Silicon Mediated Changes in Growth and Photosynthetic Pigment of Wheat Plant Under Salt Stress

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Research Article

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Abstract

Purpose

Salinity is a most important environmental stress which adversely affects the crop production and yield. In recent years, Silicon (Si) is gaining an increased attention in the field of stress management. Wheat (*Triticum aestivum* L.) is one of the moderately prone crops to different abiotic stresses which instantly damage the crop yield under stress condition. This work demonstrates the positive impact of Si on growth and photosynthetic pigments in wheat under saline conditions.

Methods

In this research work, two genotypes of wheat i.e. KRL 210 and WH 1105, were grown-up in soil under different salt stress concentration. There were different treatments under which they grown included T0= Control without salt stress (0 dS m^{-1}), T1= Sodium silicate without salt stress (2 mM), T2= Control with salt stress (4 dS m^{-1}) T3= Control with salt stress (8 dS m^{-1}) T4= Control with salt stress (12 dS m^{-1}) T5= Sodium silicate with salt stress ($4 \text{ dS m}^{-1} + 2 \text{ mM Si}$) T6= Sodium silicate with salt stress ($8 \text{ dS m}^{-1} + 2 \text{ mM Si}$) T7= Sodium silicate with salt stress ($12 \text{ dS m}^{-1} + 2 \text{ mM Si}$). At vegetative stage, both the wheat genotypes were compared with their growth parameters and photosynthetic pigments.

Results

Plant biomass, shoot-root length and photosynthetic pigments (chlorophyll- a, b, carotenoid & total chlorophyll) of wheat decreased under salt stress when increased up to 12 dS m^{-1} NaCl concentration. However, in salt stressed wheat plants, plant biomass increased by the Si application. Supplementation of Si improved the plant length as well as chlorophyll pigments which were decreased by the high salt concentration in plants. Silicon was found more effective in salt stressed condition than in alone with control.

Conclusion

So, it was determined that the Si application aided the wheat genotypes in alleviating salinity and enhancing their biomass and photosynthetic pigments which were declined in salt stress condition.

1. Introduction

Salinity stress is a major environmental problem among the world. The overall land area of world which is highly affected by salinity is around 7%, as is parallel to its plough lands [1]. In arid and semi-arid area, almost every irrigated land is affected by the accumulation of salt which can be harmful for the plant growth and crop production. Around 50% of crop fields are badly damaged with the accumulation of sodium ions in the root epidermis and facing severe problem. These are highly distressed by irregular transport of ions and water from soil to plants [2]. The consequences of high level of salt stress are both osmotic stress which creates a water deficit condition and in excess of Na^+ ions which affect all the biochemical and metabolic processes in plant [2]. In salt stress condition, due to large accumulation of Na^+ ions during the osmotic phase, a number of events occur in plant like retardation of leaf expansion, delay in leaf appearance and enhance early leaf senescence condition [3,4]. At higher level of salinity in soil, plant's water potential declines and hence after making it tough for uptake of water from soil and causes wilting of plants. It damages the plant growth and their processes.

So, the main focus is to overcome the salt stress for the sustainable agricultural food production.

Salinity affects all the morphological and biochemical processes in plant such as growth, ionic imbalance, germination, photosynthetic pigments, water potential, osmotic stress and production. Salt stress reduces the germination percent in many plant species.

Khan and Weber, [5] reported the alteration in imbibition by seed through lowering the osmotic potential of sprouting medium, result in harmful changes in the enzyme activities of nucleic acid [6], in the process of protein breakdown [7], reduction in seed reserve utilization [8] and hormonal imbalance [9]. Salinity can lead to decrease in production of crop and sometimes death may occur. It can be observed at whole level of plant [10]. Production of crop declines after exceeding the soil pH to 8.5 or the electrical conductivity (EC) rises above 4 dS m^{-1} . Crop yield declined to a large extent at higher EC value [11]. Salt stress causes toxicity of ions in plants and declines the plant production. It disturbs the chloroplast movement, decreased in photosynthetic reactions and metabolic and biochemical changes such as increased in ROS species [2]. Salt stress causes the disruption of proteins, amino acid and lipids in the plant cell and damage the plant growth. These are occurred because of formation of ROS which are of more reactive nature during stress condition [12].

