SI EFFECT ON THE PLANT RESISTANCE TO SALT TOXICITY

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Introduction

The total area of saline soils is 397 million ha (FAO, 2004). Of the current 230 million ha of irrigated land, 45 million ha are salt-affected soils (19.5 percent) and of the almost 1 500 million ha of dryland agriculture, 32 million are salt-affected soils (2.1 percent) to varying degrees the result of human-induced processes (FAO, 2004). Salt-affected lands are reflected as saline seeps in dryland agriculture and secondarily salinized irrigated lands. Globally more than 77 million ha of land is salt-affected by human-induced salinization (FAO, 2004).

Approximately 5.7 million hectares of farmland in Australia is now at high risk from dryland salinity, with the possibility that the figure could raise to 17.1 million hectares by the year 2050 (NLWRA, 2001). Approximately 2.5 million ha are affected by secondary salinization processes. Secondary salinity, resulting mostly from agricultural activities is predominantly caused by changes in groundwater patterns that result from increases in water accessions to aquifers. A change in the water balance underlies the expression of salinity problems in both dryland and irrigated soils. Depending on the soil structure, surface salinity problems occur when the watertable rises to within 1 to 2 m from the surface. Salinity problems are usually associated with waterlogging. In dryland soils, clearing of deep-rooted (perennial) native vegetation and replacement with shallow rooted (usually annual) crops has changed the patterns of water use. Because annual crops usually use less rainfall, excess water moves to deeper aquifers causing rise in the watertable level. In irrigated soils, rise in groundwater, due to increased applications of water for irrigation affect large areas of the Murray Darling Basin (Victoria, New South Wales, and small area in Tasmania) (Figure 1). At least 250 000 ha of irrigated land are presently affected. There is a potential for serious effects in a further 615 000 ha over the next 20 to 40 years (FAO, 2002).

Silicon (Si) is the second most abundant element of the earth surface. Silicon fertilization has a double effect on the soil-plant system. Firstly, improved plant Si nutrition reinforces plant protective properties against diseases, insect attack, and unfavorable climatic conditions. Secondly, soil treatment with biogeochemically active Si substances optimizes soil fertility through improved water, physical, and chemical soil properties and maintenance of nutrients in plant-available forms. The optimization of Si plant nutrition increases the plant resistance to both biotoc and abiotic stresses, include salt stress (Matichenkov *et al*., 2001). There are several hypothesis for this effect. They are (i) improved photosynthetic activity, (ii) enhanced K:Na selectivity ratio, (iii) increased enzyme activity, and (iv) increased concentration of soluble substances in the xylem, which results in reduced sodium adsorption by plants (Ahmad *et al*., 1992; Liang, 1999; Matichenkov *et al*., 2001).

The main aim of this investigation was investigation of mechanisms of active Si effect on the plant salt resistance.

Materials and Methods

Materials

The laboratory and greenhouse experiments were conducted in the Institute Physical-Chemical and Biological Problems, Soil Science Russian Academy of Sciences (Russia). The following Si-rich materials will be used in these experiments:

- Amorphous silicon dioxide (SiO_2) as chemically pure source of active Si;
- Zap-Sil (solid Si fertilizer, LTD “Iteren”, Moscow, Russia) as commercial Si fertilizer;
- Diatomaceous Earth (DE) (Natural Agricultural Solution, Pallkarra (Australia) as commercial Si fertilizer;
- Quick-Sol (liquid Si fertilizer, Product Plus Corporation, Miami, USA) as commercial liquid Si fertilizer..

The washed quartz sand was used for greenhouse experiments. Wheat (*Triticum aestivum* L.) or Barley (*Hordeum vulgare* L.) were used as test plant.

Experiment with Barley

Barley germination with solid and liquid forms of Si fertilizers was conducted under normal condition in “Petri” dishes. Barley seeds (30 per dish) were germinated in distilled water as control, in distilled water with SiO_2 (0.5 g per dish), with Zap-Sil (0.5 g per dish) or with DE, and with diluted solution of Quick-Sol (1000, 2000, 3000, 5000 and 10000) under salt stress (NaCl solution). All treatments were conducted with or without application of sodium silicate. The following final concentrations of Na were using for simulation of stress creation – 0.3, 0.6 and 1.2%. After 72 hours of germination the caleoptels (shoots) and roots height were measured and average for all seeds was calculated. The amount of survived germinated seeds was determined as well. Four replications for each treatment were conducted.

