Revista Agrarian
ISSN: 1984-2538

Aluminium silicate fertilization in the quality of wheat seeds under salt stress

Adubação com silicato de alumínio na qualidade de sementes de trigo sob estresse salino

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Recebido em: 24/07/2014 Aceito em: 07/10/2014

Abstract. Wheat is used as raw material in the production of several foods and it is the first cereal as in the world production of grains. However, the agricultural production is limited for the salinity effect in about 50% of irrigated areas in the world. An alternative to reduce the salt stresses caused in the plants is the silicon use. The objective of this study was to evaluate the fertilizing effect with aluminum silicate using kaolin as a source, on seed quality of wheat produced under salt stress. The experiment was accomplished in greenhouse using wheat seeds of Quartzo cultivar sowed in pots of 10 L containing soil and maintained until harvest. The kaolin (77.9% SiO_2) was applied in doses of 0 (control); 1,000; 2,000 and 3,000 kg ha^{-1}. Salt stress was simulated through irrigation with NaCl solutions in the concentrations of 0 (control), 8 and 16 mM. Agronomic characteristics and the physiologic seed quality were evaluated. The results showed that the salt irrigation caused decrease in the number of ears per plant, number of ears with seeds, in the weight of the ears without threshing and in the weight of the produced seeds. The aluminum silicate use increased the weight of a thousand seeds independent of the presence of salt stress. Silicon application contributed to increase the percentage of germination of the produced seeds when the plants were not exposed to the salt stress.

Keywords: kaolin, physiological quality, silicon, *Triticum aestivum* L.

Resumo. O trigo é usado como matéria-prima na fabricação de diversos alimentos e é o primeiro cereal quanto à produção mundial de grãos. No entanto, a produção agrícola se vê limitada pelo efeito da salinidade em cerca de 50% das áreas irrigadas no mundo. Uma alternativa para reduzir os estresses que os sais causam nas plantas é o uso do silício. O objetivo deste estudo foi avaliar o efeito da adubação com silicato de alumínio, usando como fonte o caulim, sobre a qualidade de sementes de trigo produzidas sob estresse salino. O experimento foi realizado em casa de vegetação utilizando sementes de trigo da cultivar Quartzo semeadas em vasos de 10 L contendo solo e levadas até colheita. O caulim (77,9% de SiO_2) foi aplicado em doses de 0 (controle); 1.000; 2.000 e 3.000 kg ha^{-1}. Para simular o estresse salino foi realizada a irrigação com soluções de NaCl nas concentrações de 0 (controle), 8 e 16 mM. Foram avaliadas as características agronômicas e a qualidade fisiológica das sementes. Os resultados mostraram que a irrigação salina causou diminuição do número de espigas por planta, número de espigas com sementes, no peso das espigas sem debulhar e no peso das sementes produzidas. O uso de silicato de alumínio aumentou o peso de mil sementes independente da existência ou não de estresse salino. A aplicação de silício contribuiu para aumentar a porcentagem de germinação das sementes produzidas quando as plantas não foram expostas ao estresse salino.

Palavras-chave: caulim, qualidade fisiológica, silício, *Triticum aestivum* L.

Introduction

Wheat (*Triticum aestivum* L.) is a cereal of *Poaceae* family that is used as raw material in the production of several foods. Among the cereals, wheat ranks first in world production of grains, and in the last season (2012/2013) more than 697 million tons were globally produced in about 220 million hectares (USDA, 2013a). In Brazil, the wheat production in the 2012/2013 harvest season was 4.4

millions of tons in an area of 1.9 millions of hectares (CONAB, 2013).

Although wheat cereal is produced in greater quantity in the world, grain production could be higher, since agricultural production is prevented by the effects of salinity on about 50% of irrigated areas in the world (USDA, 2013b). FAO (2006) estimates indicate that around 45 million hectares of irrigated land and 32 million of non-irrigated land in the world have problems caused by salts, a figure that increases each year by 1.5 million hectares on average.

Salt effects more common in plants are the reduction of the growth of these and several disturbances in the membranes permeability, water exchange, stomatal conductance, photosynthesis and ionic balance (Dias & Blanco, 2010). However, the ways as the salts affect the plants are discussed, due to the complexity of the salt stress. Thus, there are evidences that the stress caused by the salts and its effect in the plant depend on: the solution concentration in contact with the roots, the soil particle size, the place where the plants are exposed to the stress, the stage of plant development, the stress type, the stress duration and the interaction of this with other types of stresses, whether biotic or abiotic (Prisco & Enéas Filho, 2010).

