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INFLUENCE OF SILICON SOURCES & CONTROLLED RELEASE FERTILIZER ON THE GROWTH OF WHEAT CULTIVARS OF BALOCHISTAN UNDER SALT STRESS

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Abstract

Wheat (*Triticum aestivum* L.) is a staple food of Pakistan and constitutes 60% of the daily diet of a human being in Pakistan. Production of wheat can be improved by using marginal lands and the salt affected areas by silicon supplementation and improving fertilizers. As Nanotechnology has brought revolutions in agriculture, therefore silica nanoparticles (SiO_2 Nps) have been used in this study to reduce the salinity stress. Seeds of four wheat varieties, Umeed and Raskoh (salt tolerant) and Zarghoon and Shahkar (salt sensitive) were grown in Hydroponics. Hoagland's Nutrient Solution (HNS) was used as control while treatments included CRF (Controlled Release Fertilizer), CRF with SiO_2 Nps, sodium silicate, SiO_2 Nps and silicic acid. Salt stress of 100 mM NaCl was induced. Data was recorded for TDS, germination rate, length of root and shoot, fresh and dry weight and chlorophyll content. All results were statistically significant at 0.05 level, sodium silicate and SiO_2 Nps were found to control salinity. Excellent results were achieved using CRF and CRF containing SiO_2Nps. It has been concluded that SiO_2 Nps or its CRF can be useful to compete the salinity and drought stress for growing wheat in the marginal and salt affected land in Pakistan.

Key words: Silicon, Silica nanoparticles, Wheat, Balochistan, Saline.

Introduction

Most edible crop in Pakistan is wheat. Wheat production should also be increased for the ever growing population. In Pakistan, wheat is grown on an area of more than 9 Mha with an annual production of 25 mt (Sultana *et al*., 2019). The agricultural productivity decreases due to salt accumulation (Khan *et al*., 2009), about 40,000 hectare of land is tumble-down yearly because of salinity in Pakistan (Ghafoor *et al*., 2004). According to a recent survey about 6.68 million hectare of land in Pakistan is under salt stress (Hussain *et al*., 2012). Out of which Sindh has 294.3, Punjab 130.4, Balochistan 15.2 and KPK 0.2 hectares is saline and waterlogged (Afridi, 2009). Province of Balochistan is the largest in size but is a wheat deficit province, depends on Sindh and Punjab for wheat requirements. In Balochistan, environmental stresses are the main limiting factors in crop production. Major stresses are cold and drought in winters also the salinity is one of major abiotic environmental stress that reduces the wheat production in Balochistan. Silicon supplementation can overcome the salinity problem. Production of wheat can be improved by using marginal lands and these salt affected areas by silicon supplementation and improved fertilizers.

It is evident that silicon is valuable for growth of crops in many abiotic (drought, salt and metal toxicity) and biotic (pests and plant diseases) stresses (Liang *et al*., 2001; Ma *et al*., 2001). Wheat is a silicon accumulator that can alleviate the salinity damage by conserving plant's water position, better Na: K ratio and improving plant's resistance to diseases. Different silicon sources have been used by researchers among which sodium silicate has been found very helpful in improving growth parameters in drought and salt stress in wheat (Mecfel *et al*., 2007) (Hameed *et al*., 2013). Calcium silicate has been reported to increase number of tillers, number of grains per spike, grain yield, and biological yield (Ali *et al*., 2009). Silicon potassium metasilicate (K_2SiO_3) maintained water potential significantly in plants under drought stress (Ahmad *et al*., 2015). Silica gel enhanced some growth parameters like proline, relative water content, spike length, biological and grain yield (Ahmed *et al*., 2016). Silicon supplementation significantly increased the plants ability to withstand water deficit conditions through increased silicon uptake, most effective was foliar spray applied at tillering stage (Bukhari *et al*., 2015).

Water stress causes significant reduction in vegetative growth, yield and yield components of wheat varieties (Mirbahar *et al*., 2009), however, by using controlled release of fertilizers growth and yield could have been improved (Li *et al*., 2014). Controlled release fertilizers are getting great attention today due to their promising nature of water and nutrient management. It is need of the time to increase fertilizer efficiency by developing controlled release fertilizers and using silica nanoparticles that can help to increase production of wheat in drought and saline environments. The present study is carried out to see the effect of controlled release fertilizer containing silica nanoparticles in drought and saline environments in order to increase the production of wheat in Balochistan.