Experiment with Wheat

This experiment was conducted only with amorphous silicon dioxide, because commercial forms of active Si has other elements, which can be classify as nuisance parameters. Wheat seeds (5 seeds per pot) were grows in the washed sand in 1 kg volume pots. The treatments in the experiment were: control, 0.5 g Si and 1g Si as amorphous Si, per kg of soil with 0.3; 0.6; and 1.2 % NaCl in irrigated water. After 3 weeks of experiment, physiological parameters such as photosynthesis, respiration, and chlorophyll fluorescence were tested. Plants were harvested and weight of shoots and roots were measured as well.

Results and Discussion

Experiment with Barley

The effect of selected sources of Si on the germination of barley under salt stress is presented in the Table 1. The optimization of Si nutrition has a positive effect on the height of both roots and caleoptels with or without the presence of salt. In the control, the gradual increasing of salt concentration dramatically reduced the amount of surviving plant. Under the highest concentration of sodium chlorate, all plants in the control dishes died (Table 1). Solid or liquid forms of active Si increased the plant resistance to salt toxicity. The greatest effect was observed for DE. Without salt stress the application of Quick-Sol (any diluting) had a similar effect on the germinated barley. But the salt stress has demonstrated that the highest effect was obtained for Quick-Sol diluted by 2000 times (Table 1). The mechanism of active Si on plant under salt stress was not investigated in this study.

Experiment with Wheat

In our work, physiological response of salt-stressed wheat plants (*Triticum aestivum* L.) in the presence and absence of silicon in soil was studied under controlled conditions. Response to treatments was determined by analysis of growth parameters (leaf + stem and root dry matter content) (Table 2, 3). Growing of plants under salt stress led to decrease in photosynthesis rate from 6.4±0.4 to 0.4±0.1μmol g^{-1} s^{-1}. Adding of Si to the soil resulted in increasing rate of photosynthesis from 158 to 520% depending on salt concentration in the soil (Table 4). Chlorophyll fluorescence analysis and model parameters of photosynthesis indicated that Si enhances photochemical efficiency. Leaf and stem dry matter was depressed under salt stress but negative affect decreased by additional Si. So, the Si is beneficial in improving the photosynthesis and growth of wheat plants under high soil salinities.

Basically, plants as monosilicic acid or its anion absorb Si. In the plant tissue monosilicic acids can transforms to polysilicic acids, which are chemically inert. Consequently the stabilization of chlorophyll molecules under salt stress and optimization of Si plant nutrition can be occurs by monosilicic acid. The obtained data has demonstrated that monosilicic has direct influence on the biochemical processes in plant tissue. Considering high effect of active Si on the plant salt resistance (Table 1) and importance of this problem, it is necessary to activate investigations in this area.