There are several plant responses to salt stress, which depend largely of the species and cultivars. Nevertheless, all the plants can be classified in two major groups, depending on their tolerance level to salinity. The first one is denominated of halophytes plants, which are characterized by developing usually in environments with high salt concentrations. The second group is denominated of glycophyte plants which are normally the plants that fail to develop in salt environments. In general, the glycophyte plants show a reduction in its growth when the culture medium exceeds a salt concentration of 10 mM, depending on the species and cultivars (Willadino & Camera, 2010).

The great majority of the cultivated species, including wheat, are considered glycophyte plants. Thus several researches have accomplished studies to making possible the use of agricultural in areas with salinity problems, with emphasis in evaluation of species and cultivars under different levels of salt stress; creating new tolerant cultivars by the genetic breeding, and attempt methods of agronomic management with purpose of reducing salts excessive in the plants. Among these managements, there is the use of silicon.

The silicon use in the agriculture shows some benefits for the plants, such as the increase of the yield, tolerance to pest and disease attacks, decrease of toxic metals effects and tolerance to salt and water stress (Rodrigues et al., 2011). In the same way Dias & Blanco (2010), founded that silicon can bring certain benefits for the plants under salt stress, also the potassium and calcium, due the absorption of these elements that keep high K/Na relationships in the plant. However, it is not still clear as the silicon contributes exactly for the plants to increase their tolerance to the salt stress (Shi et al., 2013).

Some researchers have evaluated the effect of the silicon on cultivated plants under salt conditions, For example, Tahir et al. (2006) evaluated two wheat cultivars, one salt tolerant and the other not, and found that the intake of calcium silicate at 50 and 130 μg Si g^{-1} concentrations, was positive for seed yield and plant dry weight, both under normal or (EC soil 10 dS m^{-1}) stress conditions. Also, Ali et al. (2012) working with a wheat cultivar tolerant to salinity and other susceptible, grown in a soil with 2 dS m^{-1} (control) and 12 dS m^{-1} electrical conductivity, observed that the application of 150 mg Si per kg of soil increased grain yield even under normal or salinity conditions also observed that the Si keeps water potential and stomatal conductance of plants subjected to salt stress. Considering the above, it is necessary more studies to investigate the effect of this element in the production of seeds under salt stress. For this reason, this study aimed to evaluate the effect of the silicon, using aluminium silicate (kaolin) as source, about the production of wheat seeds cultivated under salt stress.

Material and Methods

The experiment was performed in a greenhouse being used pots (10 liters) containing soil (ALBAQUALF HAPLUSTULT Solodic Eutrophic) (Streck et al., 2008). The lime application and Nitrogen (N), Phosphorus (P) and Potassium (K) incorporation were made 15 days before the sowing. The liming and the fertilization were applied as the result of the soil analysis and the technical recommendation for wheat, applying in each pot 13.5 g of dolomitic limestone, 2.0 g of urea, 3.5 g simple superphosphate and 0.6 g of potassium chloride. At booting was administered 1.0 g of urea per pot in coverage. An amount of 12 wheat seeds (Quartzo cultivar) were sowed in each pot and 15 days after emergency a rough-hewing was accomplished leaving five plants for pot, which were maintained until the harvest.

Revista Agrarian
ISSN: 1984-2538

The experimental design was a completely randomized in a factorial 3 x 4 with four replications. The first factor was the salt stress, caused by the irrigation system, being administered 400 mL day^{-1} of sodium chloride (NaCl) solutions with 0 (control); 8 and 16 milimolar (mM) concentrations, per pot. The second factor was the fertilization with silicon in the sowing moment, being used as source the kaolin in growing doses of 0 (control); 1,000; 2,000 and 3,000 kg ha^{-1}, the dosages correspond to application of 0; 6.4; 12.8 e 19.2 grams of kaolin per pot, respectively. These quantities were calculated assuming that one hectare of plow layer of a wheat crop is around two million liters, the volume of each pot used in the experiment was 10 liters and that the chemical composition of kaolin used was 77.9% de SiO_2, 23.73% de Al_2O_3, 0.23% de CaO e 0.36% de K_2O.

The crop was manually harvested when more than three-quarters of the ears presented gold color, indicating the physiological maturity of the seeds. The ears were cut, packed in paper bags and dried in an oven with forced circulation of air until to reach 13% of moisture content. Then, the seeds were handy threshed. And in laboratory, some agronomic characteristics of the plants and physiological characteristics of the were determined according to the procedures described below:

Number of ears per plant: The total of ears harvest in each pot were counted and the value divided by five (number of plants for pot).