Silicon is the utmost element found on earth and has been considered to be useful element for the plant growth in stress condition by improving their tolerance to the particular stress [13]. But it is not available in the form in which plants can take up. It is found in the form of monosilicic acid (H_4SiO_4) in the soil. The concentrations of Si vary from 0.1 to 0.6 mM SiO_2 in soil environment. Plants take up Si in this form in quantities fluctuating from >0.1% to around 12% on the dry weight source depending on the type and variety of plant. In past years, Si is not considered as an important element among higher plants. However, there are many reports that show the interaction between Si application and the poaceae family to different abiotic and biotic stresses [14-18].

Si treatment enhances the plant water status and photosynthetic activity [19], by improving their tolerance to the salt stress in various plants [20]. Salinity impairs the balance of Na^+ and K^+ [21-23], advanced K^+ : Na^+ discrimination [24], halts the Na^+ transport [25] by bonding with Si [26] and stimulate the ROS scavenging system [27]. Si mitigates the negative consequence of salt on tomato by maintaining its growth and plant water status [19]. Similarly, Si has a great impact on plant tolerance with several additional role like alleviation of the harmful effect of manganese (Mn) and aluminium (Al) toxicity, along with the increased in salinity resistance [15,19,28]. Si helps in improving the cell wall by increasing the deposition of silica, lignification and suberization [29]. The

biosilicification occurs in the apoplast of the cell which leads to form a barrier of amorphous silica that helps in providing the stress tolerance to the plants [30]. Many studies showed that the plant species which exhibits greater uptake of Si found better benefits from the Si application [31]. It supports the plant to improve their stress resistance and apart from this it also helps to increase the effectiveness of major nutrients as well as biofertilizers under saline soil condition [32].

Wheat is a moderately salt tolerant plant and can accumulate Si in their plant parts as it is a Si-accumulator species [33]. Some major findings showed that Si drops the concentration of sodium ion in root and leaves of wheat plant and enhanced its salt tolerance ability [23,28,34-35]. Wheat is a better Si-accumulating plant and uptake a large amount of Si in its plant part [33]; therefore, it will be fascinating to identify the role of Si on the physiological and biochemical processes by mitigating the harmful impacts of salinity stress in wheat.

This study was conducted on the wheat genotypes with Si effect under salt stress. Wheat is grown as a most popular staple food crop worldwide and is in increasing demand in countries undergoing urbanization and industrialization. Therefore, maintaining wheat production is necessary for undeveloped countries to fulfil the increased demand of population. It is one of the reasons to study the wheat genotypes in stress condition.

2. Material And Methods

2.1 Plant Material & Experimental Conditions

In this research, two wheat genotypes (KRL 210 and WH 1105) were grown in normal environment situations of Maharshi Dayanand University, Rohtak. KRL 210 is a salt tolerant variety of wheat from CSSRI (Central Soil Salinity Research Institute), Karnal. WH 1105 is a new wheat variety from CCS Haryana Agricultural University (HAU), Hisar, which is sensitive for salinity stress. In the initial stage, the seed were grown in earthen pots lined with plastic bags and occupied with 8.0 kg of sandy soil and placed in natural condition. Each bag is having a drainage hole at the center sealed pad of glass wool to avoid the water logging. The seeds were treated with dilute solution of sodium hypo chlorite, before sowing, to prevent any fungal contamination, then washed thrice with distilled water. The different treatments in which wheat seeds were grown includes ; **T0**= Control without salt stress (0 dS m^{-1}) , **T1**= Sodium silicate without salt stress (2 mM) , **T2**= Control with salt stress (4 dS m^{-1}) **T3**= Control with salt stress (8 dS m^{-1}) **T4**= Control with salt stress (12 dS m^{-1}) **T5**= Sodium silicate with salt stress ($4 \text{ dS m}^{-1} + 2 \text{ mM Si}$) **T6**= Sodium silicate with salt stress ($8 \text{ dS m}^{-1} + 2 \text{ mM Si}$) **T7**= Sodium silicate with salt stress ($12 \text{ dS m}^{-1} + 2 \text{ mM Si}$). There were five replicates of both genotypes grown under eight treatments in 80 pots.

