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Influence of Silicon on Alleviation of Salinity Effect in Rice

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ABSTRACT

A pot culture experiment was conducted to study the influence of silicon on alleviation of salinity on rice during *kharif,* 2016 at Saline Water Scheme, Agricultural College Farm, Bapatla. In this study soils of similar characteristics but variable salinity (2,5 and 10 dS m^{-1} of ECe) were collected from Nizampatnam were tested along with four different sources of silica *viz.,* potassium silicate, calcium silicate, paddy straw, paddy husk and one control (no silica) treatment in a split plot design with three replications. In this experiment salinity levels were taken as a main plots whereas silica sources taken in sub plots. Significant influence of salinity levels was observed on yield attributes, yield and nutrient uptake of rice crop. The data pertaining to grain yield revealed a significant influence of soil salinity levels and source of silica. The maximum grain yield (15.66 g $plant^{-1}$) was observed at a salinity level of 2 dS m^{-1} and it was significantly superior to rest of tha salinity levels. Among different sources of silica, potassium silicate recorded significantly higher grain yield (14.69 g $plant^{-1}$) as compared to no silica treatment (10.9 g $plant^{-1}$). The highest grain yield (16.67 g $plant^{-1}$) was recorded in treatment combination of potassium silicate with a salinity level of 2 dS m^{-1}.

Keywords: *Pot culture, Rice, Salinity and Silicon*.

Salinity is one of the major factor limiting crop growth and productivity in irrigated areas of the world. Living with salinity is the only way for sustaining agricultural production in the salt affected soil. Oxidative damage induced by salt may be alleviated by Si addition (Ahmad *et al.,* 1992). Silicon application to the plants under salt stress limits the transpiration ratio and increases root activities. Decrease in transpiration lead to reduced osmotic stresses in plant cells and improved the root activity. As a consequence of increased root activities, plants can increase the nutrients uptake and decrease salt toxicity. Silicon absorption by plants leads to increased ATPase activities in vacuoles, which reduces Na^{+} uptake and enhances K uptake by the cell membrane. Separation of salt ions into the vacuoles and increasing the K/Na ratio in the cells of the roots and leaves decrease Na toxicity (Liang *et al*., 2003).

The beneficial effect of Si under salt stress has been observed in barley (Liang *et al*., 2006), rice (Yeo *et al.,* 2009) and wheat (Ahmad *et al*., 2011). The Na concentration in the shoot decreased to about half by Si addition. This function of Si may be ascribed to the Si-induced decrease in transpiration which lead to the partial blockage of the transpirational bypass flow pathway by which a large proportion of the uptake of Na in rice occurs (Yeo *et al*., 2009). Si increase the leaf superoxide dismutase activity and suppresses the lipid peroxidation caused by salt stress and stimulate the root H^{+}-ATPase in the membranes, further, Si may affect the structure, integrity and functions of plasma membranes by influencing the stress-dependent peroxidation of membrane lipids (Yin *et al.,* 2016). The present study was carried out to evaluate the rice crop performance through different sources of silica in different soil salinity levels.

MATERIAL AND METHODS

The experiment was conducted at Saline Water Scheme, Agricultural College Farm, Bapatla during *kharif* 2016. In this study soils with similar characteristics but variable salinity (2, 5 and 10 dS m^{-1} of ECe) collected from Nizampatnam were tested along with four different sources of silica *viz.,* potassium silicate, calcium silicate, paddy straw, paddy husk and one control (no silica) treatment in a split plot design and replicated thrice. In this experiment salinity levels taken as a main treatments and silica sources taken as a sub treatments. Nitrogen, phosphorus and potassium were applied throug urea, single super phosphate and murate of potash, respectively. Recommended agronomic management practices and plant protection measures were followed during crop growth. The EC was estimated by conductivity meter. The data recorded were analyzed following standard statistical analysis of variance procedure.

RESULTS AND DISCUSSION

Plant height

Plant height was significantly affected by soil salinity. Maximum plant height (69.3 cm) was obtained at salinity level of 2 dS m^{-1} and the lowest plant height (57.0 cm) was observed at salinity level of 10 dS m^{-1}.

