Advance Journal of Food Science and Technology 7(4): 302-306, 2015
DOI:10.19026/ajfst.7.1313
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: September 07, 2014 Accepted: October 11, 2014 Published: February 05, 2015

Research Article

Effects of Sodium Silicate on Growth and Physiological Characteristics under Salt Stress in Dry-land Wheat Seedlings

Zhanli Hu and Yan Shi
Dryland-technology Key Laboratory of Shandong Province, Qingdao Agricultural University, Qingdao 266109, Shandong Province, China

Abstract: In order to find an appropriate Sodium Silicate (SS) application amount and improve the resistance to salt stress in dry-land wheat. The effects of SS on growth and physiological characteristics under 0.2% salt stress in dry-land wheat seedlings by applying different amounts of SS had been studied in the pots in the artificial climate chamber with the variety wheat Jimai22. The results indicated that, SS can increase root-shoot ratio, aboveground and underground fresh weight under 0.2% salt stress in dry-land wheat seedlings. Meanwhile, SS also could improve Superoxide dismutase (SOD), Peroxidase (POD) activity and reduce Malondialdehyde (MDA) content. In the SS amount range of 0~7.5 kg/667 m^2, the SS application amount of 5 kg/667 m^2 was the best to promote the growth of dry-land wheat seedlings under 0.2% salt stress.

Keywords: Dry-land wheat seedlings, growth characteristics, protective enzymes actives, salt stress, sodium silicate

INTRODUCTION

Soil salinization has a negative impact on the development of agricultural production. In recent years, the lack of rainfall and excess irrigation exacerbated salinization and increased soil salinization area year by year (Jianxin *et al*., 2008). Soil salinization has become a major factor in seriously restricting agroforestry production. Therefore, improving the salt tolerance of plant has become an important issue to research plant stress and an important way to overcome soil salinization.

Silicon is the second largest abundant element in the soil and crust and the basis for the majority of plants' life. In recent years, a number of studies on silicon have been reported. Many studies have shown that silicon is a beneficial element to plant health and can improve the biomass yield of many plants especially making a significant impact on the monocots. Silicon can promote the growth of rice and increase the yield (Liang *et al*., 2013). Silicon also could reduce the transpiration rate in rice, increase chlorophyll content, photosynthetic rate, intercellular CO_2 concentrations and stomatal conductance, maintain a high leaf area index and improve canopy structure, improve energy efficiency and increase the material accumulation and transfer (Fengying *et al*., 2014). At the same time, it plays an important role in improving the resistance to promote the growth of plants. What's more, silicon could improve morphological structure of plants, enhance the root activity, reduce the transpiration rate, so as to effectively regulate the photosynthesis and transpiration; meanwhile, it succeeds in improving plant resistance to biotic and abiotic stress and enhancing its adaptation to adversity capacity (Jiaojiao *et al*., 2013). Silicon could relieve a variety of metal ions toxic to plants (Chengxiang *et al*., 2004). Silicon can improve the drought resistance of Kentucky bluegrass (Xin and Yajun, 2013). It has been reported that Silicon has an important role in metabolic and physiological changes of plant and it can increase the salt tolerance of soybean (Liyan, 2013). Exogenous Silicon can decrease the content of MDA in leaves of wild type rice and improve the root activity under salt stress (Yizong *et al*., 2009). Under the condition of salt stress, silicon can enhance perennial ryegrass seedlings' ability to scavenge reactive oxygen species, protect the photosynthetic mechanism, improve the photosynthetic function and enhance plant salt tolerance by improving the SOD, CAT, POD and APX activity and glutathione (GSH) content.