The seeds were grown during second week of November. Pots were supplied with salinity concentration of 0, 4, 8 and 12 dS m^{-1} , to maintain salt stress concentration. Si as Na_2SiO_3 , was supplied one month after the sowing and sampling was done after 15 days of Si application.

2.2 Growth Parameters

Fresh and Dry Weight (FW & DW) of leaves, root and shoot

Three plants from each set of treated plant and from control were randomly uprooted. Sand was removed with the help of tap water and soft brush. Shoot, root and leaves were separated, and their separate weights were taken. These samples were then kept in oven at 65°C to obtain constant weight and dry weight was recorded. FW and DW of root, shoot and leaves was measured with weighing machine and reading was taken in gram.

Shoot-root length

Three plants of each genotype from each treatment were randomly uprooted and the sand was removed with the help of a soft brush. The length of the shoot-root was measured and expressed in cm.

2.3 Photosynthetic Pigments

This experiment was performed on the fresh leaves of wheat plant by Hiscox and Israelstam [36] method with slight modifications.

The recorded data was analysed by ANOVA for two factors using Complete Randomized Design (CRD). After that treatments were compared with the value of CD at 5% level of significance.

3. Results

In salt stress conditions, the results obtained in Table 1 showed a substantial decrease in both shoot-root length of wheat plant. The shoot-root length was expressively declined under salt stress condition in both genotypes as compared with control. The shoot length decreased with increased in salt stress from 4 to 12 dS m^{-1} concentration in comparison of control plants. Plant length improved gradually with the addition of Si under stressed condition. Comparing these genotypes, in control condition showed that, shoot-root length increases in KRL 210 more than WH 1105, whereas under saline conditions, WH 1105 variety declined with less rate than KRL 210. The shoot length was adversely affected by the high concentration of salt. The length of shoot of wheat plants reduced from 51.05 cm (T2) to 29.9 cm (T4) in KRL 210 and 32.6 cm (T2) to 29.4 cm (T4) in WH 1105 after increasing the salt concentration. This reduction in shoot length was improved by Si application in T5, T6 and T7 under salt stress in both genotypes (Fig. 1). In control, the average root length was 15.7 cm (T0) which reduced to 9.5 cm (T4) in KRL 210 and 10.6 cm (T0) to 7.4 cm (T4) in WH 1105 under salt stress (Fig. 2). Whereas with Si application in salt stressed plants, the root length was significantly increased up to 13.8 cm (T7) in KRL 210 and 8.8 cm (T7) in WH 1105 which exhibited that supplementation of Si enhanced the development of wheat under salt stress (Table 1).

The fresh and dry weights of the two genotypes grown-up under different concentration of salt stress were compared to the control (T0). The results obtained (Table 1) showed a sharp decline in the FW of leaves, root and shoot in different salinity levels. In control condition (T0), the shoot FW was 2.03 ± 0.464 g which reduced up to 0.80 ± 0.233 g (T4) in KRL 210 and 1.12 ± 0.005 g (T0) to 0.92 ± 0.026 g (T4) in WH 1105 in stressed condition (Fig. 3). Whereas Si supplementation improves this value up to 1.61 ± 0.247 g (T7) in KRL 210 and 1.19 ± 0.03 g (T7) in WH 1105 variety under high salt concentration. In the control condition, average FW of root was 0.387 ± 0.150 g (T0) which reduced up to 0.112 ± 0.011 g (T4) in KRL 210 and 0.104 ± 0.002 g (T0) to 0.056 ± 0.000 g (T4) in WH 1105 in stressed condition. This reduction was overcome by Si in T5, T6 and T7 under salt stress at a greater extent in both genotypes (Fig. 4). Similarly, the FW of leaves of control plant which was firstly 0.751 ± 0.173 g (T0) then reduced to 0.402 ± 0.106 g (T4) in KRL 210 and 0.454 ± 0.016 g (T0) to 0.375 ± 0.009 g (T4) in WH 1105 variety in salt stressed plants. Application of Si significantly improved the decreased FW of leaves in both the genotypes under salt stress (Fig. 5). The declined rate in FW was highly noticeable in KRL 210 as compared to WH 1105 (Fig. 3,4,5).