With regard to silica sources potassium silicate application recorded the highest plant height (64.8 cm) whereas the lowest plant height (59.8cm) was recorded in paddy husk treatment. This may be attributed to the fact that silicon might increased the erectness of leaves, thereby increased photosynthetic capacity leading to higher plant height (Fallah, 2012).

Drymatter accumulation

In different soil salinity levels, with increase in soil salinity drymatter accumulation was decreased drastically. At 10 dS m^{-1} soil salinity the lowest drymatter was accumulated (14.98g $plant^{-1}$) as compared to 5 dS m^{-1} and 2 dS m^{-1} soil salinity. High salinity levels reduced the nutrient availability to the plant and accumulate osmotic affect in the root zone. Silicon application through different sources showed significant differences in drymatter accumulation. Among different sources of silicon, potassium silicate recorded the highest drymatter (24.06 g $plant^{-1}$) when compared to all other silicon sources. The lowest drymatter accumulation was recorded in control treatment (13.06 g $plant^{-1}$). The accumulation of silicon in plant parts reduced the lodging and enhanced the resistance against biotic and abiotic stress. The application of silicon enhanced photosynthetic activity, water and nutrient use efficiency, which ultimately results into better vegetative growth. The higher straw yield was mainly associated with increased plant height and number of tillers $hill^{-1}$. These results are in conformity with the findings of Patil (2013).

The highest dry matter accumulation (29.07 g $plant^{-1}$) was recorded in combination of potassium silicate at 2 dS m^{-1}, whereas the lowest dry matter production of 10.23 g plant $^{-1}$ was observed in treatment combination of no silica application at 10 dS m^{-1}. Increase in levels of soil salinity progressively reduced the quantity of dry matter produced.

Grain yield

Significant differences were noticed among different EC levels of soils and different sources of silican applied to the paddy crop. In paddy crop the treatment of 2 dS m^{-1} recorded the maximum grain yield (15.66g $plant^{-1}$) followed by 5 dS m^{-1}. However, minimum grain yield (8.21g $plant^{-1}$) was recorded at soil salinity level of 10 EC. In open field no yields were obtained at 10 dS m-^{1} salinity level but it is a pot culture experiment and irrigated with good quality water resulted in minimum yields. Among different sources of silica, potassium silicate treatment recorded significantly higher grain yield (14.69g $plant^{-1}$) and yield attributing characters when compared to control treatment (10.9 g $plant^{-1}$) and it was found to be on par with calcium silicate application treatment. More grain yield and biomass accumulation under salt stress conditions showed beneficial effects due to introduction of silicate in growth environment which was in lines with the findings of Al-aghabary *et al.* (2004) and Mukkram *et al.* (2011) who observed beneficial impact of Si application on chlorophyll quantity and antioxidative enzyme system of tomato and wheat plants grown under salt stress environment.

Straw yield

The data indicated that significant difference was observed in soil salinity levels and different sources of silica but there was no significant difference was observed in interaction. Maximum straw yields (21.05 g $plant^{-1}$) was recorded with 2 dS m^{-1} soil salinity level and minimum straw yield (13.27 g $plant^{-1}$) was recorded with 10 dS m^{-1} soil salinity level. Among different sources of silicon, potassium silicate treatment recorded significantly higher straw yield (20.98 g $plant^{-1}$**)** when compared to control treatment and it was on par with calcium silicate application treatment (20.58 g $plant^{-1}$).

Sodium uptake

Sodium uptake in grain and straw increased with increase in soil salinity levels. The highest sodium uptake was recorded both in grain (43.88 mg $plant^{-1}$) and straw (161mg $plant^{-1}$) at 10 dS m^{-1} soil salinity level. In case of different sources of silica application potassium silicate recorded the lowest sodium uptake in grains of 30.89 mg $plant^{-1}$ and in straw of 87.3 mg $plant^{-1}$ when compared to all other treatments. Sodium uptake was high in control treatment both in grain and straw of paddy crop.

The data on interaction indicated that, the treatment combination of potassium silicate treatment at 2 dS m^{-1} recorded the lowest sodium uptake (68.3 mg $plant^{-1}$). The highest sodium uptake was recorded in the treatment combination of paddy husk treatment at 10dS m^{-1} (286 3 mg $plant^{-1}$).

