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Effect of silicon on growth, yield and yield attributes of wheat (*Triticum aestivum* L.) under simulated soil salinity

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Abstract
A pot experiment was conducted during *Rabi* 2019-20 at Department of Agricultural Chemistry and Soil Science, J. A. U., Junagadh to assess the effect of silicon on growth, yield and yield attributes of wheat (*Triticum aestivum* L.) under simulated soil salinity. The result revealed that application of silicon @ 300 ppm found superior over other silicon levels with respect to plant height (48.48 cm), no. of effective tillers per plant (1.165), no. of spikelets per spike (11.14), spike length (11.96), grain yield (0.827 g plant-1) and straw yield (1.556 g plant-1). In salinity levels, control recorded the highest plant height (49.26 cm), no. of effective tillers per plant (1.165), no. of spikelets per spike (11.68), spike length (12.14), grain yield (0.848 g plant-1) and straw yield (1.587 g plant-1).

Keywords: Wheat, silicon, salinity, growth, yield and yield attributes

Introduction
Wheat (*Triticum aestivum* L.) is one of the most important staple food crops of the world as well as India. It is universally known as 'King of cereals' because of its wider adaptability and elevated productivity. It has been the most abundant source of calories and protein in the human diet, supplying nearly 20% of the food calories and 20% of the total dietary protein consumed globally (Braun *et al*., 2010) [6]. India is the second largest producer of wheat after China. Area and production of wheat in India were recorded 29.14 million hectares and 102.19 million tonnes, respectively with an average productivity of 3507 kg ha-1 (Anonymous, 2019) [4]. The lower productivity in most of the cases is attributed to various abiotic stresses. Soil salinity is the one of them.

Soil salinity is considered to be one of the principal causes of soil degradation. Soil salinity induces morphological, physiological and metabolic disturbances in plants affecting development, growth, yield and quality of plants (Meena *et al.*, 2012 and Patel *et al*., 2020) [18, 20]. Wheat is a moderately salt tolerant crop and it suffers due to saline soils in most of the countries of the world. Therefore, it is very important to develop various approaches to provide the salinity tolerance to plants in wheat. Applying silicon for ameliorating the salinity stress and improving wheat yield has become familiar during the past few days.

Silicon being a beneficial element, provides significant benefits to plants against various abiotic (e.g., salt, drought, metal toxicity, lodging and freezing) and biotic (plant diseases and pests) stresses (Liang *et al*., 2003) [9]. A number of possible mechanisms were reported through which Si may increase salinity tolerance in plants (Liang *et al*., 2007) [10]. Graminaceous plants accumulate more Si in their tissues than other species (Matichenkov and Kosobrukhov, 2004) [17]. Wheat is a member of Poaceae family and recently designated as Si accumulator and canalleviate salt-induced damages. So, exogenous application of Si has been professed as cost-effective approach to ameliorate the salt stress in cereal crops like wheat. In present study, an attempt has been made to discover the efficacy of silicon to provide salinity tolerance to wheat crop.

Materials and Methods
The experimental soil was clayey in texture and moderately alkaline in reaction with pH 7.5, EC 0.48 dS m-1, $CaCO_3$ 33.05% and CEC 36.2 cmol (p+) kg-1. The soil was medium in available nitrogen (258.00 kg ha-1), medium in available phosphorus (35.05 kg ha-1), high in available potassium (288 kg ha-1) and medium in available sulphur (18.5 kg ha-1). Soil available silicon was recorded 155.10 mg kg-1.

The micro nutrient Fe, Zn, Mn and Cu content of initial soil was 6.0, 0.56, 7.74 and 1.64 mg kg-1 respectively. There were sixteen treatments comprising of four levels of silicon *viz*., Si1 - 0 ppm, Si2 - 100 ppm, Si3 - 200 ppm, Si4 - 300 ppm and four levels of salinity *viz*., S1 - Control, S2 - 40 meq l-1, S3 - 60 meq l-1, S4 - 80 meq l-1 replicated thrice in FCRD. The desired soil salinity was artificially prepared by dissolving pre-determined quantity of salts in a measured quantity of water. The salts used were *viz*., CaCl2, MgSO4, MgCl2 and NaCl. Forty-eight pots were filled with each soil bulk of 22 kg as per treatment after artificial simulated saline soil. Si treatments were applied in the form of SiO2 (65% Si) after calculating the proper quantities to be applied as per the treatment details. Recommended dose of N @ 120 kg ha-1, P2O5 @ 60 kg ha-1 and K2O @ 60 kg ha-1 was applied through urea, DAP and MOP, respectively. After applying treatments, fifteen healthy seeds of wheat variety GW-366 were sown into each pot. After germination, ten plants per pot were maintained. In this study, Germination percentage, plant height, number of effective tillers per plant, number of spikelets per spike, spike length, grain yield and straw yield were recorded at harvest.

