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Effects of silicon to salt stress on strawberry plant

Silisyumun çilek bitkisinde tuz stresine etkileri

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ABSTRACT

Strawberry is often affected by salinity due to poor drainage and excessive fertilization. Silicon application is becoming a feasible and cheap treatment to relieve the damages of salt stress. In the current study, the effects of silicon was investigated on plant growth, relative chlorophyll content and stomatal conductance of strawberry plant. A strawberry plant (*Fragaria* × *ananassa* Duch.) cv Kabarla was chosen for the experiment with following a randomized plot design involving three replications, with three plants per replication. Up until the start of the experiment, all plants were irrigated with tap water and 1 month later plants were applied with three different $CaSiO_3$ doses (0.5, 1 and 2 mM) and were watered with 35 mM NaCl solution. Control and salt plants were not applied with $CaSiO_3$, salt plants were watered with NaCl solution compared to control. Three months after the salinity (in March), many plant growth properties such as root volume, root tissue density, root mass ratio, shoot mass ratio, were evaluated. End of the study, salt decreased root volume by 37% compared to the control, while 1 mM Si decreased 26%. Root tissue density was significantly reduced when plants were subjected to salt stress. Compared to the control group, salt decreased root tissue density by 34%, while 0.5 mM Si declined by 2%. As a result, Si diminished the adverse effects of salt stress on strawberry plant growth.

Key Words: Plant growth, Salt stress, Silicon, Strawberry

ÖZ

Çilek bitkisi yetersiz drenaj ve aşırı gübrelemeden dolayı tuzluluktan etkilenmektedir. Silisyum, tuz stresinin zararlı etkilerini azaltmada hem uygun hem de ucuz bir uygulamadır. Çalışmamızda silisyumun; bitki gelişimi, nispi klorofil içeriği ve stoma iletkenliği üzerine etkileri araştırılmıştır. Kabarla çilek çeşidi çalışma için seçilmiş ve deneme tesadüf parselleri deneme desenine göre 3 tekerrürlü ve her tekerrürde 3 bitki olacak şekilde kurulmuştur. Deneme başlayana kadar tüm bitkiler musluk suyu ile sulanmıştır ve dikimden 1 ay sonra bitkilere 3 farklı dozda $CaSiO_3$ (0.5, 1 ve 2 mM) uygulanmış ve 35 mM NaCl çözeltisi verilmiştir. Kontrol ve tuz bitkilerine $CaSiO_3$ uygulanmamış olup tuz uygulanan bitkiler kontrol bitkileriyle kıyas edilmiştir. Üç aylık tuz stresinden sonra (Mart ayında) kök hacmi, kök yoğunluğu, kök ağırlık oranı, sürgün ağırlık oranı gibi birçok bitki büyüme özellikleri değerlendirilmiştir. Çalışma sonucunda, tuz kök hacmini kontrol grubuna kıyasla %37 azaltırken, 1 mM Si %26 azaltmıştır. Tuz stresine maruz bırakılan bitkilerde kök yoğunluğu önemli derecede azalmıştır. Kontrol grubuna kıyasla, tuz grubu bitkileri kök yoğunluğunu %34 azaltırken, 0.5 mM silisyum %2 azaltmıştır. Sonuç olarak, silisyum çilek bitkilerinde tuz stresinin zararlı etkilerini azaltmıştır.