Materials and Methods

A factorial experiment was designed in hydroponics to investigate the effect of silicon sources like sodium silicate (Na_2SiO_3), silicic acid (H_4SiO_4) and silica nanoparticles (SiO_2 Nps) onthe growth of wheat genotypes. Silica nanoparticles (SiO_2Nps) have been synthesized by the modified Stober method using tetraethylorthosilicate as a precursor (Mushtaq *et al*., 2017). A CRF encapsulating SiO_2 Nps and ¼ Hoagland nutrients was synthesized

(Mushtaq *et al*., 2018), and used in this study to compare the nutrient availability to wheat plants by simple Hoagland nutrient solution and by CRF.

The CRF beads (T1 & T2) were placed in the Hydroponic tanks once in the beginning as they were capable of releasing the nutrients slowly till end. While for other treatments (T3 –T5) silicon sources (0.1g/Liter) were added in ¼ Hoagland's solutions and was changed fortnightly (Table 1). All the study was carried out in a growth chamber with controlled light and temperature conditions (day/night about 25/18ºC) and the pH was maintained at 6.3. Seeds of four selected wheat varieties (Umeed, Raskoh, Zarghoon and Shahkar) obtained from Agriculture Research Institute (ARI), Quetta, were sterilized by Mercuric chloride 1% for few minutes and were sown on filter paper, incubated at 25ºC and the final germination percentage (FGP) was calculated after five days using this formula.

Table 1. Different treatments used in hydroponics.

Treatment No.	Treatments
Control	Control (Hoagland's solution)
T1	CRF beads encapsulating Hoagland's nutrients
T2	CRF beads of Hoagland's nutrients + Silica Nanoparticles
T3	Hoagland's solution + Silica Nanoparticles
T4	Hoagland's solution + Sodium silicate
T5	Hoagland's solution + Silicic Acid

Table.1. Wheat grown in Hydroponic under these treatments (in saline and non-saline environments)

$$\text{FGP} = \frac{\text{Number of seeds germinated on the final day X 100}}{\text{Total Number of seeds sown}}$$

After ten days the young seedlings were transferred to the hydroponic tanks that were aerated through air pumps throughout the experiment. Plants were placed in holes on styrofoam sheet floating on the water. When third leaf appeared then 100 mM NaCl was incremented slowly and the wheat plants were harvested 30 days after this treatment. Data was recorded for final germination percentage, root length, shoot length, fresh weight of plant, dry weight of plant, chlorophyll content and TDS. The recorded data was subjected to analysis of variance and means were compared using least significant differences using standard statistical software SPSS (Version 20).

Results and Discussion

The beneficial role of silicon in salt stress was explored in the beginning of this century. It has been found that the silicon accumulator species grow better in the presence of silicon (Broadley *et al*., 2011; Hajiboland *et al*., 2016). Significant effects of silicon have been reported in wheat that is a silicon accumulator (Ahmed *et al*., 2013; Anser Ali *et al*., 2012; Saqib *et al*., 2008; Tahir *et al*., 2006; Tuna *et al*., 2008).

Silicon supplementation in rice, wheat, oats and sorghum led to increase the leaf and root growths when compared to the control plants, it may be due to increase in the cell wall extensibility in the apical regions (Hattori *et al*., 2003; Hossain *et al*., 2002). Silicon increased growth and yield due to decreased sodium uptake in wheat under saline environments (Tahir *et al*., 2006). Salicylic acid seed priming improved germination, chlorophyll content, soluble sugars, proteins and phenolic contents in wheat (Sultana *et al*., 2019). As Silicon supplementation is proved to increase salinity tolerance as well as to improve production of wheat therefore, silica nanoparticles can also be used to increase silica availability in wheat that is under salinity stress and silica nanoparticless might give better results due to their nano size. The ultrasonication assisted modified Stober method produced spherical silica nanoparticles ranging from 50 nm to 100 nm (Mushtaq *et al*., 2017). In the present study silica nanoparticles were used for the first time to control salinity in wheat and were found to improve the growth of wheat cultivars of Balochistan. The mean values of all the growth parameters of three replicates of each genotype under five treatments and control (Table 2) in Non-saline (NaCl=0mM) and saline (NaCl=100mM) environments showed significant differences to compete salinity under different silicon sources. The two wheat genotypes Umeed and Raskoh were found to be resistant to the salt stress while Zarghoon and Shahkar were susceptible to the salt stress. The final germination percentage (FGP) after five days in the four wheat genotypes was Raskoh 70% > Umeed 69 % > Zarghoon 68% > Shahkar 64%.