Results and Discussion

Effect on growth parameters

The different levels of silicon did not produce significant effect on germination percentage, however they had significant influence on plant height and number of effective tillers per plant (Table 1). Plant height and number of effective tillers increased with consequent increasing silicon levels. Significantly the highest plant height (48.48 cm) and number of effective tillers per plant (1.165) were reported with silicon level Si4 (300 ppm), which found statistically at par with silicon level Si3 (200 ppm) in both. This result of increase in plant height with increasing silicon level is corresponding with research work done by Ahmad *et al.* (2007) [2] and Maamoun (2014) [12]. Deposition of silicon in cell wall can make the leaves and stems more erect and increase plant height (Yoshida, 1980) [26]. In other words, Si amendment can improve plant water uptake and plant water storage by reducing the osmotic effect and helps to increase plant growth. Similarly, Martin *et al.* (2017) [15] found that number of fertile tillers increased with the foliar application of silicon in wheat. This fact is important because silicon stimulates tillering, which then cause an increase in the number of spikes, filling the empty spaces in the field as well as indicating that the plant is in good growing condition (Zagonel *et al.*, 2002) [27].

In this study, different tested levels of salinity exerted non-significant effect on germination percentage. However, plant height and number of effective tillers per plant were significantly affected by salinity levels (Table 1). Plant height and number of effective tillers per plant decreased significantly with increased salinity levels. The significantly highest plant height (49.26 cm) and number of effective tillers per plant (1.165) were noted in salinity level S1 (Control), which found statistically at par with salinity level S2 (40 meq l-1) in both the cases. Yadav *et al*. (2011) [25] and Kalhoro *et al*. (2016) [8] also found decreased plant height with increasing salinity level. Adverse effect of salinity on plant height might be due to lower uptake of water and nutrients from the growing media because of higher concentration of salts in the root zone, which causes nutrient imbalances due to increase in osmotic pressure. In similar way, Abbas *et al*. (2013) [1] also found that salinity significantly reduced the number of tillers per plant.

Effect on yield attributes

Application of silicon significantly influenced the yield attributes like number of spikelets per spike and spike length (Table 1). These two were increased with increasing level of silicon. The highest number of spikelets per spike (11.14) and spike length (11.96 cm) were noted at silicon level Si4 (300 ppm), which found statistically at par with silicon level Si3 (200 ppm) in respect to both, while the lowest number of spikelets per spike (9.71) and spike length (11.12 cm) were noted at silicon level Si1 (0 ppm). Maamoun (2014) [12] also observed increase in spike length as a result of silicon application.

We observed that number of spikelets per spike and spike length were significantly decreased with increasing salinity levels (Table 1). Salinity level S1 (control) recorded significantly the highest number of spikelets per spike (11.68) and spike length (12.14 cm). However, it found statistically at par with salinity level S2 (40 meq l-1) in respect to spike length. Significantly the lowest number of spikelets per spike (9.25) and spike length (11.09 cm) were observed in S4 (80 meq l-1) level of salinity. As spikelets initiate at the vegetative stage, the negative effect of salinity on spikelet number indicates that the number of spikelets per spike is a sensitive parameter at the vegetative stage. El-Hendawy *et al.* (2005) [7] and Asgari *et al.* (2011) [5] also revealed that number of spikelets per spike and spike length decreased significantly by increasing the levels of salinity. As salinity decreases the rate of water entry into the plant and increases the entry of toxic ions, which results in a severe reduction in such yield attributes.

Effect on grain and straw yield

Wheat grain and straw yield were significantly influenced by the levels of silicon application and were increased with the progressive increase in silicon levels from Si1 (0 ppm) to Si4 (300 ppm) (Table 1). Significantly highest grain yield (0.827 g plant-1) and straw yield (1.556 g plant-1) were found at silicon level Si4 (300 ppm). Whereas, the lowest grain yield (0.729 g plant-1) and straw yield (1.340 g plant-1) were observed at silicon level Si1 (0 ppm). Soratto *et al.* (2012) [22] found that the wheat grain yield was significantly increased by Si leaf application compared to the control (without Si application). Similarly, Ali *et al.* (2012) [3] reported that wheat plants harvested at maturity indicated a concomitant increase in straw yield with Si application both under optimal and stressful conditions. Silicon application may enhance crop yield by several indirect actions such as decreased shading due to greater leaf erectness (Marschner and Rimmington, 1988) [14]. Ma and Takahashi (1993) [11] also noted that erectness of wheat leaves as a result of Si fertilization could account for about 10% increase in the photosynthesis, thereby indirectly increasing yield.