As showed in Table 1, the DW of shoot of KRL 210 decreased in high salt concentration up to 0.157 ± 0.049 g (T4) from 0.624 ± 0.14 g (T0) and 0.257 ± 0.023 g (T4) from 0.324 ± 0.009 g (T0) in WH 1105 variety. These values significantly increased by the Si application up to 0.371 ± 0.043 g (T7) in KRL 210 and 0.294 ± 0.003 g (T7) in WH 1105 in salinity condition (Fig. 6). The average control value of DW of root was 0.136 ± 0.028 g (T0) which reduced up to 0.044 ± 0.006 g (T4) in KRL 210 and from 0.058 ± 0.006 g (T0) to 0.041 ± 0.004 g (T4) in WH 1105 under high salt condition (Fig. 7). These values of DW of root were enhanced by the supplementation of Si under salt stress in T5, T6 and T7. Likewise, in leaves, the value of DW in control was 0.184 ± 0.052 g (T0) which decreased to 0.091 ± 0.027 g (T4) in KRL 210 and from 0.101 ± 0.009 g (T0) to 0.073 ± 0.008 g (T4) in WH 1105 under salt stress. Application of Si help out in increasing the DW up to 0.117 ± 0.011 g (T7) in KRL 210 and 0.085 ± 0.004 g (T7) in WH 1105 in higher salinity (Fig. 8). Overall, the declined rate was more in KRL 210 than WH 1105 in salt stress condition (Fig. 6,7,8).

The results obtained from Table 2 showed that the increased salt stress concentration in wheat plant decreased the chlorophyll (Chl) a, chl b, carotenoid and total chl content. In KRL 210, chl a in control was 0.752 ± 0.030 mg/g FW (T0) which decreased up to 0.424 ± 0.052 mg/g FW (T4) and in WH 1105, 0.708 ± 0.025 mg/g FW (T0) to 0.446 ± 0.033 mg/g FW (T4) under high stress condition. The chl content increased by supplementing the Si in T5, T6 and T7 under salt-stressed condition (Fig. 9). Under salt stress, the chl b content decreased from 0.221 ± 0.014 mg/g FW (T0) to 0.076 ± 0.014 mg/g FW (T4) in KRL 210 and 0.165 ± 0.014 mg/g FW (T0) to 0.066 ± 0.006 mg/g FW (T4) in WH 1105 variety. These decreased values significantly improved by the addition of Si in salt-stressed situations. They exhibited that Si enhanced the chl content in both genotypes (Fig. 10). Moreover, the carotenoid content also decreased from 11.05 ± 0.062 mg/g FW (T0) to 8.54 ± 0.023 mg/g FW (T4) in KRL 210 and 12.10 ± 0.09 mg/g FW (T0) to 10.22 ± 0.09 mg/g FW (T4) in WH 1105 at higher concentration of salt stress. In addition, Si improved these values up to 13.01 ± 0.90 mg/g (T7) in KRL 210 and 12.50 ± 0.12 mg/g FW (T7) in WH 1105 under stressed conditions (Fig. 11). Similarly, under stressed condition, the total chl content was also reduced from 0.972 ± 0.035 mg/g FW (T0) to 0.420 ± 0.018 mg/g FW (T4) in KRL 210 and 0.873 ± 0.040 mg/g FW (T0) to 0.438 ± 0.033 mg/g FW (T4) in WH 1105. Whereas, in salt stressed condition with Si, total chl content significantly increased up to 0.575 ± 0.025 mg/g FW (T7) in KRL 210 and 0.667 ± 0.010 mg/g FW (T7) in WH 1105 (Fig. 12). Overall WH 1105 exceeds from KRL 210 with less declined rate in adverse stress (Fig. 9, 10,11,12).

