Agricultural Water Management 185 (2017) 1–12

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Long-term field response of pistachio to irrigation water salinity

Houda Mehdi-Tounsi[a,1], Azza Chelli-Chaabouni[b,*,1], Dalenda Mahjoub-Boujnah[c], Makki Boukhris[a]

[a] Laboratoire de Biologie des plantes, Faculté des Sciences de Sfax, Université de Sfax, PB 1171, 3000 Sfax, Tunisia
[b] Laboratoire d'Amélioration et de Protection des Ressources Génétiques de l'Olivier, Institut de l'Olivier, Université de Sfax, BP 1087, 3000 Sfax, Tunisia
[c] Laboratoire d'Amélioration de la Productivité de l'Olivier et de la qualité du Produit, Institut de l'Olivier, Université de Sousse, PB 14, 4061 Sousse, Tunisia

ARTICLE INFO

Article history:
Received 1 November 2016
Received in revised form 30 January 2017
Accepted 4 February 2017

Keywords:
Irrigation
Rootstock
Growth
Mineral nutrition
Yield

ABSTRACT

A three years field study was conducted to assess the effects of moderate and high saline irrigation water on the behavior of 5-year-old female trees of pistachio. Mateur cultivar was grafted on *Pistacia vera* L. and *Pistacia atlantica* Desf. rootstocks. Different water irrigation qualities were used: (i) tap water (ECw: 1.95 dSm^{-1}); (ii) moderately saline water (ECw: 5 dSm^{-1}); and (iii) highly saline water (ECw: 12 dSm^{-1}). Rootstock and scion growth were measured. Fruit yield was monitored during the three years of salt treatment and the following year after salt stress was relieved. Leaf mineral content and electrolyte leakage were determined monthly during growing seasons. Results showed that tree growth was not affected by moderate salinity after the first season of experiments but the response changed at higher salinity and when salt treatment duration increased. Salinity of irrigation water did not affect average fruit yield per tree but when saline water irrigation was stopped, yield of trees previously irrigated with highly saline water increased significantly on *P. atlantica* rootstock in comparison with control. Sodium and chlorides ions content in leaves accumulated proportionally to salinity level and duration. Nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca) as well as K/Na and Ca/Na ratios decreased with increasing salt concentration in the irrigation water. This reduction was more significant in the second and third years of the study. Water management practice was proposed to take advantage from the stimulating effects of mild/short term salinity on growth and production of pistachio Mateur cultivar.

1. Introduction

Soil salinization is increasing steadily in many parts of the world under global climate change (Nikolskii-Gavrilov et al., 2015). This situation is aggravated by the development of intensive orchard practice and irrigated lands using poor water quality. Salinity causes serious problems to plant growth, development and survival particularly in arid and semi-arid areas (Abdel Latef and Chaoxing, 2014) where the impact of only stress on plants is seldom occurring (Niinemets, 2010; Grattan et al., 2015). In these conditions, salt effect is often associated to high temperature, low atmospheric humidity, and intense luminosity. The combined effects of high evaporative demand and salinity have more deleterious impacts on crops (Maas and Grattan, 1999). Inversely, some diurnal and seasonal climatic variations alleviate temporally the negative effect of salts giving a plant a short period of favorable conditions that allow partial recover from stress. For instance, seasonal rainfall contributes to the leaching of salts accumulated in the root-zone which contribute to the reduction of osmotic pressure of the soil solution. The instance of woody species, including nut trees, is more complex. As long-lasting species, they have to cope with adverse conditions through the development of different mechanisms according to developmental stage (Shannon et al., 1994; Niinemets, 2010), nature of the surrounding environment, and intensity and duration of the stress. Hence, tree growth and production are influenced by various ongoing and periodic stresses whose impact may vary significantly with duration (Kozlowski, 1991).