Number of ears with seeds per plant: It was also obtained through of the counting of the number of ears by pot that had seeds and the results divided by five.

Weight of ears without threshing per plant: It was obtained weighing the ears in analytical scale, after removing of the stem. The result was expressed in grams.

Weight of seeds produced per plant: The ears of each plant were threshed and the seeds were cleaned, weighed expressed in grams.

Weight of ears threshed per plant: It was obtained by the difference among the weight of the ears without threshing and the seed.

Number of seeds per ear: In the moment of threshing was made the counting of the seeds per each ear.

Thousand seed weight: Eight replicates of 100 seeds were counted, being calculated the weight of a thousand seeds conforms the "Rules to Seed Evaluations" (Brasil, 2009).

Germination test: This test was performed according to the RAS (Brasil, 2009), a total of 200 seeds for replicate were sowed in paper rolls (four rolls with 50 seeds each) moistened with distilled water in proportion 2.5 w/v. The germination temperature was 20°C and the seedling counting was made 4 and 8 days after the sowing. At the end of the experiment was obtained the percentage of normal seedlings germinated.

First counting germination test: The germination test was performed in according to the RAS (Brasil, 2009).

Seedling length: It was conducted using 15 seeds for each replicate and measuring shoot and root length of 10 normal seedlings randomly selected in 8 days after the sowing in paper rolls moistened with distilled water in proportion 2.5 w/v and placed to germinate at 20°C of temperature.

Shoot and root dry weight: The same seedlings used in the test of seedling length was used. The shoot and the root were separated, put in paper bags and taken to dry in an oven with forced air circulation, regulated to the temperature of 60 ± 2°C, until reaching constant weight. Later, the samples were weighed and the results were expressed in g $seedling^{-1}$.

For the statistical analysis, the results were submitted to analysis of variance and significant event, there were comparisons of means by Tukey test or polynomial regressions, both with 5% of probability, using Winstat 1.0 (Machado & Conceição, 2003) statistical program. The data obtained in percent failed to meet the assumption of normality, so were transformed using the arc.sin (square root x/100).

Results and Discussion

The analysis of variance demonstrated that the factors did not have effect on the variables: weigh of ears threshed and number of seeds per ear. The variables: number of ears, number of ears with seeds, weight of ears without threshing and weight of seeds produced, showed effect of the application of salt through of the irrigation (Table 1), while the variable of thousand seeds weight showed significant effect of the salt and silicon factor, however, it did not happen interaction among them.

Table 1 shows that increasing the salinity stress caused by NaCl concentration in the irrigation water has reduced wheat yields as a result of decreasing the number of ears, number of ears with seeds, of the weight of ears without threshing and weight thousand seeds, confirming the results already shown in other studies such as those of Ali et al. (2012) and Blanco et al. (2008). This reduction in productivity occurs because the salt stress causes premature senescence of leaves and the plant nutrient imbalances due to absorption of toxic ions (Hu et al. 2006). In addition, plants subjected to saline conditions decreased their growth in response to water deficit or decrease of the osmotic potential (Hu & Schmidhalter, 2005).

Table 1. Number of ears per plant (NE), number of ears with seeds per plant (ES), number of seeds per ear (SE), weight of ears without threshing per plant (WEWT), weight of threshed ear per plant (WTE), weight of seeds produced per plant (WS) and thousand seeds weight (TSW), depending on the application of NaCl concentrations in the irrigation water to the wheat crop, cv. Quartzo. Capão do Leão, RS, Brazil, 2014.