All the growth parameters were found to be affected by 100mM salt stress in control while the plants survived better in CRF, sodium silicate and silica nanoparticles treatments. All the results were found statistically significant at 0.05 level (Table 3). The Mean values of all the growth parameters with SE (Standard Error) are represented as bar graphs. The length of root was found to be higher than the control in the plants under CRF (Fig. 1). Although the silicon sources increased the root length to some extent, except the silica nanoparticles, which showed a significant increase in the root length. Our results agreed with the experiments (Anser Ali *et al*., 2009) on silicon optimization for wheat, in which shoot growth was improved but the root growth was not significantly affected by silicon application. However, shoot length was significantly improved (Fig. 2) in this order SiO_2Nps>sodium silicate >silicic acid while remarkably increased by using CRF. The results are in agreement with the findings of (Kalteh *et al*., 2014) who demonstrated that shoot height and weight were increased by silica nanoparticles.

Fresh weight of the whole plant after one month (Fig. 3), showed highest values for the control and the CRF in the non-saline environment. Fresh weight was dropped remarkably when salt stress of 100mM was applied in the control while silicon sources were found to improve the fresh weight of plants in the saline environments. Dry weight was also dropped significantly in the saline environment (Fig. 4). Less differences in the dry weight existed among all other treatments except silica nanoparticles and sodium silicate that had higher values of dry weight. Silica nanoparticles had similarly improved seed germination, seedling fresh and dry weight of tomato and can be effective for crop improvement if used in fertilizers (Siddiqui & Al-Whaibi, 2014).

Table. 2. Mean values of three replicates for each variety under different treatment.

Treatments	Varieties	Results of hydroponic experiment									
		Non-saline (NaCl=0 mM)					Saline (NaCl=100 mM)				
		Root length (cm)	Shoot length (cm)	Fresh weight (g)	Dry weight (g)	Chlorophyll contents (units)	Root length (cm)	Shoot length (cm)	Fresh weight (g)	Dry weight (g)	Chlorophyll contents (units)
Control	Umeed	21.0	34.0	4.5	1.1	1.15	14.0	26.0	2.8	0.9	0.99
	Raskoh	20.0	33.3	4.5	1.1	1.13	15.0	26.7	3.0	0.9	1.01
	Zarghoon	20.0	32.7	4.0	0.9	1.07	12.0	23.7	2.3	0.7	0.64
	Shahkar	20.0	33.0	4.0	0.8	1.10	12.0	24.0	2.4	0.8	0.74
Mean		20.3	33.3	4.2	1.0	1.1	13.3	25.1	2.6	0.8	0.8
T 1	Umeed	21.0	33.0	4.2	1.1	1.19	19.7	30.0	3.8	0.9	1.11
	Raskoh	21.0	32.0	4.2	1.0	1.18	20.0	30.3	3.8	1.0	1.15
	Zarghoon	20.0	32.0	4.0	0.9	1.01	17.0	29.0	2.5	0.8	0.77
	Shahkar	20.7	32.0	4.1	0.9	1.04	19.0	29.3	3.4	0.8	0.95
Mean		20.7	32.3	4.1	1.0	1.1	18.9	29.7	3.4	0.9	1.0
T 2	Umeed	20.3	33.3	4.2	1.1	1.15	20.0	33.0	4.3	1.2	1.16
	Raskoh	21.0	32.3	4.2	1.1	1.15	21.0	33.0	4.4	1.2	1.20
	Zarghoon	20.0	32.0	4.1	1.0	1.10	19.0	31.0	4.1	0.8	0.96
	Shahkar	19.7	31.7	4.1	0.9	1.12	19.0	32.0	3.8	0.8	1.06
Mean		20.3	32.3	4.2	1.0	1.1	19.8	32.3	4.1	1.0	1.1
T3	Umeed	20.0	31.0	4.0	1.0	1.10	20.0	30.7	3.7	0.9	1.08
	Raskoh	20.0	30.3	4.0	0.9	1.20	21.0	31.0	3.8	0.9	1.12
	Zarghoon	20.0	29.0	4.0	0.9	1.10	18.0	29.0	3.5	0.8	1.03
	Shahkar	20.0	29.7	4.0	0.9	1.10	19.0	29.3	3.6	0.9	1.09
Mean		20.0	30.0	4.0	0.9	1.1	19.5	30.0	3.7	0.9	1.1
T 4	Umeed	14.7	26.0	3.3	0.8	0.88	14.0	27.0	3.0	0.9	0.93
	Raskoh	15.7	24.0	4.1	0.8	0.91	15.0	25.0	4.2	0.9	0.99
	Zarghoon	10.0	19.0	2.4	0.7	0.51	10.0	21.0	2.8	0.7	0.79
	Shahkar	14.3	24.0	3.1	0.8	0.61	14.7	25.0	3.1	0.8	0.87
Mean		13.7	23.3	3.2	0.8	0.7	13.4	24.5	3.3	0.8	0.9
T5	Umeed	11.7	19.0	3.2	0.8	0.71	11.3	21.0	3.4	0.8	0.89
	Raskoh	11.0	21.0	2.1	0.8	0.62	11.7	24.0	2.6	0.8	0.88
	Zarghoon	10.0	20.0	3.0	0.7	0.45	9.0	21.0	3.0	0.7	0.79
	Shahkar	10.0	23.5	2.9	0.7	0.54	10.0	24.0	2.3	0.7	0.86
Mean		10.7	20.9	2.8	0.7	0.6	10.5	22.5	2.8	0.8	0.86

