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Role of fig rootstock on changes of water status and nutrient concentrations in 'Sabz' cultivar under drought stress condition

Moslem Jafari[a,b], Majid Rahemi[a,*], Ali Akbar Kamgar Haghighi[c]

[a] *Department of Horticultural Science, Shiraz University, Shiraz, Iran*

[b] *Fig Reseach Station, Fars Agricultural and Natural Resources Research and Education Center, Agricultural Research, Education and Extension Organization (AREEO), Estahban, Iran*

[c] *Department of Water Engineering, Shiraz University, Shiraz, Iran*

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ABSTRACT

To investigate the effects of fig rootstocks on scion water and nutrient content under drought stress conditions, 'Sabz' cultivar was budded onto rootstocks of 'Siah', 'Shah Anjir', 'Dehdez', 'Matti' and 'Tousorkh'. Stem water potential (Ψ_{stem}), relative water content (RWC), stomatal conductance (g_s) and leaf concentration of N (nitrogen), P (phosphorous), K (potassium), Ca (calcium), Zn (zink), and Fe (ferrous) were measured in scion and root growth factors in rootstocks. The results showed that rootstocks altered scion leaf Ψ_{stem}, RWC, g_s and some mineral concentrations significantly. Plants on 'Shah Anjir' rootstock had the greatest leaf concentrations of N and Zn whereas 'Siah' was the most efficient rootstock in P uptake. Under drought stress, 'Siah' and 'Dehdez' rootstocks transferred more amounts of water to 'Sabz' scion cultivar. Leaf P and K concentrations, g_s in the scion leaves and root volume of rootstocks were positively correlated with RWC of scion under drought stress.

1. Introduction

Fig (*Ficus carrica* L.) is one of the most important horticultural crops grown in arid and semi-arid regions of Iran where is one of the largest dried fig production centers in the world (FAO stat, 2011). Estahban, located in the south-east of Fars province of Iran, is the biggest dry fig producer area in Iran. 'Sabz' cultivar is the best commercial cultivar of dry fig in Iran. Establishment of rain-fed fig orchards has decreased in this region in the last decade because of reduction in the rain fall. Nevertheless, some cultivars show better tolerance to drought than the others in this situation. Although fig trees are drought tolerant, they still require sufficient amount of water for optimal performance and production. In general, nutrient availability, roots uptake and transfer to the shoots are reduced under water stress conditions (Goicoechea et al., 1997). However, there are very limited numbers of research dealing with the effect of top and root relationship on water and nutritional status of fig under water stress. 'Zidi' is a vigorous and suitable rootstock for 'Masui Dauphine' fig trees in the orchards with soil sickness. 'Zidi' rootstock had no effect on fruit brix and skin color (Hosomi et al., 2002). Ibnouali-El-Aloui et al. (2005) reported that root biomass and weight of fig tree are important to introduce of drought tolerant genotypes. Mechanism of drought resistance in tree crops is associated with roots (hydraulic conductivity, root length and deeply rooting habit (Rieger and Duemmel, 1992)). In drought conditions deep root systems provide a better protection. Drought-tolerant grapevine (*Vitis vinifera* L.) rootstocks, as compared to drought-sensitive rootstocks, had more new roots during a dry and hot season allowing the grapevine to increase the uptake of water (Serra et al., 2014). Drought tolerant rootstocks can have positive effects on fruit yield and quality under water stress conditions. Root structure and density of rootstocks can show different ability to use available water in the soil (Romero and Botía, 2006). In plants that are routinely grafted, such as grapevine rootstocks provide tolerance to exogenous limiting factors such as pests, salinity, water and oxygen deficit (Rizk-Alla et al., 2011; Marguerit et al., 2012). Optimizing the balance between carbon gain and water loss of the plant is controlled by stomata (Rogiers et al., 2011). The patterns of stomata response, in terms of timing and intensity, are genetically determined (Chaves et al., 2010). For ranking of the drought tolerant scion genotypes the relationship between stomatal conductance and leaf water potential was used (Rogiers et al., 2011). Stomatal conductance should be considered as equally essential to the necessary progress in yield potential as other traits such as resistance to biotic stresses (Roche, 2015). However, the interaction between rootstock and scion on plant adaptation to stress is still very much debated (Gambetta et al., 2012). Water and nutrients uptake depend on morphological and anatomical characteristics of the root system (Fitter, 1991).

* Corresponding author.
E-mail addresses: figmanestahban@gmail.com (M. Jafari), rahemi@shirazu.ac.ir (M. Rahemi), akbarkamgar@yahoo.com (A.A.K. Haghighi).

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This study aimed to investigate the effects of fig rootstock on water status and nutrient concentrations of the scion leaves under drought stress condition for improvement fig production under rain-fed conditions.

2. Material and methods

2.1. Plant material

Cuttings from 1-year-old shoots of mature fig trees (*Ficus carica* L. 'Sabz', 'Siah', 'Shah Anjir', 'Matti', and 'Tousorkh') were collected in the Estahban Fig Research Station, Fars province, Iran. 'Dehdez' was collected from the Ize Mountains of Khouzestan province. 'Dehdez' and 'Tousorkh' were two wild genotypes and 'Dehdez' has been referred as 'Deym-e-Ahvaz' in the previous research by Gholami et al. (2012). There were not any rooted plants of these cultivars in any nursery except 'Sabz' cultivar. So, for rooting of cuttings the bases of the cuttings (20 cm height and 1 cm width) were treated with indole-3-butyric acid (1500 ppm in 96% ethanol) and planted in the sand.