Anahtar Kelimeler: Bitki gelişimi, Tuz stresi, Silisyum, Çilek

Introduction

Salt stress is one of the most critical environmental stresses impairing the productivity of many horticultural crops, affecting about 20% of the world's cultivated land (Cao, et al., 2018). Increasing soil salinity possess a major threat to plant growth and production of crops worldwide, especially in the regions of poor drainage, excessive fertilization and near seashore lands (Chinnusamy et al., 2005; Aras & Eşitken, 2018). Growth and yield reductions due to the presence of salt stress have been reported for many plants (Akçay & Eşitken, 2017; Kaya & İnan, 2017; Aras & Eşitken, 2018; Çebi et al., 2018). Strawberry has been suggested to be salt-affected and can result diminish in strawberry fruit yield and quality (Garriga et al., 2015). Salt-induced morpho-physiological alterations in strawberry have been reported (Turhan & Eris, 2005; Özlem & Yıldız, 2014). Among soluble salts, sodium chloride (NaCl) is the dominant salt type with malignant effects on plant growth and fruit production (Pessarakli & Szabolcs, 2010). The major influences of NaCl salinity on strawberry include accelerating leaf necrosis, senescence, peroxidation of lipids and decrease in photosynthesis (Pırlak & Eşitken, 2004; Turhan et al., 2008; Tanou et al., 2009).

In regard with several detrimental effects of salt stress on strawberry plant, finding a suitable strategy is of great importance. Many management practices such as use of salt tolerant varieties, seed priming and treatment of chemicals promoting growth can be applied plants in order to acquiring salinity tolerance (Shaka et al., 2016). Moreover, the strategies for removing the inhibitory effect of salt stress on plant growth such as using beneficial mineral nutrients can be applied to plants. In recent years, use of silicon (Si) as a new approach has been put forward and has yielded very promising results. Silicon is the second most abundant element which is ubiquitously present in the environment (Broadley et al., 2002). Silicon nutrition has been shown as an important application to mitigate enviromental stresses (Zhu et al., 2006; Pavlovic et al., 2013). Furthermore, the ameliorative effects of Si have been well documented in inducing salt tolerance in many crops (Liang et al., 2005; Murillo-Amador et al., 2007; Dehghanipoodeh et al., 2016). Root-applied Si is an important approach to decrease the undesirable effects of salt stress on plants. Some researchers have been reported that Si treatment leads to reinforcement of cell walls due to deposition of Si in the form of amorphous silica that decrease the translocation of salts to the shoots (Wang et al., 2004). Liang et al. (2003) used Si to reduce the damaging effects of salt stress on barley plant, and reported that silicon-induced cell membrane integrity, stability and function of barley plant may be closely associated with enhanced salt tolerance.

Strawberry is one of the most important berry fruits which is widely distributed around the world with a large scale and is sensitive to salt stress. In this research, the effects of different concentrations of silicon were investigated on several characteristics such as root volume, root tissue density, root mass ratio, shoot mass ratio, root:shoot dry weight, SPAD and stomatal conductance in the presence or absence of salt stress in strawberry plant.

Material and Methods

Pot trials and experimental design

The study was conducted in 2015 (in November)- 2016 (in March) in a heated greenhouse of Department of Horticulture at Selcuk University in Turkey. A strawberry plant (*Fragaria × ananassa* Duch.) cv Kabarla was chosen for the experiment with following a randomized plot design involving three replications, with three plants per replication and was planted in 5 L pots filled with mixture of soil, peat and perlite in a volume proportion of 1:4:1 in November in 2015. Up until the start of the experiment, all plants were irrigated with tap water and 1 month later plants were applied with three different $CaSiO_3$ doses (0.5, 1 and 2 mM) and were watered with 35 mM NaCl solution. We chose 35 mM dose for NaCl treatment, because that dose is used in many studies and reveals the symptoms of moderate salt stress for strawberry (Kaya et al., 2002; Keutgen & Pawelzik, 2008; Karlidag et al., 2011). Control and salt plants were not applied with $CaSiO_3$, salt plants were watered with NaCl solution compared to control. Irrigation was performed once two days and excess solution was allowed to drain from the pot. Three months after the salinity (in March), many plant growth properties were evaluated.