4. Discussion

Plants which are generally grown in highly saline areas might faces severe problems in their growth and developmental processes. High level of salt accumulation in the soil converts the cultivated lands into non-cultivated waste land. On such non-cultivated lands which resulted due to high salinity in soil, the plant growth has been retarded and declines its yield [37]. Application of Si can be an auspicious approach for providing tolerance to the salt stressed plant and also improving salt tolerance in plants like wheat. Some major findings showed that Si can partially mitigate the negative outcome of salinity on different plants [38,39]. Moreover, Si helps in stress alleviation, it has been proved good in the overall plant growth [40-42]. Plant biomass was adversely affected in wheat genotypes under salinity treatment. But the seedling weight enhanced significantly by the application of Si under salt stress [43]. It has been observed that when Tuberose plants were treated with high level of salinity stress, a decline in the plant length and number of leaves were found. This decline was overcome by Si application [44]. A significant reduction of dry matter was observed in rice plant by increasing the concentration of salt stress either as NaCl alone or mixture of different salts. Whereas, the supplementation of Si increases the plant biomass. NaCl alone was proved to be more effective than mixture of salts in reducing the growth parameters [45]. In *H. marinum*, the FW and DW of root and shoot were greatly decreased with the higher concentration of salinity level but this was remarkably mitigated by Si supplementation [46]. Salt stress decreases the production of crops by ion toxicity and reduce the length of shoots and root [47]. Likewise, in present study a reduction in plant's length occur which decreased the root, shoot and leaves weight of the wheat plant. According to a study, the different levels of salinity (0 mM to 150 mM) affects the plant growth adversely while below 125 mM, a substantial reduction in shoot and root growth found [48]. It proves that this is the threshold limit of the wheat plant after which the plant growth and production are badly affected. Consequently, in the present study up to 12 dS m^{-1} salt concentration was specified to the wheat plant, which highly damage the plant growth by decreasing the root, shoot and leaves weight with plant's height. But when these plants were given under the application of Si, there was an enhancement in the FW and DW of root, shoot and leaves when compared to the salt stress condition. Si showed a positive response on the growth of wheat plant when it was applied under the salt stressed condition. It improved the plant performance at a better level in stressed condition. The root-shoot length also increased up to a great level by addition of Si in salt stress. Many studies on Si shown that it enhances the growth and expansion of plant under salt-stressed condition in cucumber [49] and tomato [50]. A remarkable increase in the plant biomass occur with the accumulation of Si in various plant parts. Its addition with salt stress, promotes the growth activities such as increase in root-shoot length under normal and also stressed conditions. Our research findings on the effect of Si under salt condition meets the results of [25,51-52] for mung bean, wheat and barley. In salt stress, the growth of maize plant improved by priming of seed with Si [42]. Si can enhance the plant growth of barley [53] and soya bean [54] plant when given it exogenously. In addition, when Si is applied exogenously, it can improve the root-shoot length and plant height and can increase the plant biomass. In a report, salt stress greatly reduced the biomass, relative water content (RWC) and uptake of K^+ ion in barley plant which were gradually improved by the application of Si in the rooting medium [55]. In *Sorghum bicolor* L. and *Helianthus annuus* L., Si mitigates the negative effects of salinity by reducing the uptake of Na^+ and K^+ ions [56]. Salinity also causes reduction in photosynthetic pigments, the carotenoid content and disrupts the photosynthetic reactions in wheat plant [57]. Salt stress causes toxicity of ions and

imbalance the K⁺ and Na⁺ absorption from the soil which reduces the photosynthetic efficiency and growth of rice plant [58]. Although it disturbs the osmotic potential by imbalancing of ion level and formation of solute in the plant cell. Salt stress causes the damage of chloroplast activity, decrease the photosynthetic reactions, metabolic and biochemical changes [2]. Chlorophylls in the plant leaves are the chief pigments that helps in the process of photosynthesis and conduct the light reactions [59]. Exogenous Si application may increase the chl and carotenoid content in the plant, which probably because Si can enter into the chloroplast by absorption and transport [60,61]. In our research, the chl content formed better in the control condition. However, in different salt stress concentration, chl and carotenoid content decreased gradually in both the wheat genotypes which damage the overall production and growth of the plants as shown in Fig. 9,10,11,12. According to a report in barley plant, Si improves the growth rate of the plant by enhancing the photosynthetic activity and chl content [62]. A noticeable improvement was shown in chl pigments and carotenoid content in all barley varieties grown under different Si concentration, whereas a simultaneous decrease in salt stress condition was found [55]. Supplementation of Si enhanced the chl b and carotenoid contents in maize plant under both control and saline stress conditions [63]. Salt stress affects the chl a and b in wheat plants at higher level but the addition of Si in both salt and control condition increased the chl a and b content significantly [43]. In many plants, Si has improved the photosynthesis and chl pigment in high stressed condition [64,65]. Likewise, in Table 2 of the present work, chl and carotenoid content decreased significantly under high salt concentration in both the genotypes (Fig. 9,10,11). However, addition of Si improved the value of chl and carotenoid in normal as well as in salt stress.