			Silicon Dose (kg ha^{-1})					CV %
			0	1,000	2,000	3,000	Mean	
NE	NaCl Dose (mM)	0	4.8	4.8	4.0	4.7	4.6 a	11.34
		8	4.5	4.2	4.5	4.4	4.4 a	
		16	4.3	4.1	3.9	3.3	3.9 b	
	Mean		4.5	4.4	4.1	4.1	LSD = 0.42	
ES	NaCl Dose (mM)	0	3.3	3.2	3.0	3.5	3.2 ab	17.44
		8	3.4	3.6	3.6	3.6	3.6 a	
		16	2.9	3.0	3.3	2.0	2.8 b	
	Mean		3.2	3.3	3.3	3.0	LSD = 0.48	
SE	NaCl Dose (mM)	0	21.52	23.31	21.52	19.12	21.37 ns	12.37
		8	21.80	19.95	19.77	21.29	20.70 ns	
		16	19.88	19.09	19.88	19.58	19.61 ns	
	Mean		21.07 ns	20.78 ns	20.39 ns	20.00 ns	LSD = 1.82	
WEWT (g)	NaCl Dose (mM)	0	4.15	4.14	3.62	3.96	3.96 ab	11.41
		8	4.45	4.08	4.44	4.20	4.29 a	
		16	4.02	3.49	3.80	3.02	3.58 b	
	Mean		4,21	3.90	3.95	3.73	LSD = 0.39	
WTE (g)	NaCl Dose (mM)	0	1.61	1.49	1.46	1.61	1.54 ns	10.96
		8	1.50	1.53	1.69	1.47	1.54 ns	
		16	1.43	1.49	1.45	1.27	1.41 ns	
	Mean		1.51 ns	1.50 ns	1.53 ns	1.45 ns	LSD = 0.14	
WS (g)	NaCl Dose (mM)	0	2.53	2.65	2.17	2.35	2.43 ab	16.58
		8	2.95	2.56	2.76	2.74	2.75 a	
		16	2.59	2.00	2.35	1.74	2.17 b	
	Mean		2.69	2.40	2.43	2.28	LSD = 0.35	
TSW (g)	NaCl Dose (mM)	0	36.19	36.70	36.71	37.09	36.67 b	1.67
		8	37.38	37.88	38.29	37.49	37.76 a	
		16	36.44	37.21	37.28	38.20	37.28 a	
	Mean		36.67	37.26	37.43	37.59	LSD = 0.54	

Means values followed by different letters are significantly different according to Tukey´s test ($p<0.05$). LSD ($p<0.05$).

In this way, Borzouei et al. (2012) studying the wheat plants irrigated with saline water and maintained it until the crop moment, founded less fresh and dry weight of roots and leaves as well reductions of grains the production, attributing these results to the toxic effects caused by the high salt concentration, and also due to the imbalance in the absorption of nutrients by the roots.

In relation to the thousand seed weight (TSW), it was observed that the treatments that received irrigation with saline water produced seeds with higher weight than the observed in the control (without salt), but it can be seen through the number of seeds for ear that there was a trend to produce more seeds for ear, however with less weight (Table 1). Ali et al. (2012) evaluated the difference in the

Revista Agrarian
ISSN: 1984-2538

responses of 97 inbred lines of wheat compared with a considered salt-tolerant cultivar, exposing them to different conditions of soil salinity (EC of 2.2 (control), 10 and 15 dS m^{-1}) and noting that in all cultivars tested the weight of 100 grains was higher when plants were subjected to salt stress, however, found that the values for grains per ear and yield showed opposite behavior, which is similar to that observed in this work. These results are contrary to those observed by Lemes (2013), they observed that thousand seeds weight of rice decreased when the NaCl concentration in the irrigation water increased. However, Jácome et al. (2003) found which the solution with salt did not have significant effect on the thousand seed weight of cotton cultivars.

The Figure 1 shows the tendency of the TSW, which increased with the addition of incorporated kaolin in the soil together the base fertilization. It can be observed through of the positive lineal model, increasing in 0.3 g t^{-1} of supplied kaolin it is possible to reach an increment of 0.9 grams between the dose of 0 and the 3,000 kg ha^{-1}. Lima Filho & Tsai (2007) found increase of oat and wheat seed weight supplemented with silicon solutions.