Potassium uptake

Significantly the highest potassium uptake was observed at 2 dS m^{-1} soil salinity level both in grain (90.47 mg $plant^{-1}$) and straw (548 mg $plant^{-1}$) of paddy crop when compared to 10 dS m^{-1} soil salinity. Among different silica sources, the highest potassium uptake was observed in potassium silicate followed by calcium silicate application and the lowest potassium uptake was observed in control plot both in grain and straw. The application of silicon significantly increased the potassium uptake by rice plants. The positive response of higher silicon application towards uptake of potassium can be linked to silicification process of cell walls. Increased in the potassium uptake possibly might

Table 1. Effect of different soil salinity levels and sources of silica nutrient on plant height and drymatter accumulation of paddy.

Main treatments	Plant height(cm)	Dry matter accumulation (g plant^{-1})
Salinity levels of soil		
EC-2dS m^{-1}	69.3	23.13
EC-5dS m^{-1}	62.2	21.61
EC-10dS m^{-1}	57	14.98
SEm+_	1.86	0.47
CD(0.05)	5.7	1.83
CV (%)	5.5	6.41
Sub treatments		
Control	62.41	13.06
Potassium silicate	64.8	24.06
Calcium silicate	63.8	22.26
Paddy straw	63.3	20.37
Paddy husk	59.8	19.8
SEm+_	2.8	0.64
CD(0.05)	NS	1.93
CV (%)	9.4	3.92
Interaction		
SEm+_	1.4	0.79
CD(0.05)	NS	2.31
CV (%)	4.2	3.37

Table 2. Effect of different soil salinity levels and sources of silica nutrient on drymatter accumulation of paddy

Silica sources	Salinity levels (dS m^{-1})			
	2	5	10	Mean
T_1- Control	14.74	14.2	10.23	13.06
T_2- Potassium silicate	29.07	26.09	17.03	24.06
T_3-Calcium silicate	25.61	24.49	16.68	22.26
T_4- Paddy straw	23.31	21.95	15.87	20.37
T_5-Paddy husk	22.92	21.34	15.13	19.8
Mean	23.13	21.61	14.98	
	SEm+_	CD (0.05)	CV (%)	
Salinity levels	0.47	1.83	6.91	
Silica sources	0.64	1.93	3.92	
Interaction	0.79	2.31	3.37	

Table 3. Effect of different soil salinity levels and sources of silica nutrient on grain yield and straw yield of paddy

Main treatments	Grain yield (g $plant^{-1}$)	Straw yield (g $plant^{-1}$)
Salinity levels of soil		
EC -2 dS m^{-1}	15.66	21.05
EC -5 dS m^{-1}	14.83	19.74
EC -10 dS m^{-1}	8.21	13.27
SEm+_	0.13	0.47
CD(0.05)	0.42	1.52
CV (%)	2.7	5.46
Sub treatments		
Control	10.9	12.05
Potassium silicate	14.69	20.98
Calcium silicate	13.64	20.58
Paddy straw	12.94	18.61
Paddy husk	12.33	17.91
SEm+_	0.53	0.69
CD(0.05)	1.59	2.09
CV (%)	4.65	6.12
Interaction		
SEm+_	0.65	0.85
CD(0.05)	NS	NS
CV (%)	5.8	5.2

Table 4. Effect of different soil salinity levels and sources of silica nutrient on sodium uptake in grain and straw of paddy

Main treatments	Na uptake in grain (mg $plant^{-1}$)	N Na uptake in straw (mg $plant^{-1}$)
Salinity levels of soil		
EC -2 dS m^{-1}	43.88	102.9
EC -5 dS m^{-1}	38.3	133.1
EC -10 dS m^{-1}	30.5	161
SEm+_	1.87	1.5
CD(0.05)	NS	4.7
CV (%)	4.61	4.5
Sub treatments		
Control	53.42	161.8
Potassium silicate	30.89	87.3
Calcium silicate	31.76	120.3
Paddy straw	37.39	136.2
Paddy husk	34.35	156.1
SEm+_	1.2	1.7
CD(0.05)	3.63	5.12
CV (%)	4.4	4.3
Interaction		
SEm+_	2.3	1.3
CD(0.05)	NS	4.2
CV (%)	4.4	4.9

