Agricultural Water Management 194 (2017) 214–221

Contents lists available at ScienceDirect

Agricultural Water Management

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

Research Paper

Water use and crop performance of two wild rocket genotypes under salinity conditions

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ARTICLE INFO

Article history:
Received 23 July 2017
Received in revised form 29 August 2017
Accepted 15 September 2017

Keywords:
Diplotaxis tenuifolia
D. muralis
Critical threshold
Slope
Salinity tolerance
WUE

ABSTRACT

In literature, the parameters of salinity tolerance of the main cultivated species are known, but are missing for many minor species such as wild rocket, whose cultivation in many areas of southern Italy affected by salinity is growing. Therefore, a research has been carried out i) to evaluate the response to salinity in water use, water use efficiency, yield characteristics and morfological features, and ii) identify the salinity tolerance parameters of two genotypes of wild rocket: *Diplotaxis tenuifolia* (L.) DC and *D. muralis* (L.) DC. The study was carried out in the spring of 2007 and 2008 in Policoro (MT), southern Italy, under unheated plastic greenhouse conditions. Wild rocket was sown in plastic pots containing 20 dm^3 of soil. For each genotype, six soil salinity levels were compared, obtained by accurately mixing before sowing the soil with 0.0, 0.5, 1.0, 2.0, 3.5 and 5.5 g dm^{-3} of NaCl + $CaCl_2$ 1:1 (on a weight basis). Irrigation was performed with fresh water having electrical conductivity of 0.5 dS m^{-1}. In each year, 3 harvests were performed; water use and the main production and plant growth parameters were recorded. *D. tenuifolia* provided a yield 47.3% higher than *D. muralis*. By rising salinity, progressive decline in marketable yield and growth of the leaves was recorded, while the dry matter content increased. The increase in salinity has led to the progressive reduction of water use in both genotypes. From moderate salinity values (about 5.5 dS m^{-1}), the reduction in yield water use efficiency as a result of increased salinity has been observed. In addition, salinity reduced specific leaf area and increased leaf succulence. Both genotypes rank among moderately salt sensitive species, according to Maas and Hoffman's model (1977). However, *D. tenuifolia*, with a critical threshold of 1.98 dS m^{-1} and a slope of 6.61% m dS^{-1}, showed a slightly higher tolerance than *D. muralis* (threshold 1.34 dS m^{-1} and slope 7.25% m dS^{-1}). Reduction in yield due to salinity occurred mainly for the decrease in leaf size and, secondly, number of leaves.

1. Introduction

The beginning of 21st century is marked by global scarcity of water resources, environmental pollution and increased salinization of soil and water (Shahbaz and Ashraf, 2013).

It has been estimated that worldwide 20% of total cultivated and 33% of irrigated agricultural lands are affected by high salinity. Furthermore, the salinized areas are increasing at a rate of 10% annually for various reasons, including low precipitation, high surface evaporation, weathering of native rocks, irrigation with saline water, and poor cultural practices. It has been estimated that more than 50% of the arable land would be salinized by the year 2050 (Jamil et al., 2011). Particularly, in the Mediterranean countries groundwater discharge increased over the second half of the 20th century and, as a consequence, a great number of aquifers are currently overexploited and at risk of seawater intrusion (Polemio, 2016). This overuse is concentrated in coastal areas, where increasing population, growth of urban areas, and increases of irrigation and industrial demands and tourism are occurring (Polemio et al., 2013; Taniguchi et al., 2009; Tulipano et al., 2005). These trends were also observed in Italy, where seawater intrusion is the main cause of groundwater quality degradation in coastal karst aquifers, the largest of which are located in the Apulia region (Polemio et al., 2011).