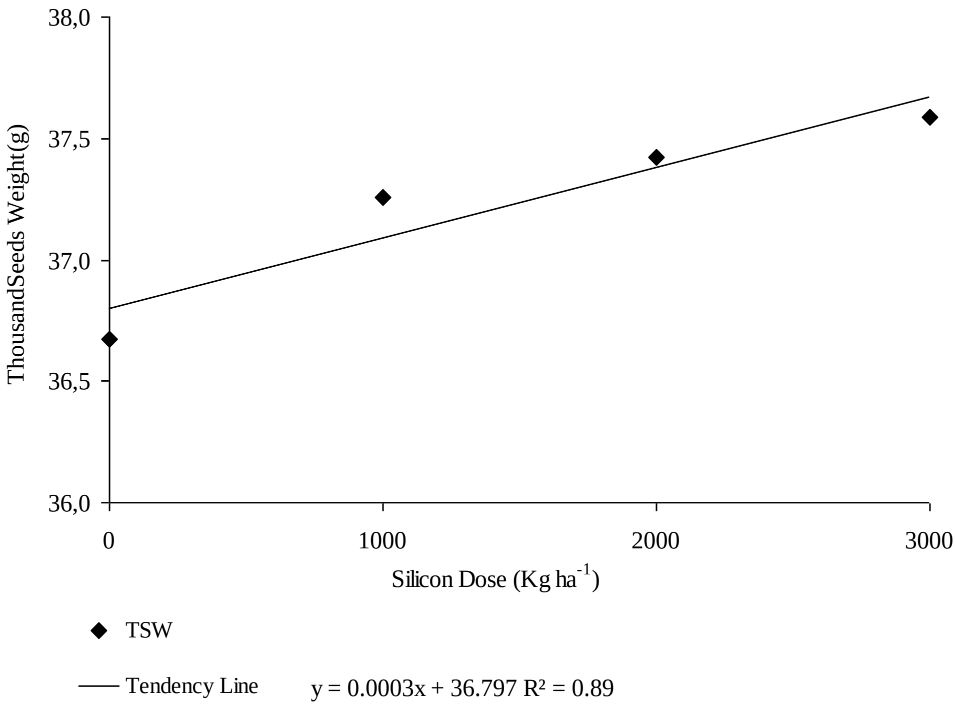

Figure 1. Thousand Seeds Weight (mean of three salt concentrations) according to the fertilization with kaolin soil-incorporating the wheat crop, cv. Quartzo. TSW: Thousand Seeds Weight. Capão do Leão, RS, Brazil, 2014.

The variables germination and first counting of germination of the produced seeds responded to the interaction between the factors salt and silicon dosage (Table 2 and Figure 2). However, although significant differences found, the germination of the seeds was high in all treatments.

The germination percentage did not show statistical differences in function of the irrigation with saline water when it was fertilized with kaolin up to 2,000 kg ha^{-1}, however, when the dose of 3,000 kg ha^{-1} was applied, it was observed higher seeds germination when the irrigation with water without salt was done (Table 2). In the Figure 2A shows that the germination percentage is adjusted to a growing lineal model when the irrigation is accomplished with water without salt, increasing in a rate of 0.4% for each ton of supplied kaolin. When the plants were irrigated with a concentration of 8 mM NaCl, the data obtained were adjusted to a negative quadratic model, being observed that the silicon doses 1,000 and 2,000 kg ha^{-1} maintained the germination percentage, in relation to the 0 dose, while in the 3,000 kg ha^{-1} there was a reduction of the germination. At higher salt concentration, 16 mM, the data of the germination percentage were adjusted to a negative lineal model, decreasing in a rate of 0.6% for each ton of contributed silicon. Lemes (2013) observed that the germination of rice seeds produced under saline stress and with silicon fertilization decreased when the salt concentration in the irrigation water increased, however she did not find silicon effect on this response variable. Lima et al. (2005) noticed that the germination of rice seeds decreases when the salt dosage in the substrate increases, concluding that the salinity affects the normal seedlings development and reduces the seed vigor.

Table 2. Germination (G) and first counting of germination (FCG) of produced seeds and length of shoots (LS) and root (LR) of seedlings derived from produced seeds by wheat plants cv. Quartzo cultivated under management with application of NaCl concentrations in the irrigation water and different levels of silicon in the form of kaolin soil-incorporating. Capão do Leão, RS, Brazil, 2014.

			Silicon Dose (kg ha^{-1})					CV %
			0	1,000	2,000	3,000	Mean	
G (%)	NaCl Dose (mM)	0	99 a	99 a	98 a	100 a	99	0.75
		8	99 a	99 a	99 a	97 b	99	
		16	99 a	99 a	99 a	97 b	99	
	Mean		99	99	99	98	LSD = 1.29	
FCG (%)	NaCl Dose (mM)	0	95 a	94 a	92 a	94 a	94	2.52
		8	94 a	94 a	95 a	87 b	93	
		16	94 a	93 a	91 a	90 ab	92	
	Mean		94	94	92	90	LSD = 4.04	
LS (m)	NaCl Dose (mM)	0	0.135 a	0.128 b	0.127 a	0.131 a	0.130	4.97
		8	0.132 a	0.140 a	0.134 a	0.129 a	0.134	
		16	0.129 a	0.144 a	0.131 a	0.135 a	0.135	
	Mean		0,132	0.137	0.131	0.132	LSD = 0.01	
LR (m)	NaCl Dose (mM)	0	0.156 a	0.146 b	0.142 b	0.155 a	0.150	3.78
		8	0.153 a	0.158 a	0.153 a	0.164 a	0.157	
		16	0.147 a	0.158 a	0.156 a	0.161 a	0.156	
	Mean		0.152	0.154	0.150	0.160	LSD = 0.01	

Data values followed by different letters are significantly different according to Tukey´s test ($p<0.05$). LSD ($p<0.05$).