Table. 3. Statistical Analysis and ANOVA with (LSD) showing significance of results among treatments.

Growth parameters	Means and ANOVA					
	Significance of Means and ANOVA					
	Minimum	Maximum	Mean	Std. Error	Std. Dev.	Significance level
Root length	10.00	21.00	17.59	0.84	4.14	0.000**
Root length (Saline)	9.00	21.00	15.89	0.80	3.94	0.000**
Shoot length	19.00	34.00	28.66	1.04	5.11	0.000**
Shoot length (Saline)	21.00	33.00	27.33	0.78	3.81	0.000**
Fresh weight	2.10	4.50	3.76	0.13	0.65	0.000**
Fresh weight (Saline)	2.30	4.40	3.32	0.13	0.65	0.002**
Dry weight	0.70	1.10	0.90	0.03	0.13	0.001**
Dry weight (Saline)	0.70	1.20	0.86	0.03	0.13	0.142
Chlorophyll content	0.45	1.20	0.96	0.05	0.25	0.000**
Chlorophyll content (Saline)	0.49	1.20	0.96	0.04	0.22	0.001**

**The mean differences among treatments are significant at 0.05 level

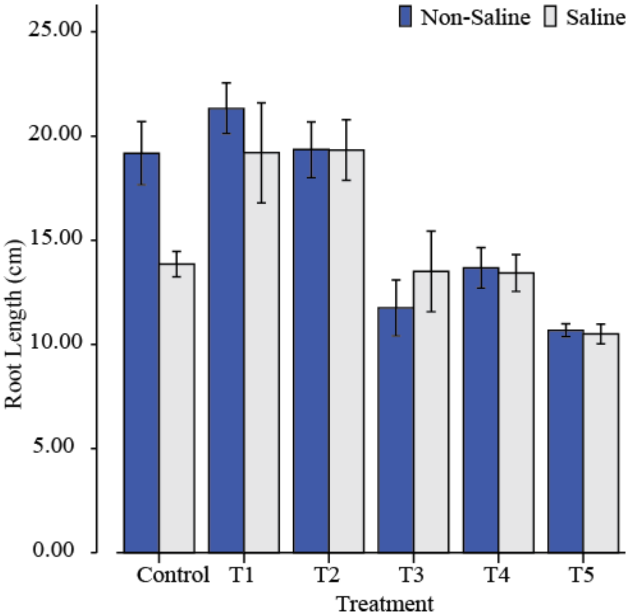

Fig. 1. Effect of different siliconsources (T3-T5) and CRF (T1&T2) on Root length of wheatgenotypes.