At present, it has been widely reported that silicon can promote plant growth and resistance, but the studies have focused on ryegrass, poplar, rice, cucumbers, soybeans, so as other crops. Wheat is an important crop in the world. However, the research that silicon could promote the growth of wheat is not much. Especially there are very few studies about the effects of silicon on physiological characteristics, protection system of leaves and lipid peroxidation under the salt stress in dry-land wheat seedlings. Thus, this pot experiment studied the effects of SS on growth and physiological

Corresponding Author: Yan Shi, Dryland-technology Key Laboratory of Shandong Province, Qingdao Agricultural University, Qingdao 266109, Shandong Province, China

Table 1: Design of treatments (g/pot)

Treatment	CK	T1	T2	T3
SS (kg/667 m^2)	0	2.5	5	7.5
NaCl (%)	0.2	0.2	0.2	0.2

characteristics under 0.2% salt stress in dry-land wheat seedlings with the variety wheat Jimai22. Select an appropriate SS application amount to strengthen the resistance to salt stress and explore the mechanism of silicon improving salt resistance in dry-land wheat. This study provides a new technical way to improve the yield of dry-land wheat.

MATERIALS AND METHODS

Experimental design: This experiment was carried out from November, 2013 to January, 2014 by pots in the artificial climate chamber of Qingdao Agricultural University with the variety wheat Jimai22. The soil was sandy loam soil with soil organic matter content 1.1%, total N 1.2%, available nitrogen 89 mg/kg, available phosphorus 36 mg/kg, available potassium 105 mg/kg. This experiment designed 4 treatments with 4 replicates per treatment, contrast check (CK), treatment 1 (T1), treatment 2(T2) and treatment 3 (T3), which were detailed in Table 1. The uniform mixture of Sodium silicate (SS, molecular formula of $Na_2SiO_3 \cdot 9H_2O$, Na_2O content of 19.3-22.3%, ratio of Na_2O and SiO_2 being 1.03±0.03) in different treatments and 1.2 kg soil were applied into the pot with length of 20 cm, width of 13.5 cm and a height of 7 cm. After accelerating germination of wheat seeds, the test pots with 6 seeds were cultured into artificial climate chamber. According to the growth period of wheat seedlings, we irrigated these treatments with the same amount of 0.2% saline. When wheat seedlings grow to the four-leaf stage, we began to sample. The indicators of physiological characteristics in dry-land wheat seedlings were measured on Dec 1st, Dec 16th, Dec 31st, 2013 and Jan 15th, 2014.

Items: The aboveground and underground fresh weight was weighed by analytical balance; the root ratio is the provider of the root dry weight divided by the shoot dry weight. Determine Superoxide dismutase (SOD) activity, Peroxidase (POD) activity and Malondialdehyde (MDA) content in accordance with the methods of Aiguo *et al*. (1983), Hecheng (2000) and Zhifang *et al*. (1984).

RESULTS

Effects of different application amounts of SS on aboveground and underground fresh weight under salt stress in dry-land wheat seedlings: We can find out from Fig. 1 and 2 that aboveground and underground fresh weight were gradually increasing with the growth of dry-land wheat seedlings. At the same time, aboveground and underground fresh weight of T1, T2 and T3 were significantly higher than that of CK. As can be seen from Fig. 1, the aboveground fresh weight of all treatments was T2>T1>T3>CK in each measurement period. On December 31st, the aboveground fresh weight of T1, T2 and T3 were respectively higher than that of CK 50.9, 62.1 and 18.8%, respectively. It revealed that the aboveground fresh weight of T2 was the highest.

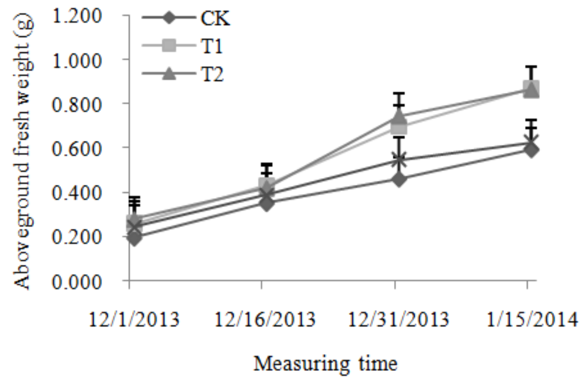

Fig. 1: Effects of different application amounts of SS on aboveground fresh weight under salt stress in dry-land wheat seedlings