Results data (Table 2) indicated that grain yield and straw yield decreased significantly with increasing salinity level. The significantly highest grain yield (0.848 g plant-1) and straw yield (1.587 g plant-1) were observed at salinity level S1 (Control), while the lowest grain yield (0.678 g plant-1) and straw yield (1.238 g plant-1) were found at salt concentration level S4 (80 meq l-1). Asgari *et al.* (2011) [5]

and Tahir *et al.* (2006) [23] also found decrease in grain and straw yield with increasing soil salinity. The reduction in yield due to salinity might be attributed to the inhibiting effects of salinity on many metabolic processes including protein, nucleic acid and polyamine synthesis (Mittle and Dubey, 1991) [19], activity of mitochondria and chloroplasts (Udovenko and Tsibkovaskayai, 1983) [24], decreasing transpiration, stomatal conductance and photosynthesis (Sharma, 1995) [21], restricts the absorption of water by plant roots and water use efficiency (Mansour, 1994) [13] and the toxic effects of certain ions present in soil solution (Mass and Nieman, 1978) [16].

The interaction effect of silicon and salinity levels was found significant for grain and straw yield of wheat (Table 2). Among the different treatment combinations of silicon and salinity, the highest grain yield (0.941 g plant-1) and straw yield (1.777 g plant-1) were found at Si4 (300 ppm) X S1 (control) level which was at par with Si4 (300 ppm) X S2 (40 meq l-1) level of treatment combination. Whereas, the lowest grain yield (0.660 g plant-1) and straw yield (1.220 g plant-1) were noted under Si1 (0 ppm) X S4 (80 meq l-1) combination.

Table 1: Effect of silicon and salinity on growth, yield and yield attributes

Treatments	Germination (%)	Plant height (cm)	No. of effective tillers/plant	No. of spikelets/spike	Spike length (cm)
Silicon (Si)					
Si1: 0 ppm	77.50	43.51	1.000	9.71	11.12
Si2: 100 ppm	79.45	45.07	1.055	10.27	11.58
Si3: 200 ppm	80.56	46.96	1.083	10.61	11.74
Si4: 300 ppm	81.67	48.48	1.165	11.14	11.96
S. Em. +	1.78	0.68	0.034	0.21	0.16
C.D. (P=0.05)	NS	1.96	0.097	0.61	0.47
Salt concentration (Salinity) (S)					
S1: Control	82.50	49.26	1.165	11.68	12.14
S2: 40 meq l-1	81.11	47.22	1.110	10.97	11.81
S3: 60 meq l-1	80.00	45.33	1.028	9.82	11.37
S4: 80 meq l-1	75.56	42.21	1.000	9.25	11.09
S. Em. +	1.78	0.68	0.034	0.21	0.16
C.D. (P=0.05)	NS	1.96	0.097	0.61	0.47
Si x S Interaction					
S. Em. +	3.57	1.36	0.067	0.43	0.33
C.D. (P=0.05)	NS	NS	NS	NS	NS
C.V. %	7.75	5.13	10.85	7.07	4.85

Table 2: Interaction effect of silicon and salinity on grain and straw yield (g plant-1) of wheat

Treatment	Grain Yield (g plant^{-1})					Straw yield (g plant^{-1})				
	S1: Control	S2:40 meq l^{-1}	S3:60 meq l^{-1}	S4:80 meq l^{-1}	Mean	S1:Control	S2:40 meq l^{-1}	S3:60 meq l^{-1}	S4:80 meq l^{-1}	Mean
Si_1: 0 ppm	0.785	0.753	0.719	0.660	0.729	1.398	1.397	1.344	1.220	1.340
Si_2: 100 ppm	0.800	0.761	0.744	0.673	0.745	1.519	1.440	1.354	1.228	1.385
Si_3: 200 ppm	0.868	0.804	0.754	0.682	0.777	1.655	1.539	1.432	1.240	1.467
Si_4: 300 ppm	0.941	0.889	0.781	0.696	0.827	1.777	1.699	1.482	1.265	1.556
Mean	0.848	0.802	0.749	0.678		1.587	1.519	1.403	1.238	
S.Em. ±	0.019					0.044				
C.D. (P=0.05)	0.055					0.128				

Conclusion
From the forgoing results, it can be concluded that growth, yield and yield attributes of wheat were adversely affected due to salinity condition. An application of 300 ppm silicon under salinity stress condition gave better mitigating effect and resulted higher wheat growth and yield.

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