Growth measurements and physiological determinations

The growth promoting effects of $CaSiO_3$ treatments were evaluated by determination of root volume, root and shoot dry and fresh weights. Root and shoot dry weights were measured after drying the plant material at 70°C for 48-72 hours. The value of root:shoot dry weight was calculated as dry weights of root/shoot. Moreover, root volume, root mass ratio (RMR, root dry weight/whole dry weight, g g^{-1}), shoot mass ratio (SMR, shoot dry weight/whole dry weight, g g^{-1}), and root tissue density (RTD, root dry weight/root volume, g cm^{-3}) were calculated as reported previously (Lupini, et al., 2016).

Relative chlorophyll (SPAD) value was measured with a Minolta SPAD-502 chlorophyll meter (Minolta Camera Co, Ltd, Osaka, Japan). Stomatal conductivity was conducted on the youngest fully expanded leaves on upper branches of the plants with leaf porometer.

Statistical analyses were performed with the statistical software package SPSS, version 20.0. The means were compared by the Duncan' s test at 5%.

Results

In order to investigate Si during moderate salinity, prior to the salt stress period strawberry plants were treated with exogenous $CaSiO_3$. During the study, plants began to display visible symptoms of salt stress after 2 months of exposure to salinity.

To demonstrate the effect of Si pretreatment on strawberry growth under salinity condition, root volume, root tissue density, root mass ratio and shoot mass ratio were determined. With prolonged stress, salt treatment limited root volume and root tissue density and Si treatment provided better plant growth (Table 1). Salt decreased root volume by 37% compared to the control, while 1 mM Si decreased %26. Root tissue density was significantly reduced when plants were subjected to salt stress. Compared to the control group, salt decreased root tissue density by 34%, while 0.5 mM Si declined 2%.

Table 1. Effect of silicon on plant growth
Çizelge 1. Silisyumun bitki gelişimine etkisi

Uygulamalar *Treatments*	Root volume (cm^3) *Kök Hacmi (cm^3)*	Root tissue density (g cm^{-3}) *Kök yoğunluğu (g cm^{-3})*	Root mass ratio (g g^{-1}) *Kök ağırlık oranı (g g^{-1})*	Shoot mass ratio (g g^{-1}) *Sürgün ağırlık oranı (g g^{-1})*	Root:shoot dry weight *Kuru kök: kuru sürgün*
Control *Kontrol*	45.0 a	0.117 a	0.269 ab	0.740	0.363
Salt *Tuz*	28.3 b	0.077 b	0.211 b	0.737	0.286
$CaSiO_3$ (0.5 mM) + Salt *$CaSiO_3$ (0.5 mM) + Tuz*	31.6 b	0.115 a	0.266 ab	0.739	0.359
$CaSiO_3$ (1 mM) + Salt *$CaSiO_3$ (1 mM) + Tuz*	33.3 ab	0.093 ab	0.282 a	0.747	0.377
$CaSiO_3$ (2 mM) + Salt *$CaSiO_3$ (2 mM) +Tuz*	31.6 b	0.100 ab	0.304 a	0.753	0.403

Means separation within column by Duncan's multiple range test, $P<0.05$
Ortalamalar Duncan' ın çolu karşılaştırma testine göre ayrılmıştır, $P<0.05$

Salt treatment limited root mass ratio and Si applied salted plants overcame salinity damages and provided better root mass ratio compared to the control. 2 mM Si application increased root mass ratio 13% compared to the control. However, exogenous application of Si showed non-significant effects on shoot mass ratio. We concluded that Si pretreatment significantly ($P < 0.05$) alleviated the inhibition of plant growth under salt stress.

SPAD values and stomatal conductance of all treatments were presented in Table 2. A marked decrease in SPAD value was observed in salt treated plant leaves by 16% compared to control. The treatments did not significantly affect the stomatal conductance. However, salt treatment caused decrease in stomatal conductance by 8% compared to control. Moreover, Si applications increased stomatal conductance by 16-19% compared to control.