Water salinity induces both osmotic and specific-ion toxicity causing deleterious effects on plants. Species affected by salinity show growth reduction (Maas and Grattan, 1999; Garcia-Legaz et al., 2005; Abbaspour et al., 2012), nutritional imbalance or deficiencies (Ashworth et al., 1985; Lauchli and Epstein, 1990; Chartzoulakis et al., 2002; Fernandez-Ballester et al., 2003), toxicity symptoms (Fernandez-Ballester et al., 2003; Chelli-Chaabouni

---

[*] Corresponding author. Present address: Institut National de la Recherche Agronomique de Tunisie, Université de Carthage, Rue Hédi Karray, 3049 Ariana, Tunisia.

E-mail address: azza.chelli@gmail.com (A. Chelli-Chaabouni).

[1] These authors have contributed equally to this work.

http://dx.doi.org/10.1016/j.agwat.2017.02.003

et al., 2010b) and Fruit yield and quality reduction (Maas and Grattan, 1999). Plants respond to salinity by either withstand cellular dehydration through osmotic adjustment (sequestration of large amount of ions in the vacuole or biosynthesis of secondary metabolites) or minimize water loss (regulation of transpiration through stoma closure) to maintain a suitable water status for development. Hence, growth and production are tightly linked to water and ionic status of the tree. According to the structural, biological, and physiological characteristics of one tree, the response to salinity determine its tolerance or sensitivity.

As grafting is the main propagation technique for a large part of fruit trees, rootstock plays a key role in the response of plant to soil salinity. In fact, roots are the primary organ facing salinity in the root-zone and have the mission to transport water and nutrient to the shoots for optimal plant growth and production. Consequently, special attention should be given to understand mechanisms adopted by scion/rootstock combination to avoid deleterious effects of salinity. Several studies have been conducted to understand the mechanisms of tolerance/adaptation of woody plants to salinity; mostly were carried out for short term and under controlled conditions. The obtained results do not often reflect the plant response in the field (Niknam and McComb, 2000; Zeng et al., 2009; Cimato et al., 2010). In order to have more information about tree crop behavior in the field within and throughout seasons, long-term field research is needed (Maas and Grattan, 1999).

Pistachio (*Pistacia vera* L.) nut tree belongs to the Anacardiacae family that includes species known to be highly tolerant to salts (Ferguson et al., 2002). *P. vera* is the only species used for nut production at the industrial level and is considered as a suitable crop for many arid and semi-arid areas such as Mediterranean and Asian areas. The salt tolerance of pistachio is thought to be higher than all other fruit tree species (Spiegel-Roy et al., 1977). Few studies were concerned with salt effects on *P. vera* as a cultivar or a seedling (Behboudian et al., 1986; Sepaskhah and Maftoun, 1988; Walker et al., 1987, 1988; Hajiboland et al., 2014) and *Pistacia* species as rootstocks (Walker et al., 1987; Picchioni et al., 1990; Arzani and Hokmabadi, 2004; Hokmabadi et al., 2005; Chelli-Chaabouni et al., 2010a, 2010b). These evaluations were mostly made under controlled conditions. Long duration studies made under field conditions (Sanden et al., 2004; Mehdi et al., 2010) to test scion/rootstock performance were less numerous. Although controlled conditions studies are precious for detecting specific mechanisms of pistachio that could be useful in screening for salt tolerance, field evaluation is necessary to give needed knowledge for development of specific crop management strategies in salt affected growing areas.

Salinity tolerance of pistachio, as many woody species, have been associated to low growth reduction (Sepaskhah and Maftoun, 1988; Picchioni et al., 1990), low decrease in photosynthetic activity (including high chlorophyll index, chlorophyll fluorescence, and chlorophyll content) and transpiration rate (Walker et al., 1988; Karimi and Kuhbanani, 2015), smaller amounts of salt ions transported to the leaves (Ashworth et al., 1985; Walker et al., 1987; Picchioni et al., 1990), ability to maintain relative high K^+/Na^+ and Ca^{2+}/Na^+ ratio needed for osmotic adjustment and enzymatic activities (Chelli-Chaabouni et al., 2010a, 2010b; Hajiboland et al., 2014) and lesser nut yield reduction (Sanden et al., 2004; Ferguson et al., 2010).