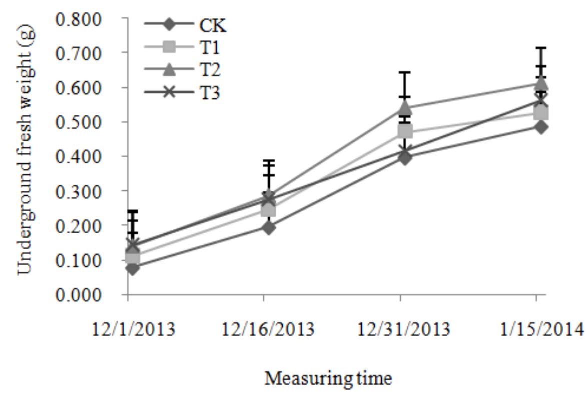

Fig. 2: Effects of different application amounts of SS on underground fresh weight under salt stress in dry-land wheat seedlings

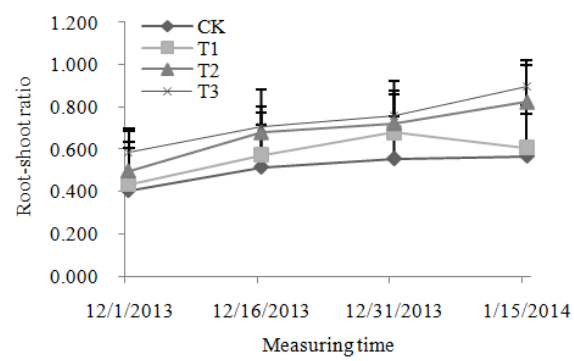

Fig. 3: Effects of different application amounts of SS on root-shoot ratio under salt stress in dry-land wheat seedlings

As was shown in Fig. 2, the underground fresh weight in the four treatments showed T2>T3>T1>CK in each growth period. Compared with the control group CK, the underground fresh weight of T1, T2 and T3 were respectively higher by 8.4, 25.9 and 15.6%, respectively on January 15th. The underground fresh weight of T2 reached the highest. It can be inferred that SS could alleviate salt-stress damage on the growth of dry-land wheat seedlings and make the aboveground and underground fresh weight increase.

Effects of different application amounts of SS on root-shoot ratio under salt stress in dry-land wheat seedlings: In the growth period of dry-land wheat seedlings, root-shoot ratio in all treatments showed an slowly increasing trend in general and root-shoot ratio of each growth period showed T3>T2>T1>CK (Fig. 3). On December 16th, the four treatments CK, T1, T2 and T3's root-shoot ratio were respectively 0.516, 0.572, 0.680 and 0.704, T3 was higher than the other treatments. We can conclude that the root-shoot ratio of dry-land wheat seedlings can be increased by SS under salt stress.

Effects of different application amounts of SS on SOD activity under salt stress in dry-land wheat seedling leaves: We can see from Fig. 4, SOD activity of the three treatments T1, T2 and T3 was higher than that of the control CK in each growth period and SOD activity of all treatments turned out to be T2>T3>T1>CK. On December 16th, it's easy to learn that SOD activity of CK was 179.82 U/g and SOD activity of T1, T2 and T3 were respectively 1.16 times, 1.33 times, 1.27 times that of CK, with T2 being the highest. It can be inferred that T2 was the most reasonable SS amount to maintain the SOD activity.

