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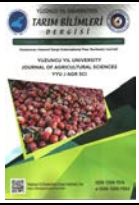

Araştırma Makalesi (Research Article)

Responses of Apple Plants to Salinity Stress

Servet ARAS[1*], Ahmet EŞİTKEN[2]

[1]Yozgat Bozok Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, 66200, Yozgat, Türkiye
[2]Selçuk Üniversitesi, Ziraat Fakültesi, Bahçe Bitkileri Bölümü, 42030, Konya, Türkiye
*Sorumlu yazar e-posta: servet.aras@bozok.edu.tr

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Abstract: Salt stress is a common agricultural problem that affects both quantity and quality of fruit crops. Responses of rootstocks against salinity possess importance due to demonstrating stress tolerance. Little is known about the early responses of apple plants to short term salinity. In our study, we investigated the physiological responses of an apple plant cv Fuji grafted onto M9 and MM106 rootstocks against 35 mM NaCl stress. After 1 month, salt-treated plants exhibited decreased chlorophyll content (SPAD). Salt stress decreased stomatal conductance values of Fuji/M9 and Fuji/MM106 by 17.0 and 30.1%, respectively when compared with own control. Membrane permeability decreased by 21.3 and 22.0% in salt-treated Fuji/M9 and Fuji/MM106, respectively compared with own control. Reduction due to salt stress in SPAD value, stomatal conductance and leaf relative water content and increase in leaf temperature and membrane permeability were greater in Fuji/MM106 than in Fuji/M9, suggesting that under short term salinity toxic effects of NaCl were less in Fuji/M9.

Elma Bitkilerinin Tuz Stresine Tepkileri

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Anahtar Kelimeler
Anaç,
Malus,
Tepki,
Tuzluluk

Öz: Tuz stresi meyve verim ve kalitesini etkileyen önemli bir tarım sorunudur. Tuzluluğa karşı anaçların tepkisi strese karşı toleransı sergilediğinden dolayı büyük bir önem arz etmektedir. Elma bitkisinin kısa dönemli tuzluluğa etkileri hakkında fazla bir bilgi bulunmamaktadır. Çalışmamızda, M9 ve MM106 anaçlarına aşılı Fuji elma çeşidinin 35 mM NaCl stresine verdiği fizyolojik tepkiler araştırılmıştır. Bir ay sonra, tuz uygulanan bitkilerde düşük klorofil içeriği (SPAD) görülmüştür. Tuz stresi stoma iletkenliğini Fuji/M9 ve Fuji/MM106' da kontrol bitkilerine kıyasla sırasıyla % 17.0 ve 30.1 oranında azaltmıştır. Membran geçirgenliği tuz uygulanan Fuji/M9 ve Fuji/MM106' da kontrol bitkilerine kıyasla sırasıyla % 21.3 ve 22.0 oranında azalmıştır. Tuz stresinden dolayı SPAD değerinde, stoma iletkenliğinde ve yaprak oransal su içeriğinde azalma ve yaprak sıcaklığı ve membran geçirgenliğindeki artış Fuji/M9' a kıyasla Fuji/MM106' da daha yüksek görülmüş olup, kısa dönemli tuzluluğun toksik etkileri Fuji/M9'da daha az görülmüştür.

1. Introduction

Salinity stress has already become a worldwide environmental problem limiting the growth, development, and yield production in crops. Temperate fruit trees are salt-sensitive plants and among fruit species, apple trees have been suggested to be salt-affected (Maas, 1986; Fu et al., 2013).

When fruit species undergo salt stress, many responses are observed, including the reduction in nutrient uptake, stomatal conductance, protein synthesis, peroxidation of lipids (Bressan et al., 1990; Yin et al., 2010). Furthermore, salt stress disrupts the biosynthesis of photosynthetic pigments and declines photosynthesis in plants (Parihar et al., 2015). Decline in plant growth under salt stress has been reported for many fruit species (Aras et al., 2015; Koc et al., 2016a,b; Akçay and Eşitken, 2017; Aras and Eşitken, 2018).