The first counting of germination (FCG) of the wheat seeds had a similar behavior to the germination percentage, but not obtaining statistical differences among the salt concentrations in the irrigation water when silicon was applied in the doses 0; 1,000 and 2,000 kg ha^{-1}, but when the same one was applied in the 3,000 kg ha^{-1}, the FCG was higher when irrigated with water without salt (Table 2). In the Figure 2B is observed that no mathematical model was adjusted to the obtained results when the irrigation was made with water without salt, however, when the irrigation was made with water with salt concentration of 8 mM, the data were adjusted to a negative quadratic model, being observed that the doses 1,000 and 2,000 kg ha^{-1} of kaolin maintained constant FCG, compared with the dose zero, but decresead the FCG when the dose of 3,000 kg ha^{-1} was applied.

When the irrigation was accomplished in the concentration of 16 mM, the FCG decreased in a lineal way as it increased the silicon dosage in rate of 1,5% for each ton of applied silicon. These results agree with the obtained in the germination percentage, where the same behavior was observed. Lemes (2013) verified that the first counting of germination of rice seeds produced under saline stress and with silicon fertilization showed quadratic behavior in function of the silicon application, increasing the FCG until the dose 1,000 kg ha^{-1} and after decreasing until to reach less than the dose zero. This behavior was observed in the three salt doses used in this experiment.

The variables shoot and root length showed response to the interaction of the factors (salt and silicon dose). Regarding the shoot lenght (SL), this did not show statistical differences in function of the irrigation with saline water when kaolin was applied in the doses of 0; 2,000 and 3,000 kg ha^{-1}, but when this was applied in the dose of 1,000 kg ha^{-1}, SL was smaller comparing the plants that were irrigated with water without salt (Table 2).