5. Conclusion

This study showed the beneficial effect of Si on wheat plant under different salinity condition through highlighting the growth parameter and photosynthetic pigment. Si in the form of sodium silicate being able to use as an effective biofertilizer to alleviate the negative impact of salinity and being useful in the development of wheat genotypes in salty regions. These results showed that the addition of Si under salt stress promote the growth and pigments that aids in photosynthesis of wheat genotypes by alleviating the toxic effect of salt. This study shows the positive effect of Si in stressed condition more than in control.

Abbreviations

Si - Silicon

Wt. -Weight

ROS – Reactive oxygen species

Chl – Chlorophyll

g -gram

mg - microgram

cm – centimetre

FW – Fresh Weight

DW – Dry Weight

SE – Standard Error

CD – Critical Difference

Declarations

Ethical Approval: Not Applicable

Consent to Participate: Not Applicable

Consent for Publication: Not Applicable

Availability of data and materials: All authors confirm that the data supporting the findings of this study are available within the separate file attached to this manuscript.

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Authors' contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Pooja Singh, Vikram Kumar, Jyoti Sharma and Asha Sharma. The first draft of the manuscript was written by Pooja Singh and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript

Compliance with Ethical Standards

Conflict of Interest All authors declare that they have no conflicts of interest.

Research involving human participants and/or animals: Not Applicable

Informed Consent: Not Applicable

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Tables

Table 1 Shoot length, Root Length, FW and DW of Shoot, Root and Leaves under saline condition with Si treatment.

Given values are mean of three replicates ± SE

Table 2 Chl ‘a’, ‘b’, Carotenoid Content and Total Chl under saline condition with Si treatment.

Given values are mean of three replicates ± SE.

Figures

Figure 1
Effect of Si on shoot length (cm) of wheat genotypes under salt stress.

Figure 2

Parameters	Genotype	Control	Silicon	Salinity without Silicon			Salinity with Silicon (2Mm)		
		0 dS m ⁻¹ (T0)	2 mM (T1)	4 dS m ⁻¹ (T2)	8 dS m ⁻¹ (T3)	12 dS m ⁻¹ (T4)	4+2 (T5)	8+2 (T6)	12+2 (T7)
Shoot Length	KRL 210	46.75±0.25	52.6±2.4	45.05±3.05	41.95±6.15	29.9±0.1	44.75±3.75	46.2±3	45.45±3.65
	WH 1105	34.75±2.45	33±0.5	32.6±1.1	31.55±3.75	29.4±1.45	33.85±1.55	31.95±2.1	31.85±0.05
Root Length	KRL 210	15.75±0.25	13.50±1.5	11.60±0.3	9.60±1.4	9.50±0.3	10.80±0.05	13.20±1.1	13.85±0.65
	WH 1105	10.55±0.75	9.90±0.3	8.90±1.6	8.10±0.2	7.35±0.45	9.05±2.15	8.95±0.65	8.80±0.1
Fresh Weight of Shoot	KRL 210	2.03±0.464	2.34±0.068	1.77±0.123	1.66±0.197	0.80±0.233	1.84±0.031	2.22±0.01	1.61±0.247
	WH 1105	1.12±0.005	1.26±0.236	1.09±0.097	1.03±0.023	0.92±0.026	1.18±0.063	1.16±0.023	1.19±0.03
Dry Weight of Shoot	KRL 210	0.624±0.14	0.599±0.066	0.443±0.024	0.419±0.063	0.157±0.049	0.468±0.0015	0.523±0.019	0.371±0.043
	WH 1105	0.324±0.009	0.313±0.039	0.309±0.011	0.279±0.007	0.257±0.023	0.318±0.01	0.283±0.005	0.294±0.003
Fresh Weight of Root	KRL 210	0.387±0.150	0.308±0.086	0.299±0.053	0.137±0.074	0.112±0.011	0.295±0.01	0.307±0.009	0.309±0.008
	WH 1105	0.104±0.002	0.101±0.003	0.082±0.021	0.064±0.003	0.056±0.000	0.112±0.038	0.106±0.037	0.102±0.002
Dry Weight of Root	KRL 210	0.136±0.028	0.119±0.036	0.093±0.023	0.057±0.011	0.044±0.006	0.123±0.004	0.129±0.005	0.132±0.055
	WH 1105	0.058±0.006	0.052±0.000	0.049±0.004	0.045±0.003	0.041±0.004	0.055±0.006	0.052±0.005	0.048±0.007
Fresh Weight of Leaves	KRL 210	0.751±0.173	0.562±0.047	0.530±0.027	0.499±0.085	0.402±0.106	0.541±0.020	0.564±0.023	0.605±0.027
		0.454±0.016	0.452±0.039						