To alleviate the effects of salinity, research in horticulture has adressed strategies capable to improve the plant tolerance to stress damage. The investigations were conducted in the past by many authors (Najafian et al., 2008; Zrig et al., 2011; Aras and Eşitken, 2018), mainly aimed at controlling plant tolerance with use of tolerant rootstocks. Moreover, rootstocks affect the nutritional status of the scion and plant height. Evaluation and screening of apple rootstocks are prominent to rootstock recommendations for salt areas. Therefore, plant responses possess a remarkable importance for screening salt tolerant rootstock. Yin et al. (2010), demonstrated that plant growth and relative water content decreased and electrolyte leakage and antioxidant enzyme activities increased in Chinese apple rootstocks under sodium chloride (NaCl) stress. In other study, Fu et al. (2013) evaluated physiological responses such as alterations in photosynthesis, membrane permeability, relative water content of some apple biotypes under salt stress. Under high salinity conditions, all growth parameters except membrane permeability were significantly decreased compared with the untreated control. Deleterious effects of salinity were reported in both herbaceous and woody plants (El-Desouky and Atawia 1998; Civelek and Yıldırım, 2019; Kıpçak et al., 2019; Turhan and Kuşçu, 2019).

Apple (*Malus domestica* Borkh) is an important fruit, which is consumed widely in the world due to its palatable flavor and rich nutrient. Some previous experiments revealed the responses of apple plant to salt stress. However, little evidence is available to date on the influence that the responses of apple plants to short term salinity. The present study examines the physiological responses of apple under short term salinity stress using two rootstocks with Fuji cultivar.

2. Materials and Methods

The study was conducted in 2014 in a greenhouse of Department of Horticulture at Selcuk University in Turkey. An apple plant (*Malus domestica* Borkh.) cv Fuji grafted onto M9 and MM106 were planted in 13 L pots consisted of soil, substrate and perlite. After one month from the initiation of the study, salt-treated plants were watered with fertilizer solution containing 35 mM NaCl during a month (growing media's salinity of plants exposed salt stress maintained in a range of 2.5-3.0 mS cm^{-1} EC through applying 35 mM NaCl), because this salt concentration is appropriate for moderate salinity in temperate zone fruit species shown in many studies (Akçay and Eşitken, 2017; Aras and Eşitken, 2018). Salt was not added to the irrigation solution of control plants. Excess solution was allowed to drain from the pot. The experiment was arranged in a randomized plot design with three replicates of three plants per replication.

Relative chlorophyll value was measured with a Minolta SPAD-502 chlorophyll meter (Minolta Camera Co, Ltd, Osaka, Japan). Stomatal conductivity and leaf temperature measurements were conducted on the leaves via leaf porometer.

Membrane permeability was determined according to the method described by Lutts et al. (1996). Pieces of leaves were taken and cut into equal-sized 1 cm segments. Leaf pieces were placed in stoppered vials containing 10 mL of distilled water and were then incubated at room temperature (25^{o}C) on a shaker (100 rpm) for 24 h. Electrical conductivity (EC) of the solution (EC_1) was measured after incubation. The samples were autoclaved at 120^{o}C for 20 min and then cooled to 25^{o}C to obtain second measurement (EC_2). The leakage was calculated as EC_1/EC_2 and expressed as percent.

Leaf relative water content (LRWC) was determined by the procedure of Smart and Bingham (1974). Fresh weights (FW) of leaves were determined and then leaves were placed in distilled water to rehydrate. After 5 hours, turgid weights (TW) were determined. Afterward, leaves were oven-dried and dry weights (DW) were determined. LRWC was calculated using the equation as:

$$LRWC(\%) = [(FW-DW)/(TW-DW)] \times 100 \quad (1)$$

SPSS software (20.0) was used to perform the statistical analyses. Significance was determined at the 5% level by the Duncan' s test.