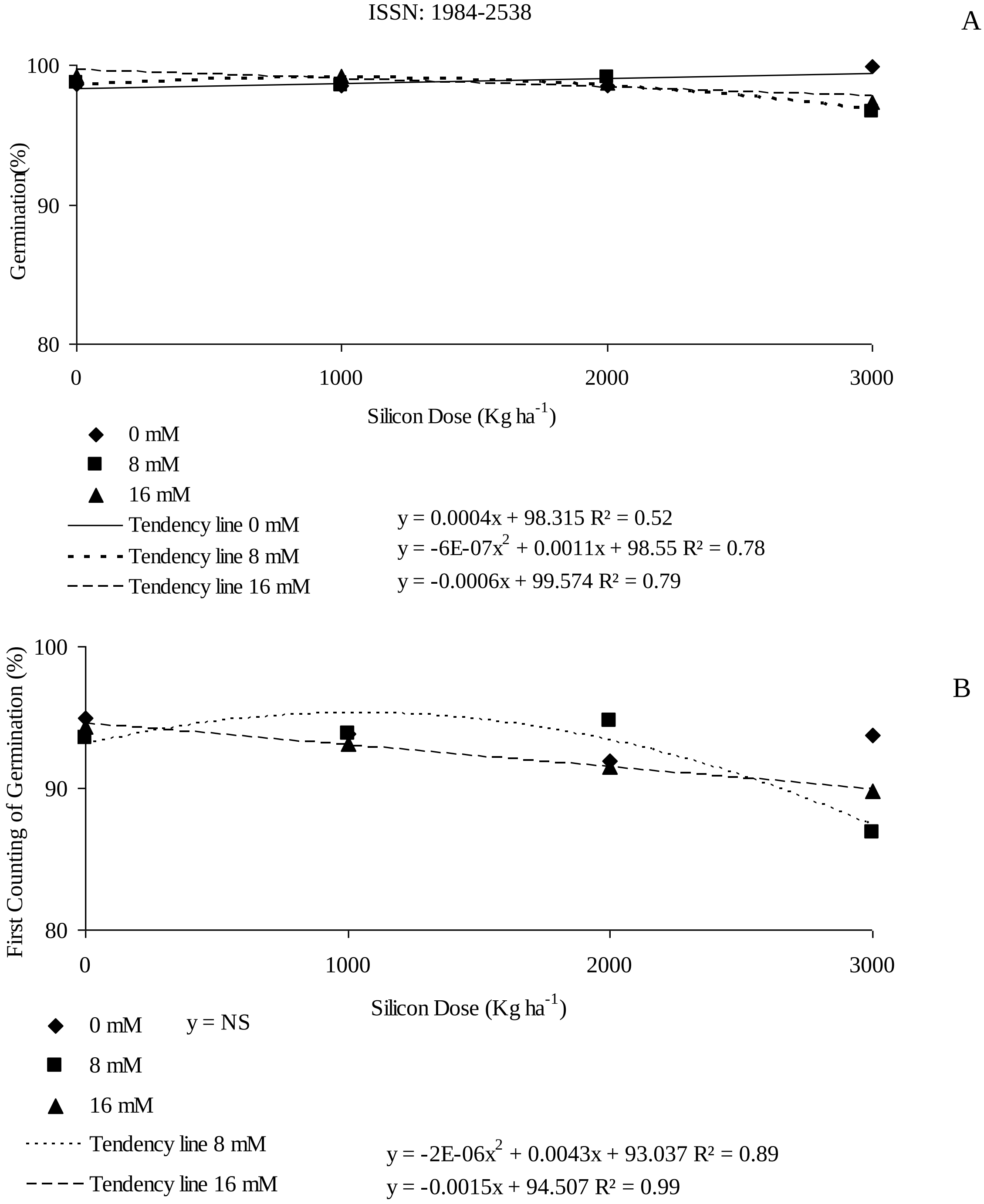

Figure 2. Germination (A) and first counting of germination (B) of produced seeds. The figures show the interaction between irrigation with saline water and fertilization with kaolin soil-incorporating in wheat crop. cv. Quartzo. mM: millimolar. NS = not significant. Capão do Leão, RS, Brazil, 2014.

In the Figure 3A, the SL is observed in function of the silicon application. The obtained results did not adjust with any mathematical model tested when the irrigation was made with water without salt and with water in the concentration of 16 mM NaCl. When the irrigation was made with water of concentration of 8 mM, the data were adjusted to a quadratic model, increasing the shoot in the dose of 1,000 kg ha^{-1} of kaolin and decreasing to equal to the dose zero when it was fertilized with 3,000 kg ha^{-1}.

In the root length (RL), it was observed that in the dosages of 0 and 3.000 kg ha^{-1} of kaolin, there were not significant differences among the different salt dosages . However, in the doses of 1,000 and 2,000 kg ha^{-1}, the RL was smaller when the irrigated was made with water without salt in comparison with saline water, independent of the dosage of NaCl

(Table 2). The data were adjusted to a quadratic model in the plants that were irrigated with water without salt, in other words, without suffering with this stress. While in the irrigation with saline water, the root length increased in a lineal way, the silicon dosage for both concentrations of salt increased, being an increase of 0.3 cm t^{-1} of applied kaolin when it was irrigated in the NaCl concentration of 8 mM of and an increase of 0.4 cm t^{-1} for the irrigation with concentration of 16 mM (Figure 3B).