Effects of different application amounts of SS on POD activity under salt stress in dry-land wheat seedling leaves: We can make it out from Fig. 5 that POD activity of all treatments performed a decline trend with the descending speed to slow after the fast. Compared with the control CK, the POD activity of T1, T2 and T3 turned out to be higher than CK. In each growth period, POD activity of all treatments presented an overall performance of T2>T3>T1>CK. On December 31st, the POD activity of the four treatments CK, T1, T2 and T3 respectively showed 102.35 U/g • min, 112.74 U/g • min, 126.53 U/g • min, 119.96 U/g • min. We can find that T2 had the highest POD activity. It showed that SS could alleviate the salt stress damage to dry-land wheat seedling and improve POD activity under salt stress.

Effects of different application amounts of SS on MDA content under salt stress in dry-land wheat seedling leaves: As can be seen from Fig. 6, the overall trend of MDA content is gradually increasing with the increase of speed to slow after the fast. MDA content of each growth period in the four treatments showed T3<T2<T1<CK. On December 31st, MDA content of T1, T2 and T3, respectively showed 0.87 times, 0.79 times, 0.67 times that of CK when MDA content in the control CK presented 6.461 μmol/g·FW. The results indicated that, the application of SS can reduce MDA content under salt stress in dry-land wheat seedling

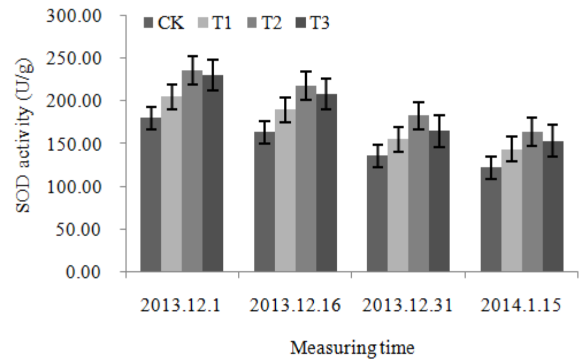

Fig. 4: Effects of different application amounts of SS on SOD activity under salt stress in dry-land wheat seedling leaves

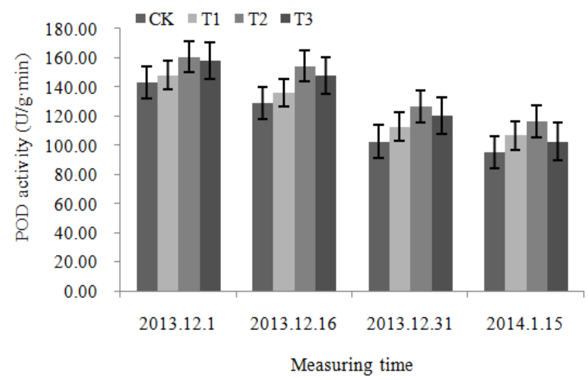

Fig. 5: Effects of different application amounts of SS on POD activity under salt stress in dry-land wheat seedling leaves

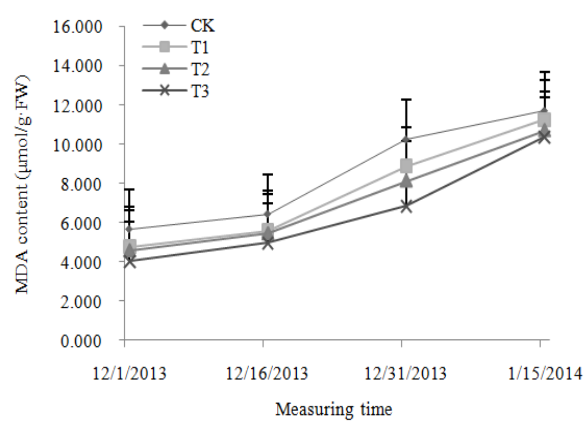

Fig. 6: Effects of different application amounts of SS on MDA content under salt stress in dry-land wheat seedling leaves

leaves and T3 was more conducive to delay the synthesis of MDA in dry-land wheat seedling leaves.