	WH 1105			0.448±0.009	0.412±0.01	0.375±0.009	0.476±0.034	0.447±0.048	0.416±0.006
Dry Weight of Leaves	KRL 210	0.184±0.052	0.144±0.001	0.111±0.023	0.107±0.018	0.091±0.027	0.112±0.011	0.114±0.017	0.117±0.011
					0.079±0.005	0.073±0.008		0.091±0.007	0.085±0.004
	WH 1105	0.101±0.009	0.104±0.008	0.086±0.009			0.099±0.013		

Parameters	Genotype	Control	Silicon	Salinity without Silicon			Salinity with Silicon (2Mm)		
		0 dS m ⁻¹	2 mM	4 dS m ⁻¹	8 dS m ⁻¹	12 dS m ⁻¹	4+2	8+2	12+2
		(T0)	(T1)	(T2)	(T3)	(T4)	(T5)	(T6)	(T7)
Chlorophyll 'a'	KRL 210	0.752±0.030	0.787±0.018	0.459±0.015	0.430±0.089	0.424±0.052	0.532±0.039	0.479±0.023	0.497±0.016
	WH 1105	0.708±0.025	0.617±0.054	0.538±0.012	0.459±0.017	0.446±0.033	0.519±0.029	0.465±0.011	0.547±0.003
Chlorophyll 'b'	KRL 210	0.221±0.014	0.230±0.022	0.082±0.029	0.080±0.019	0.076±0.014	0.187±0.005	0.160±0.002	0.178±0.005
	WH 1105	0.165±0.014	0.140±0.003	0.114±0.005	0.074±0.001	0.066±0.006	0.109±0.006	0.085±0.009	0.120±0.009
Carotenoid	KRL 210	11.05±0.62	13.39±0.92	9.53±1.61	8.96±1.62	8.54±0.23	13.19±0.22	12.89±0.57	13.01±0.90
	WH 1105	12.10±0.09	11.43±0.53	11.12±0.63	11.01±1.04	10.22±0.09	12.28±0.79	11.55±0.47	12.50±0.12
Total Chlorophyll	KRL 210	0.972±0.035	1.018±0.040	0.541±0.018	0.505±0.111	0.420±0.018	0.619±0.054	0.570±0.023	0.575±0.025
	WH 1105	0.873±0.040	0.857±0.029	0.652±0.017	0.587±0.012	0.438±0.033	0.628±0.037	0.592±0.023	0.667±0.010

Effect of Si on root length (cm) of wheat genotypes under salt stress.

Figure 3

Effect of Si on FW of shoot (g) of wheat genotypes under salt stress.

Figure 4

Effect of Si on FW of root (g) of wheat genotypes under salt stress.

Figure 5

Effect of Si on FW of leaves (g) of wheat genotypes under salt stress.

Figure 6

Effect of Si on DW of shoot (g) of wheat genotypes under salt stress.

Figure 7

Effect of Si on DW of root (g) of wheat genotypes under salt stress.

Figure 8

Effect of Si on DW of leaves (g) of wheat genotypes under salt stress.

Figure 9

Effect of Si on chl a (mg/g FW) in leaves of wheat genotypes under salt stress.

Figure 10

Effect of Si on chl b (mg/g FW) in leaves of wheat genotypes under salt stress.

Figure 11

Effect of Si on carotenoid content (mg/g FW) in leaves of wheat genotypes under salt stress.

Figure 12

Effect of Si on total chl (mg/g FW) in leaves of wheat genotypes under salt stress.