References

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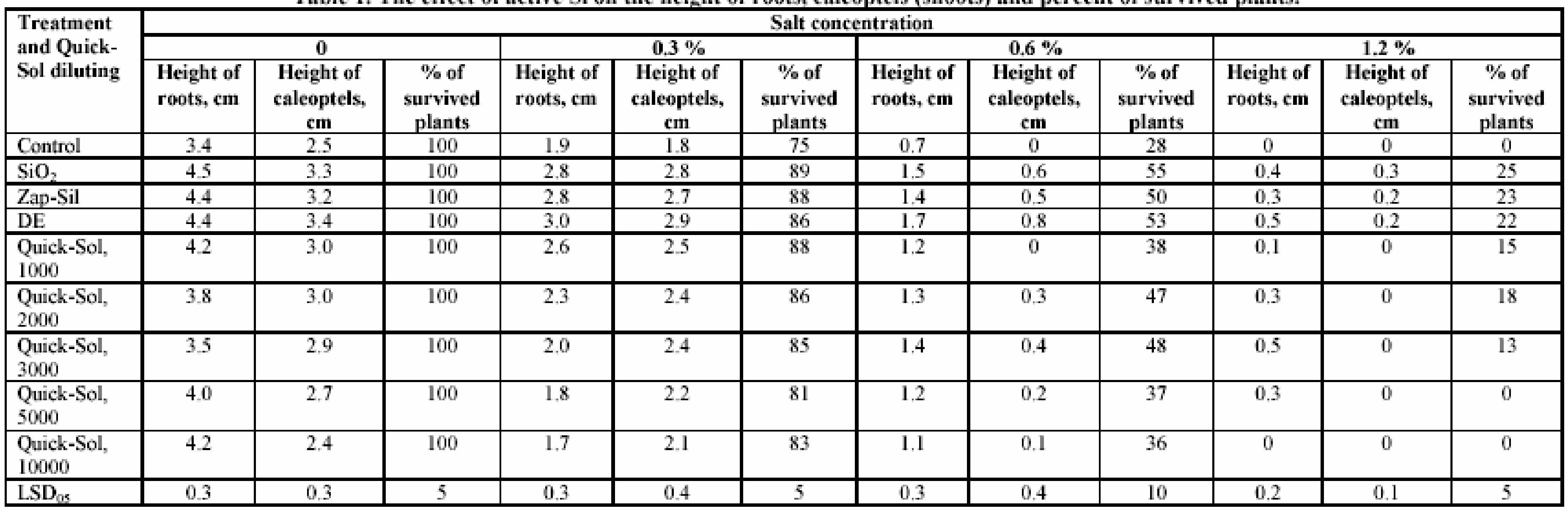
Table 1. The effect of active Si on the height of roots, caleoptels (shoots) and percent of survived plants.



Treatment and Quick-Sol diluting	Salt concentration											
	0			0.3 %			0.6 %			1.2 %		
	Height of roots, cm	Height of caleoptels, cm	% of survived plants	Height of roots, cm	Height of caleoptels, cm	% of survived plants	Height of roots, cm	Height of caleoptels, cm	% of survived plants	Height of roots, cm	Height of caleoptels, cm	% of survived plants
Control	3.4	2.5	100	1.9	1.8	75	0.7	0	28	0	0	0
SiO_2	4.5	3.3	100	2.8	2.8	89	1.5	0.6	55	0.4	0.3	25
Zap-Sil	4.4	3.2	100	2.8	2.7	88	1.4	0.5	50	0.3	0.2	23
DE	4.4	3.4	100	3.0	2.9	86	1.7	0.8	53	0.5	0.2	22
Quick-Sol, 1000	4.2	3.0	100	2.6	2.5	88	1.2	0	38	0.1	0	15
Quick-Sol, 2000	3.8	3.0	100	2.3	2.4	86	1.3	0.3	47	0.3	0	18
Quick-Sol, 3000	3.5	2.9	100	2.0	2.4	85	1.4	0.4	48	0.5	0	13
Quick-Sol, 5000	4.0	2.7	100	1.8	2.2	81	1.2	0.2	37	0.3	0	0
Quick-Sol, 10000	4.2	2.4	100	1.7	2.1	83	1.1	0.1	36	0	0	0
LSD_{05}	0.3	0.3	5	0.3	0.4	5	0.3	0.4	10	0.2	0.1	5

Table 2. Effect of active Si on the morphophysiological parameters of wheat

Salt concentration in the irrigation water, %	Control	0.5 g Si/kg	1 g Si/kg
Weight of shoots per pot			
0	2.40	2.40	2.34
0.3	1.96	2.15	1.75
0.6	1.26	1.66	1.5
1.2	0.64	1.15	0.95
Weight of roots per pot			
0	1.2	1.2	1.1
0.3	1.3	1.2	1.1
0.6	1.1	1.2	1.2
1.2	1.2	1.1	1.2
Photosynthesis			
0	6.42	4.97	N/t
0.3	2.26	2.78	N/t
0.6	0.65	1.98	N/t
1.2	0.35	1.41	N/t