3. Results

The physiological responses of apple plants were significantly changed under 35 mM NaCl condition (Table 1). The toxicity of salinity had effects on the physiology of apple plant. Responses to salinity stress were similar between Fuji apple plants grafted onto two rootstocks. Between rootstocks, Fuji/M9 had the highest SPAD value (49.89). Salt treated plants had lower stomatal conductance. Salt stress decreased stomatal conductance values of Fuji/M9 and Fuji/MM106 by 17.0 and 30.1%, respectively when compared with own control. Under salt stress condition, the leaf temperature was decreased by 2 and 3.8% in Fuji/M9 and Fuji/MM106, respectively compared with own control. Control plants presented lower membrane permeability values. Membrane permeability decreased by 21.3 and 22.0% in Fuji/M9 and Fuji/MM106, respectively compared with own control. Fuji/M9 had the highest leaf relative water content (91.42%).

Table 1. Effects of salinity on responses of apple plants

Treatment	Scion/ Rootstock	SPAD	Stomatal conductance (mmol m^{-2} s^{-1})	Leaf temperature (°C)	Membrane permeability (%)	LRWC (%)
Control	Fuji/M9	49.89 a	227.58 a	26.91 c	11.86 b	91.42 a
	Fuji/MM106	45.38 b	226.90 a	28.91 b	12.66 ab	86.73 a
35 mM NaCl	Fuji/M9	46.89 ab	188.73 ab	27.46 c	14.39 ab	87.43 a
	Fuji/MM106	40.27 c	158.56 b	30.01 a	15.44 a	74.45 b

4. Discussion and Conclusion

Our study showed that physiological responses in apple plants was affected by salt stress and suggest that the grafted M9 and MM106 rootstocks are not very sensitive to soil salinity if the condition is maintained for a relatively short period. In a previous study, we also found a similar reduction in SPAD and LRWC in cherry rootstocks irrigated with 35 mM NaCl (Aras and Eşitken 2018). Moreover, short term salinity stress did not cause any symptom or necrosis on the leaves. However, relative chlorophyll content (SPAD value) decreased in both rootstock under salt stress. Reduction in chlorophyll under salinity can be attributed to decrease in chlorophyll biosynthesis or increase in chlorophyll degradation (El-Desouky and Atawia 1998; Murkute et al. 2006). In the current experiment, chlorophyll loss by salinity was higher in Fuji/MM106 plant. Tavallali et al. (2008) reported similar result that salinity declined chlorophyll.

As plants begins to experience salt stress, stomatal conductance decreased to transpiration. Decline in stomatal conductance is an adaptive mechanism against salt stress to prevent leaf dehydration (Koyro 2006). Stomatal conductance decreased by about 30% in Fuji/MM106 compared to the control. Our results are agreement with previous reports in which stomatal conductance decreased by salinity (Massai et al. 2004). Leaf temperature changes under stress conditions. In a previous study, leaf temperature of maize plant increased under dehydration stress (Dalil and Ghassemi-Golezani 2012). In the present study, salt stress significantly increased leaf temperature. We found leaf temperature of cherry rootstocks increased under short term salinity in a previous experiment (Aras and Eşitken 2018). Decrease in leaf temperature may be a result of stomatal closure leading decrease in transpiration and temperature.

Salt stress affects degree of stability in cell membranes and increment of membrane permeability is an obvious outcome of salt stress (Fu et al. 2013). It was reported that membrane permeability can be used as an indicator of salt damage (Aras and Eşitken 2018). In our experiment, increase in membrane permeability under salinity was similar for both grafted rootstocks. Moreover, there were not great increases in membrane permeability for both rootstocks under salt stress, indicating that NaCl stress did not led to serious damage to integrity of cell membranes under short term salinity. Leaf relative water content (LRWC) is an important physiological measurement to determine differences among plants in their tolerance to salinity (Garriga et al. 2015). Significant reduction in LRWC as obtained here has been reported by Fu et al. (2013). Salt accumulation makes it harder for plants to uptake water from saline environment (Flowers and Colmer 2008; Zhu et al. 2012). Water loss in leaves was higher in Fuji/MM106 under salinity.

We addressed for the first time the effects of short term salinization on grafted apple rootstocks. Salinity triggered similar responses in both grafted rootstocks. Reduction due to salt stress in SPAD value, stomatal conductance and LRWC and increase in leaf temperature and membrane permeability were greater in Fuji/MM106 than in Fuji/M9, suggesting that under short term salinity toxic effects of NaCl were less in Fuji/M9.

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