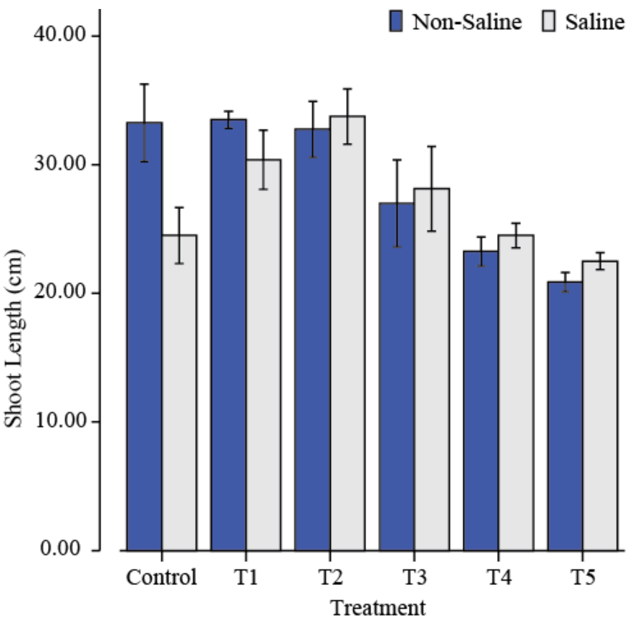

Fig. 2. Effect of different silicon sources (T3-T5) and CRF (T1 & T2) on Shoot length of wheat genotypes.

A study was carried out in hydroponics to observe the effect of sodium silicate, silicic acid, micro silica and nano silicon dioxide on maize. The germination percentage was observed highest (95.5%) by silica nanoparticles application whereas it was reduced (75-77%) by sodium silicate application and no significant differences were observed by microsilica and silicic acid application. Highest root length 168 mm was found by silica nanoparticles, 150 mm in sodium silicate and 162 mm in silicic acid as compared to 145 mm in control (Suriyaprabha *et al*., 2012). Priming of wheat seeds by silica nanoparticles has also been found to increase germination percentage and all the growth parameters under salt stress(Mushtaq *et al*., 2017).

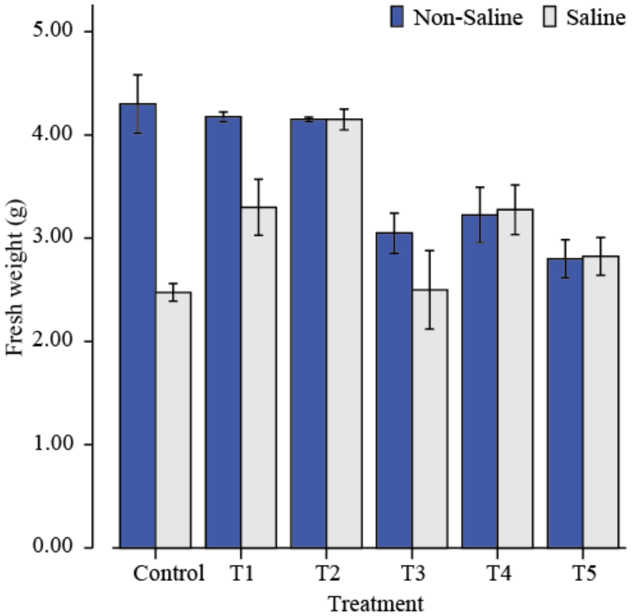

Fig. 3. Effect of different silicon sources (T3-T5) and CRF (T1 & T2) on Fresh Weight of wheat genotypes.

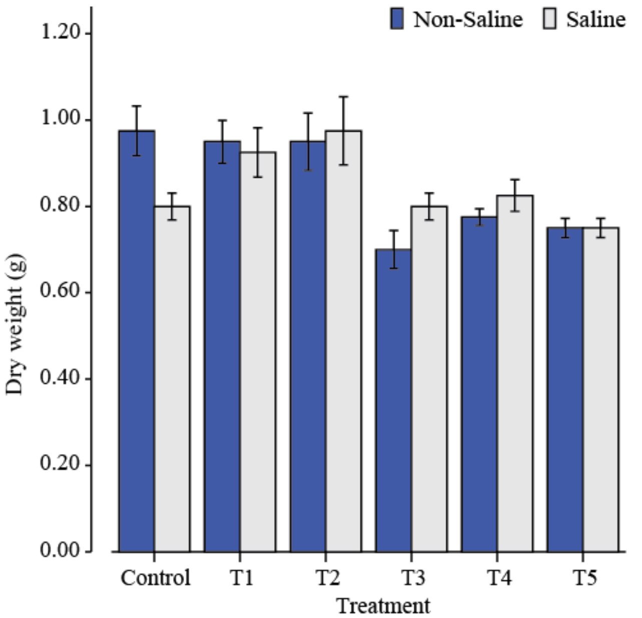

Fig. 4. Effect of different silicon sources (T3-T5) and CRF (T1 & T2) on Dry Weight of wheat genotypes.