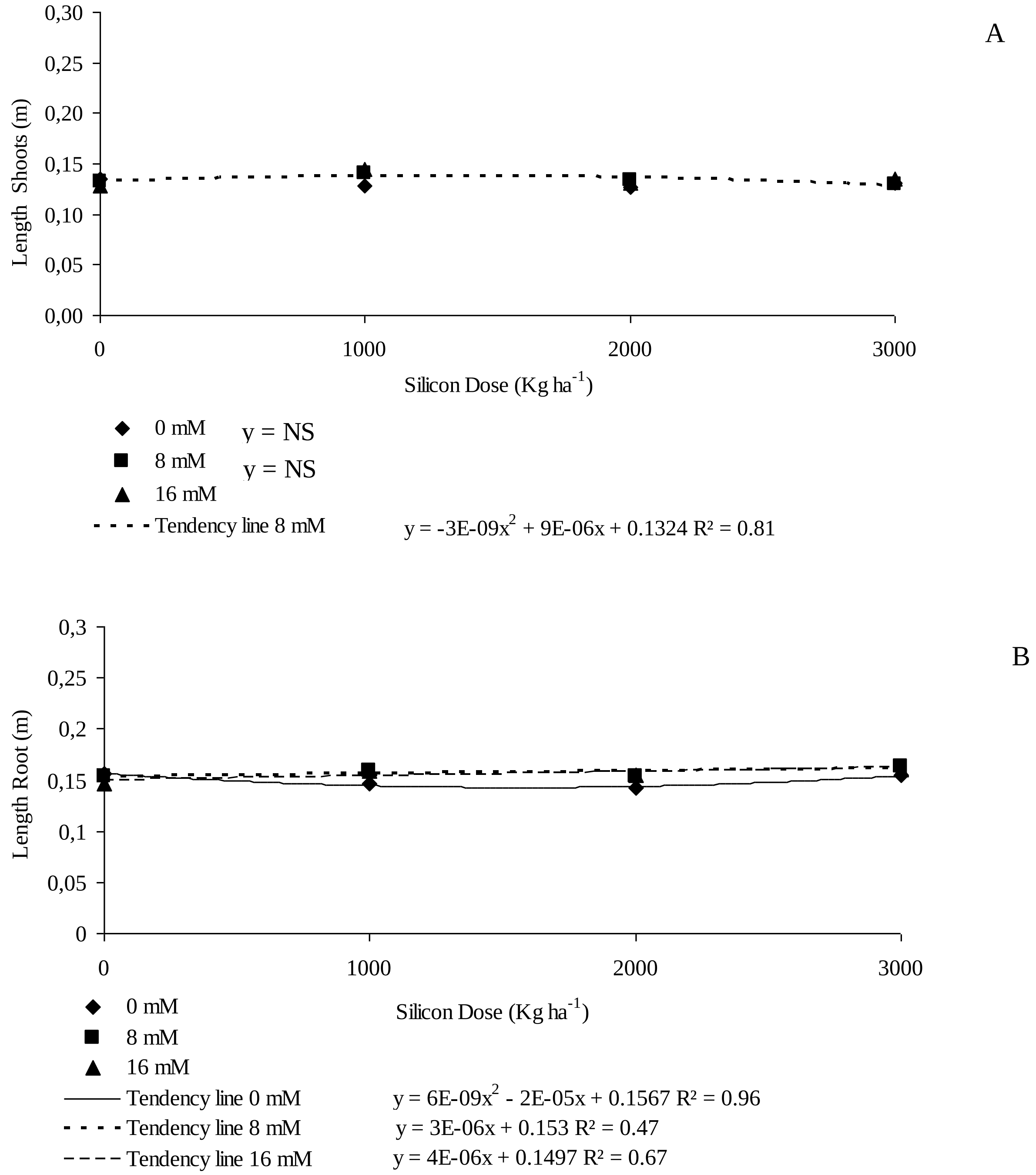

Figure 3. Length shoot (A) and length root (B) of seedlings derived from seeds produced. The figures show the interaction between irrigation with saline water and fertilization with kaolin soil-incorporating for wheat crop. cv. Quartzo. mM: millimolar. NS = not significant. Capão do Leão, RS, Brazil, 2014.

Lemes (2013) working with saline stress and silicon fertilization for rice, founded that the root length of the seedlings originating from of the produced seeds did not show response to the effect of the saline irrigation but showed to the silicon application, being adjusted to a quadratic model where the dose of 1,000 kg ha^{-1} of silicon increased the root length slightly.

The variables shoot and root dry weight of the seedlings showed answer to the applied dosage of salt by the irrigation in wheat plants (Table 3). The greater shoot and root dry weight was observed in the treatments where the irrigation was made with saline water. This increase in the weight can be related with increase in the thousand seed weight that were also irrigated with saline water presented the greatest weights.

Table 3. Shoot dry weight (SDW) and root dry weight (RDW) of seedlings derived from seeds produced by wheat plants cv. Quartzo, depending on the application of NaCl concentrations in the irrigation to the crop. Capão do Leão, RS, Brazil, 2014.

			Silicon Dose (kg ha^{-1})					CV %
			0	1,000	2,000	3,000	Mean	
SDW (g)	NaCl Dose (mM)	0	0.0874	0.0813	0.0755	0.0816	0.0814 b	7.37
		8	0.0846	0.0873	0.0894	0.0853	0.0866 a	
		16	0.0820	0.0889	0.0866	0.0887	0.0865 a	
	Mean		0.0847	0.0858	0.0838	0.0852	LSD = 0.005	
RDW (g)	NaCl Dose (mM)	0	0.0648	0.0671	0.0567	0.0709	0.0649 b	9.79
		8	0.0742	0.0769	0.0708	0.0746	0.0741 a	
		16	0.0640	0.0691	0.0748	0.0723	0.0701 a	
	Mean		0.0677	0.0710	0.0674	0.0726	LSD = 0.006	

Means values followed by different letters are significantly different according to Tukey´s test ($p<0.05$). LSD ($p<0.05$).

Conclusions

The saline irrigation caused the decrease of the number of ears per plant, number of ears with seeds per plant, weight of the ears without threshing per plant and weight of the seeds produced per plant.

The use of kaolin form increased the thousand seeds weight independent of the existence or not of saline stress.

The silicon application in the kaolin form contributed to the increase of the germination percentage of the produced seeds, when the plants were not exposed to salt stress.

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