DISCUSSION

Effects of different application amounts of SS on growth characteristics under salt stress in dry-land wheat seedlings: It is pointed out that there is a relationship of mutual promotion and mutual restraint between the aboveground and underground organs in the growth process of wheat, water and nutrients needed by the aboveground are almost entirely provided by the underground organs (Yonghui *et al*., 2013). While some nutrients that root required depends on the aboveground synthesis. Within a certain range of concentrations, silicon can increase root fresh and dry weight in wheat seedlings under cadmium stress (Qiuchan *et al*., 2011). Silicon has the function of increasing the dry weight of root, stem and leaf, improving root vigor, improving nutrients in leaf and root, but also promoting the growth of their roots and leaves (Yizong *et al*., 2009).

The results indicated that, SS can promote aboveground and underground fresh weight and root-shoot ratio in dry-land wheat seedlings, alleviate physiological damage and significantly promote the growth of dry-land wheat seedlings. With the application amounts of SS increasing, the application amount of SS in T2 was more conducive to the promotion of aboveground and underground fresh weight. However, root-shoot ratio increased following by the SS amounts' increase and T3 showed a most promotion. It suggested that SS could alleviate the physiological drought caused by salt stress and improve the metabolism status in plants. What's more, appropriate amount of silicon could be better to promote root and leaf growth.

Effects of different application amounts of SS on senescence under salt stress in dry-land wheat seedlings: SOD, POD and MDA which are indicators of the decline characteristics in wheat leaves play a crucial role in the decline of delaying wheat plants. As we all know, free radicals can lead to membrane lipid peroxidation and the damage from reactive oxygen and promote cell aging, while SOD is able to remove the excess free radicals and maintain plants a lasting health status (Huitao *et al*., 2007). POD exists in the cell of peroxides vivo. POD not only can eliminate hydrogen peroxide, phenols and amines and other harmful substances, but also it is one of the key enzymes of active oxygen scavenging system (Guowei *et al*., 2005). The content of Malondialdehyde (MDA) being an end-product from membrane lipid peroxidation is an important indicator to judge the level of membrane lipid peroxidation (Xueming *et al*., 2001). Silicon can alleviate the toxicity of lead on radix seedlings and have an effect on POD and SOD activity making them present an increasing first and then decreasing trend with the increase of silicon's concentrations (Hongmei *et al*., 2013). Not only Silicon significantly increased SOD and POD activity of cucumber leaf, but also it obviously reduced MDA content. Furthermore, MDA content had an increasing first and then decreasing trend with the gradual increasing of silicon amount, while the trends of SOD and POD activity were just the opposite to MDA (Xiyan *et al*., 2009).

The experimental results indicated that SOD and POD activity of T1, T2 and T3 were higher than that of CK under 0.2% salt stress. Meanwhile, SS could increase SOD and POD activity under salt stress in dry-land wheat seedling leaves, scavenge free radicals and prevent membrane lipid peroxidation. Among these treatments, the amount of SS in T2 was the most reasonable SS amount. These results are almost consistent with the previous research (Hongmei *et al*., 2013; Xiyan *et al*., 2009). Therefore, the reasonable application of SS can better scavenge reactive oxygen species, maintain the healthy environment and promote better growth of wheat seedlings.

The experimental results also showed that SS was conducive to control the increasing of MDA content in dry-land wheat seedlings leaves and MDA content of T3 was the lowest. This result is slightly different from Wang Xiyan's study (Xiyan *et al*., 2009). It may be inferred that appropriate amount of SS can maintain the integrity of the cell membrane under salt stress to ensure a variety of normal metabolism of plants, which will help improve the ability to resist salt damage of wheat seedlings. This may be due to the deposition of gel state silicon or soluble silicon in the cell lipid body that could enhance the stability of cell membrane, improve membrane permeability and reduce salt stress-induced membrane lipid peroxidation. Combining all the above experimental results, T2 was the best SS amount.