In present study the root length was increased from 13.3 cm in control (saline) to 19.8 cm in silica nanoparticles and was found 13.4 cm insodium silicate treatments under salt stress of 100mM. While significant increase in shoot length from 25.1 cm (control with salt stress) to 30.5 cm (silica nanoparticles) was observed. Although there was a remarkable increase in fresh weight from 2.6 g(control) < 2.8 g (silicic acid) < 3.3 g (sodium silicate) < 3.7 g (SiO_2 Nps) and the dry weight was increased from 0.80 g (control) <0.82 g(sodium silicate) and 0.9 g (SiO_2 Nps) treatment in saline environment. The chlorophyll content was also increased similarly from 0.8 units (control) < 0.90 units (sodium silicate) and 1.10 units (SiO_2 Nps) in saline environment (Table 2).

The chlorophyll contents of wheat plants was found highest in the controlled release fertilizer of Hoagland nutrients (T1) and Hoagland solution (control) in non-saline environments (Fig. 5). Although all the silicon sources have improved the chlorophyll content in the saline environments as compared to the control with 100mM NaCl but higher chlorophyll contents appeared in the plants with SiO_2 Nps (T3) followed by sodium silicate (T4) and it has been reported prior that sodium silicate increased the leaf contents of chlorophyll in wheat (Hajiboland *et al*., 2016).

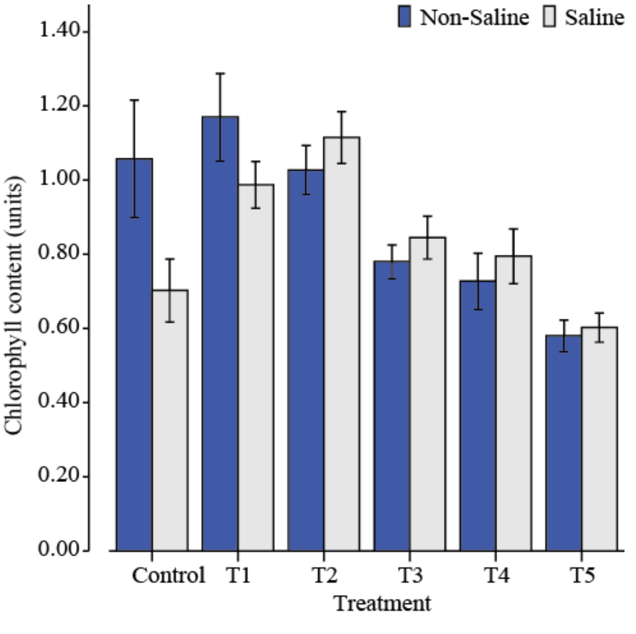

Fig. 5. Effect of different silicon sources (T3-T5) and CRF (T1 & T2) on Chlorophyll Contents of wheat.

Overall the highest results were achieved using silica nanoparticles as the nano sized particles were efficiently available to wheat plants to mitigate the effect of salt stress. The significant results of SiO_2 Nps were in agreement with increment in germination percentage and seedling growth by plants under salinity stress. Our results of increment in germination, percentage of seedling growth were in agreement with the findings on the plants as growing under saline stress of previous workers (Siddiqui & Al-Whaibi, 2014; Suriyaprabha *et al*., 2012) (Sabaghnia & Janmohammadi, 2015). Moreover sodium silicate treatment reduced the salinity stress in wheat, that coincide with the improvement in the germination and growth parameters, activities of antioxidant enzymes in drought stress in wheat by sodium silicate (Mecfel *et al*., 2007; Pei *et al*., 2010). Whereas in our study among all the silicon sources (0.1 %) the least results were produced for silicic acid that may be due to higher concentration of silicic acid in water in hydroponic environment as it has been reported prior that silicic acid (0.25 and 0.5%) had positive effect on the growth of wheat while higher than 0.75% was un-advantageous and reduced the growth and yield in wheat grown in the soil (Abro *et al*., 2009). Overall among all the silicon sources the efficiency to compete salt stress was silica nanoparticles>sodium silicate >silicic acid.

