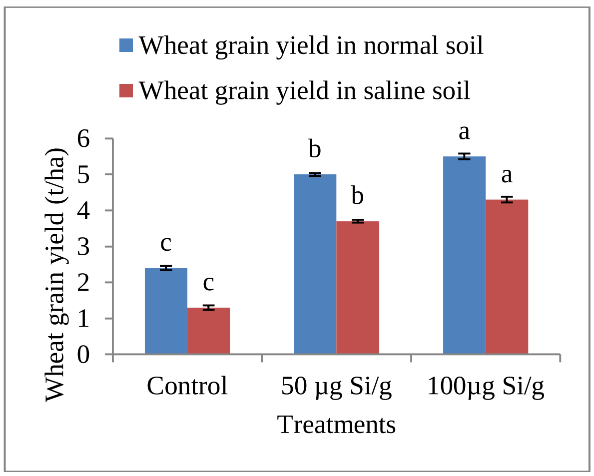

Fig. 8 Impact of various silicon concentrations on wheat grain yield (t/ha) of wheat plants under normal and salt affected soils

Silicon concentration in shoot (%)

Impact of different silicon concentrations on silicon concentration in shoots of wheat sown under normal and salt affected soil conditions was presented in Fig.8. The information indicated that various concentrations of silicon expressively influence the silicon concentration in shoots of wheat. Among all the silicon concentrations the highest silicon concentration in shoots (7.78 mg/g) was noted with 100 µg Si/g under normal soil conditions. The minimum silicon concentration in shoots (2.87 mg/g) was noted in plots where application of silicon was 0 µg Si/g under salt affected soil conditions. The medium treatment (T_2 = 50 µg Si/g) level of silicon produced 6.20 and 6.15 mg/g of silicon concentration in shoot under normal and salt affected soil respectively. It is also showed that application of 100 µg Si/g was highly efficient in producing the greater silicon concentration in shoot of wheat under both soil conditions (normal and salt stressed). Tahir et al. (2006) and Tuna et al. (2008) confirmed that accumulation of Si in root and shoot was increased when Si was applied though various sources and means in wheat crop and also reduced the effect of salinity. Saleh et al. (2017) also concluded similar findings.

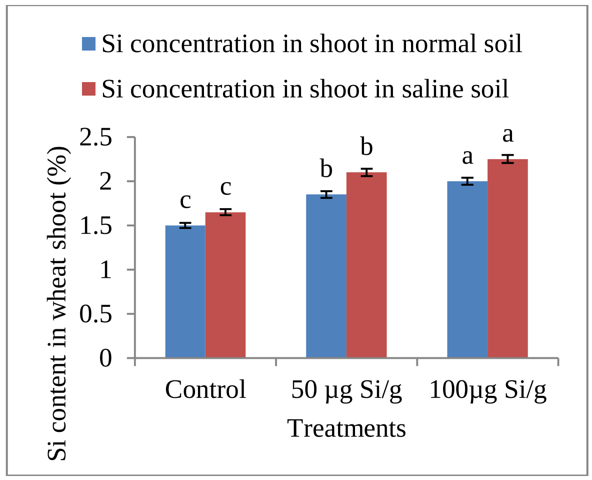

Fig. 9 Impact of various silicon concentrations on Si content of wheat shoot (%) under normal and salt affected soils

Silicon concentration in root (%)

It was depicted from the data presented in Fig. 9 that various concentrations of silicon have a changing effect on the silicon levels in the roots of wheat and rice crop. Both tested crops showed substantial response to different concentrations of silicon under normal and salt affected soil. Maximum silicon concentration in root (3.18 mg/g) was perceived with 100 µg Si/g silicon concentration under normal soil conditions. However, the minimum silicon extent in roots (1.48 mg/g) was noted with 0 µg Si/g silicon concentration under salt affected soil conditions. The application of 50 µg Si/g silicon concentration produced 2.53 and 2.77 mg/g of silicon concentration in root under normal and salt affected soil conditions respectively. It was also revealed from the data that 100 µg Si/g silicon concentration was much better than 50 and 0 µg Si/g concentrations in case of silicon concentration in the root of wheat. Tahir et al. (2006), Tuna et al. (2008) and Saleh et al. (2017) concluded that accumulation of Si in root and shoot was increased when Si was applied though various sources and means in wheat crop and also reduced the effect of salinity.