ACKNOWLEDGMENT

Supported by the program of "The research on the efficient use technology and demonstration of nitrogen fertilizer in main crops (201203079)"; "Integrated research and demonstration of the balanced increase in winter wheat and summer maize in Shandong Province (2012BAD04B05)"; Funded by Shandong Modern Agricultural Technology and Industry System-cultivation and soil fertilizer; and Innovation team of high water use efficiency in Dryland Crop of Shandong Province and The wheat and maize Collaborative Innovation Center in Shandong Province.

REFERENCES

Aiguo, W., L. Guanghua and S. Congben, 1983. Study on superoxide dismutase in soybean seeds. J. Plant Physiol., 9(1): 77-83.

Chengxiang, X., L. Zhaopu and L. Youliang, 2004. Silicon on the physiological function of plants. Plant Physiol. Commun., 40(6): 753-757.

Fengying, X., Z. Xiujuan and W. Xiaoling, 2014. Effect of liquid silicon potash fertilizer on canopy structure, photosynthetic characteristics and yield in rice. Jiangsu J. Agr. Sci., 30(1): 67-72.

Guowei, X., C. Erhua and C. Jian, 2005. Effects and influential factors of straw returning. Farming Cultivat., 1(1): 6-9.

Hecheng, L., 2000. The Principle and Technology of Plant Physiology and Biochemistry Experiment. Higher Education Press, Beijing.

Hongmei, M., H. Duohong and Z. Fenqin, 2013. Effects of silicon on physiological characteristics of Isatis indigotica seedlings under lead stress. Li Shizhen Med. Mater. Med. Res., 24(10): 2509-2511.

Huitao, B., H. Fuqiang and Q. Lin, 2007. The effect of drought stress on protective enzyme activities and lipid peroxidation of jujube. Chinese Agric. Sci. Bull., 23(2): 151-155.

Jianxin, L., H. Haobin and W. Xin, 2008. Effects of silicon on active oxygen metabolism and photosynthetic parameters under salt stress in ryegrass seeding. Chinese J. Grassland, 30(5): 25-30.

Jiaojiao, D., Y. Zihui and K. Jianjun, 2013. Study of the interaction of Sodium and silicon to improve the drought resistance of Nitraria. Acta Prataculturae Sinica, 22(2): 203-210.

Liang, C., L. Jing and H. Feng, 2013. Effects of silicon on rice yield. Shanghai Agric. Sci. Technol., 6: 115.

Liyan, W., 2013. Study of silicon on the resistance to salt and the mechanism of wild soybean seedlings. Soybean Sci., 32(5): 559-663.

Qiuchan, H., W. Youhuan and W. Fangli, 2011. Effect of silicon on root biomass and cadmium content of rice seedlings under cadmium stress. Guizhou Agric. Sci., 39(3): 66-68.

Xin, L. and C. Yajun, 2013. Study of silicon on drought resistance and physiological variation in bluegrass. M.Sc. Thesis, Northeast Agricultural University, 30(5): 1-93.

Xiyan, W., Z. Yulong and Z. Hengming, 2009. Effects of silicon on protective enzyme activity and membrane peroxidation under salt stress in cucumber. J. Northwest Agric., 18(1): 221-224.

Xueming, Z., W. Guorong and L. Changhai, 2001. Effect of Ca^{2+} on heat tolerance and active oxygen metabolism of peanut seedlings. China J. Oil Crop, 23(1): 46-50.

Yizong, H., Z. Wenqiang and Z. Lijun, 2009. Effects of silicon on root activity, MDA and nutrient elements content of rice under salt stress. J. Chem. Ecol., 4(6): 860-866.

Yonghui, Y., W. Jicheng and L. Zongjun, 2013. Effects of water retaining agent dosage on the growth and water-fertilizer utilization in winter wheat. Agr. Res. Arid Areas, 31(3): 128-132.

Zhifang, L., L. Shuangshun and L. Guizhu, 1984. The relationship between rice leaves senescence and superoxide dismutase activity, lipid peroxidation. Bot. Gaz., 26(6): 605-615.