In current study positive results were achieved using Controlled release fertilizers (CRF). Highest values of root & shoot length, fresh & dry weight and chlorophyll contents were achieved using simple CRF (T1) in Non-saline environment although it decreased under the saline environment. Whereas higher values of growth parameters did not decline in CRF containing silica nanoparticles (T2) and persisted well in the saline environments. Therefore, by using SiO_2 Nps in CRF higher values of all the growth parameters appeared in the saline rather than non-saline environment, which proved the beneficial role of silica nanoparticles in controlling salinity in the wheat grown under salt stress of 100 mM.The best results were achieved using controlled release fertilizers (CRF) because they released the nutrients slowly and gradually. The TDS record (Figs. 6 & 7) showed a comparison of release of nutrients in different treatment in saline and non-saline environments. It could be concluded that nutrient release in both cases (T1 & T2) from controlled release fertilizer was very slow and consistent and kept increasing till the end of the month while different silicon sources and control showed an abrupt increase in TDS which gradually fell down by the end of the month. As CRF can withhold large amounts of water and is capable of releasing the nutrients slowly, so CRF can help plants to tolerate water deficit conditions in Balochistan. CRF with silica nanoparticles can be very beneficial and ideal for the improvement of wheat growth in saline and water deficient areas of Balochistan.

The beneficial effect of controlled release fertilizers in recent research activities has increased their popularity and demand in the agriculture. The significant effect of controlled release fertilizer has been observed over the conventional fertilizers on the growth and yield of winter wheat in which the number of tillers and roots have increased significantly by using CRF and CRF along with conventional fertilizer as compared to the use of conventional fertilizers only (Li *et al*., 2014).

Conclusion

The results of the present study concluded thatsilicon sources were found efficient in order silica nanoparticles > sodium silicate > silicic acid, to improve the growth of plants in saline environments. While best results were achieved using CRF and CRF encapsulating silica nanoparticles. Therefore, SiO_2 Nps and the CRF containing SiO_2 Nps can be an alternative to improve crop growth and yield under salinity stress. CRF with silicon supplementation can improve the fertilizer’s efficiency to compete water deficit and saline conditions and can be useful for increasing growth of salt tolerant wheat varieties in the marginal areas of Pakistan.