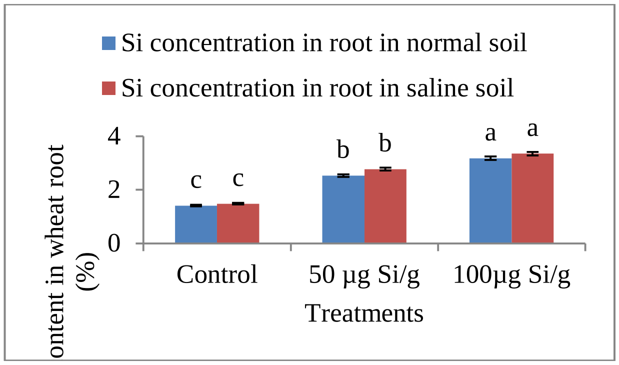

Fig. 10 Impact of various silicon concentrations on Si content of wheat root (%) under normal and salt affected soils

Total chlorophyll content (mg/g of fresh weight)

Effect of different silicon concentrations on total chlorophyll content of wheat sown under normal and salt affected soil conditions was presented in Fig. 11. Data indicated that salinity negatively affected the chlorophyll content of wheat and various concentrations of silicon positively influenced the total chlorophyll content of wheat under saline growth environment. Among all the treatments, the highest total chlorophyll content (27 mg/g of fresh weight) was noted with 100 µg Si/g under salty soil conditions. The minimum total chlorophyll content (18mg/g of fresh weight) was noted in control under salty soil conditions where no application of silicon was made. It was also concluded that non-significant effect on total chlorophyll content was recorded by the addition of Si in normal soil conditions. Similar conclusion was reported by Al-Aghabary et al. (2004) suggesting that silicon has a role in improving the defence system of plants thereby, protecting the cells from salt injury using many mechanisms such as detoxification of reactive oxygen species that is formed during salinity stress. Resultantly, chlorophyll content of plants is improved due to increased efficiency of photo systems.

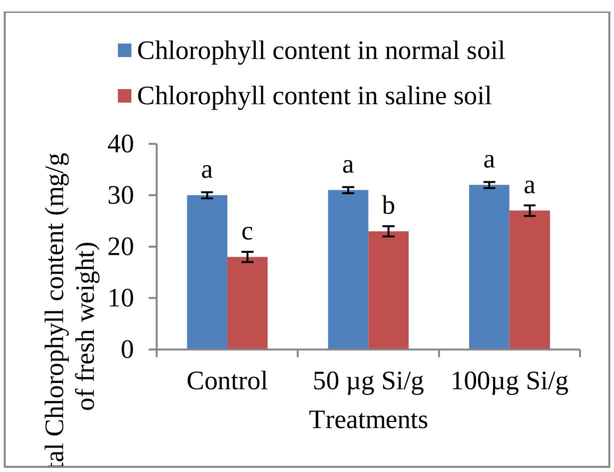

Fig. 11 Impact of various silicon concentrations on total chlorophyll content of wheat (mg/g fresh weight) under normal and salt affected soils

Total proteins (mg/g dry matter)

Impact of different silicon concentrations on total soluble protein content of wheat leaves under normal and salt affected soil conditions was presented in Fig. 12. Data indicated that salinity negatively affected the total protein content in wheat leaves and various concentrations of silicon positively influenced the total protein content of wheat under normal as well as saline growth environment. Among all the treatments, the highest total protein content (93 mg/g dry matter) was noted with 100 µg Si/g under salty soil conditions. The minimum total protein content (60 mg/g of dry matter) was noted in control under salty soil conditions where no application of silicon was made. Similarly, significant effect of Si application on total protein content by the addition of Si in normal soil conditions was also recorded. Outcomes of Menezes-Benavente et al. (2004) confirmed that salinity damages the protein synthesis due to higher concentration of Na ions in leaf tissue leading to suppression of enzymatic activity. Si application improved the protein content by defending the plant against oxidative stress caused by salinity (Tester & Davenport, 2003).

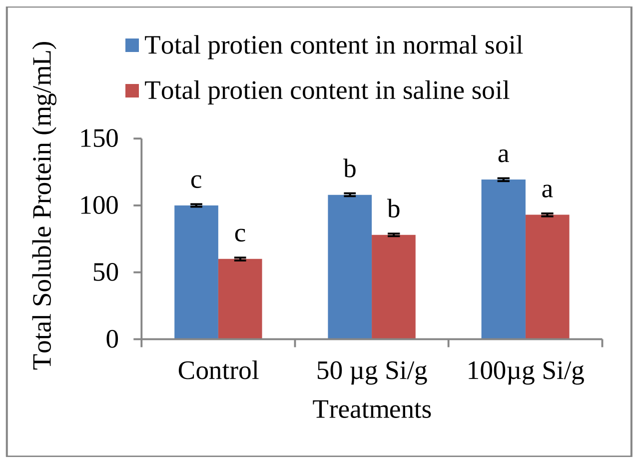

Fig. 12 Impact of various silicon concentrations on total protein content of wheat (mg/g dry matter) under normal and salt affected soils

Conclusion

Silicon application improved growth and production of wheat under normal as well as saline field conditions. Growth enhancement in wheat by application of silicon was more noticeable under salt stress. There was significant upsurge in plant tallness, total number of productive tillers, thousand grains weight, fresh biomass, dry matter, and grain yield, Si content of shoot and root as well as total chlorophyll and protein content over control due to silicon application.

Conflict of interest

There is no conflict of interest regarding publication of this article.

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