Table 5. Sodium uptake in paddy straw as affected by different sources of silica

Silica sources	Salinity levels (dS m^{-1})			
	2	5	10	Mean
T_1- Control	131.3	250.3	102	161.8
T_2- Potassium silicate	68.3	95	97.6	87
T_3-Calcium silicate	104	122.6	134.3	120.3
T_4- Paddy straw	111.3	114	183.3	136.2
T_5-Paddy husk	99.6	79.3	286	156.1
Mean	102.9	133.1	161	
	SEm+_	CD(0.05)	CV (%)	
Silica sources	1.7	5.12	4.3	
Salinity levels	1.55	4.7	4.5	
Interaction	1.3	4.2	4.9	

Table 6. Effect of different soil salinity levels and sources of silica nutrient on potassium uptake in grain and straw of paddy

Treatments	K uptake in grain (mg $plant^{-1}$)	K uptake in straw (mg $plant^{-1}$)
Salinity levels of soil		
EC -2 dS m^{-1}	90.47	548.6
EC -5 dS m^{-1}	73.38	449.3
EC -10 dS m^{-1}	43.62	325.3
SEm+_	1.96	1.7
CD(0.05)	5.89	5.2
CV (%)	4.6	4.9
Sub treatments		
Control	55.45	264.4
Potassium silicate	76.47	592.2
Calcium silicate	75.11	512.2
Paddy straw	76.18	476.7
Paddy husk	62.58	360
SEm+_	1.8	1.9
CD(0.05)	5.43	5.74
CV (%)	4.8	4.2
Interaction		
SEm+_	2.12	2.6
CD(0.05)	NS	7.9
CV (%)	4.8	4.3

Table 7. Effect of different soil salinity levels and sources of silica nutrient on potassium uptake in paddy straw

Silica sources	Salinity levels (dS m^{-1})			
	2	5	10	Mean
T_1- Control	283.3	276.7	233.3	264.4
T_2- Potassium silicate	733.3	620.3	420	591.1
T_3-Calcium silicate	680	533.3	323.3	512.2
T_4- Paddy straw	616.7	466.7	346.6	476.7
T_5-Paddy husk	430	346.6	303.3	360
Mean	548.6	449.3	325.3	
	SEm+_	CD (0.05)	CV (%)	
Silica sources	1.9	5.7	4.2	
Salinity levels	1.7	5.2	4.9	
Interaction	2.6	7.9	4.3	

Table 8. Effect of different soil salinity levels and sources of silica nutrient on potassium / Sodium ratio in paddy

Main treatments	K/Na ratio in grain	K/Na ratio in straw
Salinity levels		
EC -2 dS m^{-1}	2.06	5.33
EC -5 dS m^{-1}	1.92	3.38
EC -10 dS m^{-1}	1.43	2.02
Sub treatments		
Control	1.04	1.63
Potassium silicate	2.48	6.78
Calcium silicate	2.36	4.26
Paddy straw	2.04	3.5
Paddy husk	1.82	2.31

be due to stimulating effect of silicon on activation of H+ATPase in the membrane. Similar results were also noticed by Singh *et al.* (2006) and Wader *et al.* (2013).

The interaction between salinity and silica sources indicated that, the maximum potassium uptake was attained in the combination of potassium silicate treatment at 2 dS m^{-1} (733.3 mg $plant^{-1}$) and the minimum potassium uptake (233.3 mg $plant^{-1}$) was obtained in combination of no silica treatment at 10 dS m^{-1}.

Potassium / sodium ratio

K / Na ratio observed in paddy crop revealed that at 2 dS m^{-1} soil salinity level recorded the highest ratio of K/Na ratio both in grain and straw of paddy crop. Among different sources of silica application, potassium silicate application recorded the highest K / Na ratio followed by calcium silicate.

CONCLUSION

Finally this experiment results revealed that application of silica through potassium silicate recorded significantly the highest growth, yield attributes, yield, lowest sodium uptake and highest potassium uptake of rice followed by calcium silicate application. Among different soil salinity levels 2 dS m^{-1} recorded the maximum yield attributes, yield, lowest sodium uptake and highest potassium uptake both grain and straw of paddy followed by 5 dS m^{-1}. However, minimum yield attributes, yield and highest sodium uptake and lowest potassium uptake was recorded at soil salinity level of 10 dS m^{-1}.

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