2.2. Root measurement and growth condition

After 11 months, root parameters (including number, fresh weight, root length and volume) of 'Sabz' scion cultivar were compared statistically with other used genotypes (rootstocks). The roots were separated from the base of cuttings and the fresh weight of roots were measured by digital balance immediately. The main roots which had above 3 mm diameter were counted and the length of root in each gynotype was measured by ruler. The root volume obtained with a graduated cylander. Rootstocks were replanted in 20 liters containers filled with a mixture of leaf mould, sand, and soil (1:1:1, v/v/v) and were kept under greenhouse conditions. The physicochemical properties and nutrients availebility of the used media were shown in Table 1. The minimum and maximum temperatures during the experiment were 26 and 38 °C, respectively. Mean relative humidity was 65% and light intensity was 28.5 W/m^2.

The field capacity of the soil used for potting was determined according to the protocol described by Richards (1949). Potted fig trees were irrigated daily for 6 months to field capacity level, for proper growth and establishment and 10 g of water soluble fertilizer (N-P-K) used for each plant.

2.3. Accomplishment of drought stress

In the late August 2014 all rootstocks were budded (Inverted T) with scion of 'Sabz' cultivar. The budded plants were kept in an optimal soil water conditions (Field capacity) in the greenhouse for 6 months. The plants of each rootstock were divided in two groups: drought-stressed plants (SP) and control plants (CP) at the start of experiment. CP were maintained in field capacity during the experimental period, whereas SP subjected to drought period by withholding irrigation for 14 days until the plants showed a strong loss of turgidity. In the 1th day of experiment all budded plants were in field capacity level. After the drought period, the SP reirrigated to field capacity level and recovery rate of budded plants were evaluated after 7 days. Stem water potential (Ψ_{stem}), relative water content (RWC) and stomatal conductance (g_s) were measured on days 1, 7, 14 and 21. Nutrients content of scion leaf were measured only on days 1 (Field capacity) and 14 (drought stress) after the start of experiment.

2.4. **Relative water content** (RWC)

RWC was determined as (FW − DW)/(TW − DW) × 100, in leaves where FW is the fresh weight, DW is the dry weight after oven-drying the leaves at 80°C for 24 h and TW is the turgid weight after re-hydrating the leaves at 4 °C. Four leaves were used for RWC measurement in each replication.

2.5. Stem water potential (Ψ_{stem})

Ψ_{stem} was measured with a pressure bomb (PMS Instr. Co., Corvallis, OR, USA). The full expanded leaves in the middel of the branch were enclosed in a cellophane bag covered with aluminum foil at least 1 h before measurement. This enabled water potential in the xylem of the leaf to come to equilibrium with the potential in the xylem of the stem at attachment point of the petiole (Garnier and Berger, 1985). Ψ_{stem} was measured at midday.

2.6. Stomatal conductance (g_s)

The g_s was measured on fully developed leaves with a portable Leaf Prometer System (SC-1, Pullman, WA 99163-USA) at midday. Measurements were conducted by clamping the leaves in the leaf chamber, it does not impact the environment and instead determines stomatal conductance by measuring the actual vapor flux from the leaf through the stomates and out to the environment. Four fully expanded leaves were used for g_s measurement. After measuring g_s, the same leaves were used for measuring Ψ_{stem}.

2.7. Nutrients analysis

Leaf mineral concentrations were calculated for days 1 and 14 for nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), ferrous (Fe) and zink (Zn). The leaves that used for determation of Ψ_{stem} were washed with a mild detergent, then rinsed with distilled water and dried in a forced air drying oven at 70 °C to constant weight. The leaves were ground to pass a 40 mesh screen. One g of dried ground leaf sample was ashed at 550 °C for 5 h. Then ash was dissolved in 5 ml of 20% HCl and filled up to 50 ml with de-ionised/distilled water. These samples were analyzed for Ca, Fe and Zn by using an atomic absorbance spectrophotometer (Chapman and Pratt, 1961), P by spectrophotometer (Chapman and Pratt, 1961) and K by flame photometry (Knudsen et al., 1982). To determine the amount of N, approximately 0.18 g of dried leaf tissue of each sample was combusted, and total N (expressed as percentage of dry weight) in the tissue was measured by Kjeldahl method (Bremner, 1996).

2.8. Statistical analysis

In the first step of experiment, a completely randomized design with five replications used for comparing of root system in rootstocks. A completely randomized design, consisting of 5 rootstocks ('Siah', 'Shah

Table 1
Physicochemical properties of growing media.

Available Zn ($\mu g\ g^{-1}$)	Available Fe ($\mu g\ g^{-1}$)	Available Ca ($\mu g\ g^{-1}$)	Total K ($\mu g\ g^{-1}$)	Available P ($\mu g\ g^{-1}$)	Total N (%)	Organic carbon (%)	pH	EC ($dS\ m^{-1}$)
1.5	7.16	7480	400	23.8	0.194	1.54	6.97	0.94
Clay(%)		Silt(%)		Sand(%)		Texture		
34.4		44.2		21.4		Clay loam		