Picchioni et al. (1990) attributed the salt tolerance of pistachio to the ability to storage large amount of Na in the roots and basal stem. Evaluation based on yield reduction (Ferguson et al., 2010), revealed a full potential yield (100%) at an average electrical conductivity of the soil extract (ECe) of 4 dSm^{-1} that fell to the half (50%) at 10.7 dSm^{-1}. These authors ranged pistachio salt tolerance as less than date palm and more than olive. However, mechanisms used by pistachio to adapt to mild and high salinity for long-term scale are still poorly known. Among wild *Pistacia* species (including *P. atantica*, *P. integerrima*, *P.khinjuk*, *P. terebinthus*) and hybrids (including PG I, PG II, UCB-1, *P. atlantica x P. vera*) that are used as rootstock, *P. atlantica* was found to be highly tolerant to salt (Ferguson et al., 2005). A previous in vitro investigation revealed higher tolerance of *P. atlantica* to salt in comparison to *P. vera* (Chelli-Chaabouni et al., 2010a, 2010b). The response of these two species, used as rootstock, to water irrigation salinity under field conditions may give supplemental information on the response of trees submitted to salinity for a long period of time.

The present paper aimed to give supplemental knowledge about how pistachio responds to long-term moderate and high salinity of irrigation water under Mediterranean field conditions. Through the evaluation of plant growth and ionic status we suggested possible mechanisms used by this species and their rootstocks to cope with salt effect. This information may be used to propose water management practices for pistachio growers to maintain normal growth and production in similar field conditions.

Field assessment was performed on Mateur pistachio cultivar grafted on *Pistacia vera* and *P. atlantica* rootstocks under the Tunisian south-east climatic conditions. Results of three years monitoring of growth parameters, leaf mineral content and cell membrane permeability are presented and discussed.

2. Materials and methods

2.1. Plant materials and experimental crop design

This study was conducted from 2007 to 2009 seasons in the experimental station of Olive Tree Institute situated at 26 km in the north of Sfax (34°93′26′′N, 10°62′37′′E) at an altitude of 117.4 m above sea level. The experimental orchard was of 5-year-old at the beginning of the experimentation. Female pistachio trees cv.'Mateur' were grafted on *Pistacia vera* L. and *Pistacia atlantica* Desf. rootstocks. Tree spacing was of 6 × 6 m. Orchard was conducted in a completely randomized block design with fifteen trees per block and three blocks per variety/rootstock combination. A total number of five trees of comparable vigor were selected for each salt treatment and cultivar/rootstock combination.

2.2. Soil physico-chemical properties

The soil characteristics of the experimental orchard were determined at the beginning of experimentations. The pH and Electrical conductivity (EC) of the soil solution were measured on mixture of soil water (1:2.5 and 1:5, respectively). Total nitrogen (N) was determined by the Kjeldhal method. Phosphorus (P) content was determined by Olsen and Sommers methods (1982). The Exchangeable bases (Na and K) were determined by atomic absorption spectrophotometry (HITACHI Model Z-6100). Chloride content was determined according to a modified colorimetric method of Mohr (Mathieu and Pieltain, 2003). Walkley-Black method was used for the soil organic matter analysis (Nelson and Sommers, 1996). Soil texture analysis was determined using the standard pipette method (Klute, 1986).

The soil survey revealed a loamy sand texture composed with 76.6% sand, 13.4% clay and 5.6% silt. Organic matter was of 1.5%. The chemical composition of the soil extract was: total nitrogen (0.41‰), potassium (147 ppm), phosphorus (22 ppm), sodium (620 ppm) and chloride (570 ppm). The soil solution had an electrical conductivity (EC) of 3.25 dSm^{-1} and a pH of 8.2. In order to have information about the soil salinity evolution, the EC of soil extract was periodically measured for each treatment throughout the experimental duration. Three replications of soil samples were taken at the edge of canopy area. Each replication is composed by