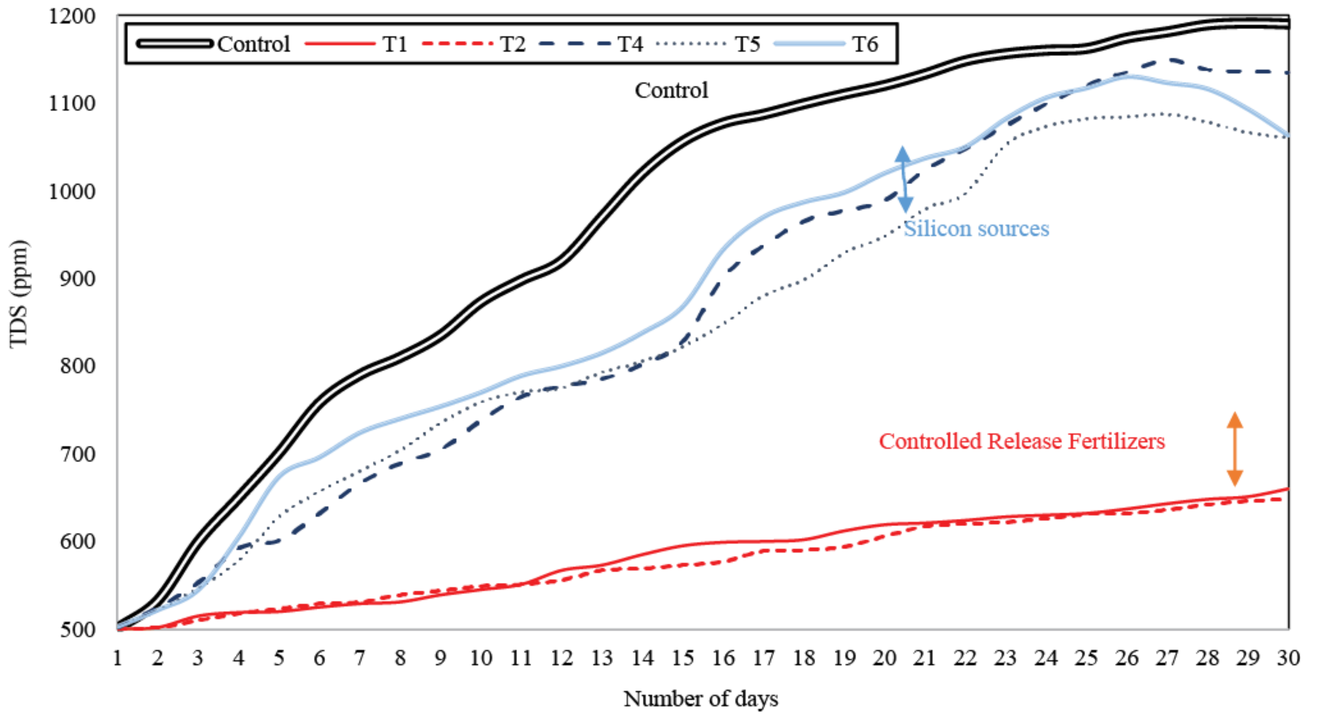

Fig. 6. Comparison of nutrients availibilty in different treatmentin Non-saline environment.

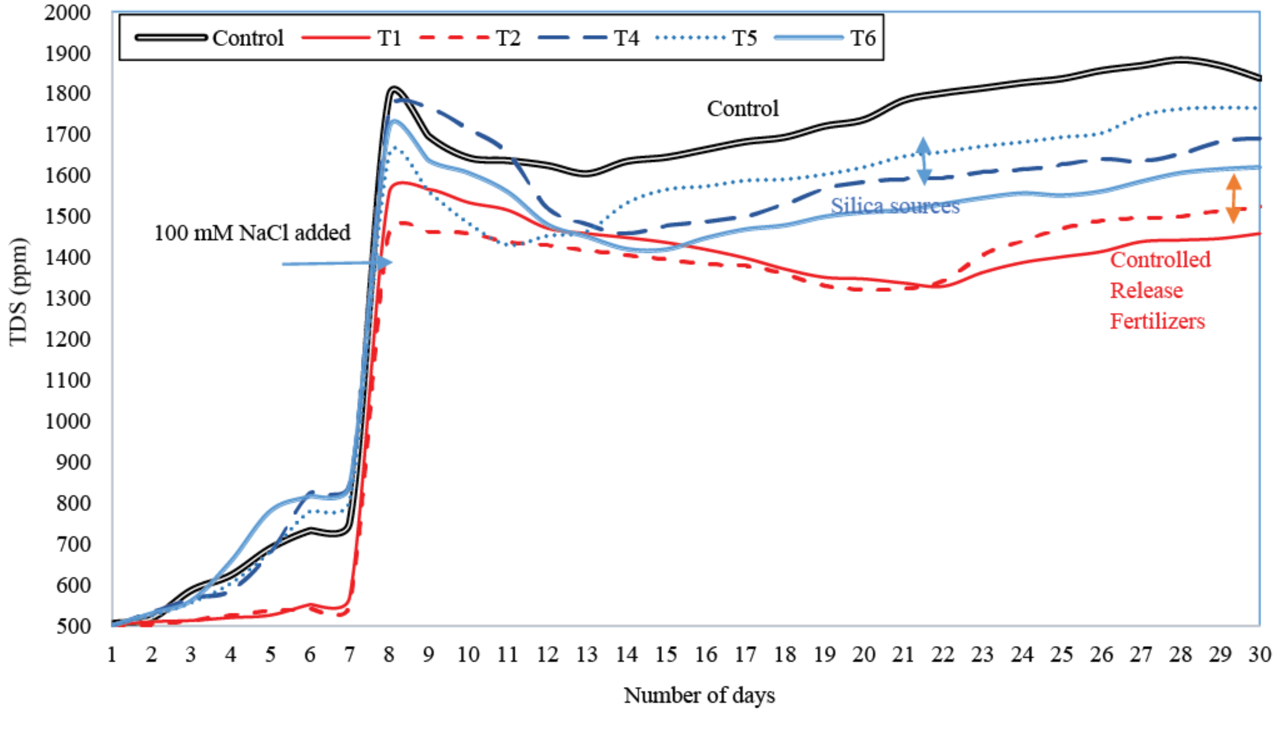

Fig. 7. Comparison of nutrients availibilty in different treatment in Saline environment.

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