Table 2. Effect of silicon on SPAD and stomatal conductance
Çizelge 2. Silisyumun SPAD ve stoma iletkenliğine etkisi

Uygulamalar *Treatments*	SPAD	Stomatal conductance (m mol m^{-2} s^{-1}) *Stoma iletkenliği (m mol m^{-2} s^{-1})*
Control *Kontrol*	45.46 a	111.60
Salt *Tuz*	38.40 b	102.83
$CaSiO_3$(0.5 mM) + Salt *$CaSiO_3$ (0.5 mM) + Tuz*	39.66 b	132.96
$CaSiO_3$(1 mM) + Salt *$CaSiO_3$ (1 mM) + Tuz*	40.83 b	131.96
$CaSiO_3$ (2 mM) + Salt *$CaSiO_3$ (2 mM) + Tuz*	41.53 ab	129.03

Means separation within column by Duncan's multiple range test, P<0.05
Ortalamalar Duncan'ın çoklu karşılaştırma testine göre ayrılmıştır, P<0.05

Discussion

Salinity is an adverse environmental factor limiting strawberry growth and yields (Turhan & Eriş, 2007; Keutgen & Pawelzik, 2008). Thus, searching an effective way of mitigation salinity damage in strawberry plants is important for strawberry production. Silicon has been demonstrated to protect many plants against salt stress. However, little information is available on the involvement of Si in growth of strawberry plant under salt stress. In the current study, we investigated the growth impacts of Si on strawberry plant under salinity condition.

Salinity caused a significant reduction on plant growth. Our study showed that root growth was more inhibited by NaCl than shoot growth. Roots are the most vulnerable part of the plant due to being directly exposed to salt, but nevertheless they are surprisingly robust (Meloni et al., 2004). Apparently, in the present study less carbon was distributed to the roots of the salt plants and dry matter was allocated to roots with 1 and 2 mM Si applications. Si applications provided higher root and shoot mass ratios compared to control plants. Higher organic matter accumulation by Si application may be related salt tolerance against salt stress. Organic solutes may contribute to osmotic adjustment, protecting cell structure and function (Hasegawa et al., 2000; de Lacerda, et al., 2005).

In the plant growth model proposed by Thornley (1972), the growth depends on the supply of carbon from shoot and nitrogen from roots to shoots. In our work, 1 and 2 mM Si applications leaded to increase in biomass in roots, therefore, leaded an elevation in biomass partitioning towards the roots, where as salt stress favoured biomass partitioning towards the shoots. Preferential partitioning of carbon to the roots and increase in root-shoot dry weight ratio under salt stress condition are also well documented for tomato plants treated by calcium sulphate (Tuna et al., 2007).

In the current experiment, salt stress impaired the strawberry growth and the decrease in plant growth subjected to stresses is often associated with decline in photosynthesis (Hu et al., 2013). Chlorophyll plays a pivotal role in photosynthesis and chlorophyll breakdown is a common process under salt stress (Moradi & Ismail, 2007; Mehta et al., 2010). In our study, there are significant inhibitions of the chlorophyll reductions by Si compared to control. The inhibition of the chlorophyll loss by Si attributed the plant growth via prevention of the photosynthesis reduction. Haghighi and Pessarakli (2013) also reported Si application prevented the chlorophyll loss in tomato plant under salinity condition. Salinity-inhibition of plant growth may be also due to the stomatal closure. The treatments did not significantly affect the stomatal conductance. However, salt treatment decreased stomatal conductance and Si applications caused increases in stomatal conductance compared to control.

Our study showed that salt stress restricted the growth of strawberry plant and pre-treatment Si increased plant growth significantly under salt stress. The positive effect of the Si application was more pronounced on the data of increased root mass ratio, shoot mass ratio and root:shoot dry weight. The promotion of plant growth by silicon under salt stress condition may be attributed to reinforcement of the cell walls and membranes by acting as a physical barrier. Moreover, the larger plant growth could be explained by the effect of Si on the prevention of the chlorophyll loss and increasing stomatal conductance, consequently hampering the photosynthesis reduction. Thus, Si diminished the adverse effects of salt stress on strawberry plant growth. This may help improve the growth of commercial strawberry grown worldwide.

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