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RESEARCH ARTICLE

Interactive Effects of Silicon and Potassium Nitrate in Improving Salt Tolerance of Wheat

Ahmad Bybordi

East Azerbaijan Research Center for Agriculture and Natural Resources, Tabriz 53555-141, Iran

Abstract

Adequate regulation of mineral nutrients might be effective to ameliorate the deleterious effects of salts and help to sustain crop productivity, particularly in glycophytes, under salt stress. In this study, laboratory and greenhouse experiments were carried out at Agricultural and Natural Resources Research Centre in East Azerbaijan, Iran, to investigate the interactive effects of silicon and potassium nitrate in alleviating NaCl induced injuries in wheat (*Triticum aestivum* L.). In the laboratory experiment, three winter wheat cultivars Pishgam, Afagh and Alvand were grown on sterile filter paper moistened with 20, 40, 60, 80, and 100 mmol L^{-1} NaCl solution. Results revealed that wheat cultivars were significantly different in their growth response to different concentrations of NaCl and Pishgam was found to be the most tolerant to NaCl stress, and used in the second part of study. In the greenhouse experiment, Pishgam was grown in a hydroponic system subjected to different NaCl levels (20, 60 and 100 mmol L^{-1}) and treated by silicon (0, 2 and 4 mmol L^{-1}, final concentration in nutrient solution using K_2SiO_3) and potassium nitrate (0, 0.5, 1, and 2 mmol L^{-1}, foliar application). The experimental design was factorial based on a completely randomized design with three replications. It was found that NaCl stress significantly increased proline accumulation and sodium content in the plant tissues while decreased potassium uptake and accumulation by plants. Moreover, plant weight, 100-seed weight, relative water content, chlorophyll content, and photosynthesis were also significantly affected by varying levels of NaCl. However, exogenous application of silicon and potassium nitrate reduced sodium uptake, increased potassium and consequently improved plant weight, 100-seed weight, seed yield, ear length, and photosynthesis rate. This study suggested that utilization of the salt-tolerant cultivar (Pishgam) combined with proper foliar application of potassium nitrate (2 mmol L^{-1}) and silicon (4 mmol L^{-1}) at the wheat booting stage might be a promising approach to obtain higher grain yield on saline lands.

Key words: germination, grain yield, foliar application, photosynthesis, proline, relative water content

INTRODUCTION

Salinity is the major stress factor, (Rueda-Puente *et al.* 2007) and is one of the most serious environmental problems influencing crop growth and production (Lopez *et al.* 2002). Excessive soil salinity, resulting from natural processes or from crop irrigation with saline water, occurs in many semi-arid to arid regions of the world where it affects plant growth and yield through osmotic effects, nutritional imbalances, oxidative damage, and/or specific ion toxicities (Mohsen *et al*. 2013). To sustain food security and the well-being of humankind, a priority should be given to minimize the detrimental effects of salt stress. Attempts to improve tolerance to salinity through physiological selection criteria has increased substantially to improve the probability of success by

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Correspondence Ahmad Bybordi, Tel: +98-412-2663914, E-mail: ahmad.bybordi@gmail.com, a.bybordi@areo.ir

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making empirical selection more efficient (Noble and Rogers 1992). Researches have shown that physiological activities such as photosynthesis and respiration (Alian *et al*. 2000), water balance, turgor pressure, degeneration of cell membranes (Kaya *et al*. 2002), efficiency of enzymes, mineral nutrients uptake, synthesis, storage of assimilates, and metabolites such as proline are directly affected by salt stress (Alia *et al*. 2001; Jamil *et al*. 2007). Plants have developed complex mechanisms that contribute to acclimate to salinity induced osmotic and ionic stresses (Meloni *et al*. 2004). Among different techniques, proper management of mineral nutrients plays a crucial role in increasing plant tolerance to salinity (Marschner 1995). A number of studies have shown that silicon may increase salinity tolerance in wide variety of plants through different mechanisms including reduced Na^+ uptake and translocation, improved plant water status (Romero-Aranda *et al*. 2006), increased photosynthetic activity and ultra structure of leaf organelles (Shu and Liu 2001), stimulation of antioxidant system (Zhu *et al*. 2004), and alleviation of specific ion effect by H-ATPase dependent enhancement of potassium in shoots (Liang *et al*. 2005). In addition, silicon is reported to reduce the effect of salinity on wheat and other crops. Saqib *et al*. (2008) have reported that silicon decreased plant sodium uptake and shoot:root sodium distribution of a salt-resistant as well as a salt-sensitive wheat genotype. They found that silicon increased cell-wall sodium binding, concentration of glutathione and antioxidants under saline conditions (Horst and Marschner 1978).

Silicon existing in the Earth's crust is classified as the most abundant element following oxygen (Epstein 1994). It is most commonly found in soils in different forms including silicon in soil solution as silicic acid ($Si(OH)_4$), and its absorption occurs directly in this form (Chen *et al*. 2010; Sharifnabi and Nili 2011; Bybordi 2012). This element is also one of the most abundant mineral elements in plant tissues (Richmond and Sussman 2003; Zhu *et al*. 2004). Although, silicon is not considered as an essential element for plant growth, it is designated as an element with a beneficial influence on plant growth and development as well as crop yield (Liang 1999; Ma 2004), and required in large amounts for Gramineae crops, in particular. Ample evidence indicated that silicon, when readily available to plants, had positive effects on plant growth, particularly under biotic and abiotic stresses. In addition, studies have shown that supplementing the soil with silicon can improve salt tolerance of barley (Liang 1999; Liang *et al*. 1999), maize (Shu and Liu 2001), rice (Kraska and Breitenbeck 2010), and wheat (Ahmad *et al*. 1992). Trenholm *et al*. (2004) have suggested that silicate crystals deposited in epidermal cells form a barrier that reduced water loss through the cuticles.

Romero-Aranda *et al*. (2006) have suggested that silicate crystals deposited in the epidermal cells form a barrier that reduces water loss through cuticle, which in turn, contributes to salt dilution, mitigating salt toxicity effects in tomato. More recently, Si benefits on salt tolerance of barley and cucumber have been related to antioxidant enzyme activity (Liang *et al*. 2003; Zhu *et al*. 2004).

Among the mineral nutrients, potassium is known to be very dynamic and a major contributor to the organic structure and metabolic functions of the plant. Potassium contents in plant tissues progressively decrease with increasing salinity. Therefore, maintenance of adequate level of K^+ is essential for plant survival under salt stress.

Potassium has substantial effect on enzyme activation, protein synthesis, photosynthesis, stomatal movement, and water relation in plants (Marschner 1995). Increased application of potassium has been shown to enhance photosynthetic rate, plant growth and yield in different crops under salinity water stress conditions (Egilla *et al*. 2001). For example, exogenous application of potassium ameliorated adverse effects of salt stress in wheat (Akram *et al*. 2007), rice (Bohra and Doerffling 1993), tomato (Lopez and Satti 1996), cucumber, and pepper (Kaya *et al*. 2001).

The aim of this study was to evaluate the effect of different concentrations of NaCl on plant growth and yield and the contribution of silicon and potassium nitrate foliar application to salt tolerance of wheat.

RESULTS AND DISCUSSION

Germination test

The results of analysis of variance on germination indexes are given in Table 1. There are significant differences between cultivars and NaCl stress levels. Comparisons