Salinity is one of the most serious factors limiting productivity of agricultural crops, which causes major reductions in cultivated land area, crop productivity and quality (Flowers, 2004; Munns and Tester, 2008; Shahbaz and Ashraf, 2013; Yamaguchi and Blumwald, 2005). Salinity inhibits plant growth i) for osmotic effect which reduces the plant ability to take up water, affects a wide variety of metabolic activities, and causes an oxidative stress because of the formation of reactive oxygen species such as superoxides and

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http://dx.doi.org/10.1016/j.agwat.2017.09.009
0378-3774/

hydroxy and peroxy radicals (Munns, 2002; Munns, 2005; Sergio et al., 2012), ii) by specific ion toxicity (*e.g.*, Na^+ and Cl^-) (Munns, 2002; Munns, 2005; Yeo et al., 1991) and iii) by ionic imbalances acting on biophysical and/or metabolic components of plant growth (Grattan and Grieve, 1999).

On the whole, the above effects lead to a reduction of net photosynthesis (Cantore et al., 2007; Munns et al., 2006; Munns and Tester, 2008), the rate of leaf surface expansion (Wang and Nil, 2000), the fresh and dry weights of leaves, stems, and roots (Chartzoulakis and Klapaki, 2000; Hernandez et al., 1995). The listed adverse effects result in a reduction in yield that, for a given level of salinity, may vary depending on the genotype, salt type, climatic conditions and agronomic techniques (Cucci et al., 2000; Flagella et al., 2002; Maas, 1986).

In many coastal areas of Southern Italy (as Apulia and Basilicata regions) where the problem of irrigation water's salinity is increasing, the cultivation of wild rocket (i.e. *Diplotaxis tenuifolia* L. DC., *D. muralis* L. DC.) is widespread and in further expansion. Indeed, the last decades wild rocket has become popular and widely cultivated in greenhouses and open field. In Italy, several species of the genus *Diplotaxis* are consumed as vegetables since ancient times. The leaves, characterized by a unique aroma and piquant flavor, can be eaten raw in salads or cooked in many recipes. Compared to other leafy vegetables, wild rocket has high content of fiber and iron, ascorbic acid, phenols, carotenoids and glucosinolates (Barillari et al., 2005; Cavaiuolo and Ferrante, 2014; D'Antuono et al., 2009; Di Venere et al., 2000), to which important bioactive properties (e.g., antioxidant, antitumour, etc.) are often ascribed (Ramos-Bueno et al., 2016).

Experimental evidence on the behaviour of wild rocket in the presence of salinity are scarce and conflicting. In particular, de Vos et al. (2013) ranked *D. tenuifolia* as a salt tolerant species, having found that yield reduction occurs with the salinity of nutrient solution greater than 100 mM NaCl. These authors claim that the species can be considered among the new halophytes. However, opposite results were obtained by Bonasia et al. (2017) that, for the same species, reported significant reductions in yield (about 20%) passing from the salinity of 2.5 dS m^{-1} to 3.5 dS^{-1}. The latter authors also observed a positive effect of moderate salinity (3.5 dS m^{-1}) on different qualitative parameters. In fact, they report a reduction in the content of nitrates, which is widely recognized as being harmful to health (Buttaro et al., 2016), and an improvement in certain qualitative features, health beneficial, such as vitamin C, polyphenols, carotenoids and antioxidant activity. With an higher salinity, however, they did not find any further qualitative improvements. Also Hamilton and Fonseca (2010) found an increase in the phenols with the salinity increase from 1.5 to 9.5 dS m^{-1} only in one of the two experiments conducted, while they did not observe any effect on vitamin C content.

Considering the growing economic importance of wild rocket cultivation in many salt-affected areas, as the case of Mediterranean countries, and the conflicting literature data on the salt tolerance of this vegetable, this work is proposed to provide further insights on the crop performance of two genotypes of wild rocket (*D. tenuifolia* and *D. muralis*) in response to the soil salinity levels. The information obtained from the research aims to provide useful information for the optimal crop management of wild rocket under salinity conditions.

2. Material and methods

2.1. Experimental site characteristics

The research was carried out in the spring 2007 and 2008 at experimental farm 'E. Pantanelli' of the University 'Aldo Moro' of Bari, Policoro (MT), Southern Italy (40°10′ NL, 16°39′ EL, altitude 15 m a.s.l.). This site is characterized by sub-humid climate according to the De Martonne classification (Cantore et al., 1987). The experiment was performed under unheated plastic greenhouse conditions (covered by an EVA 200 μm thick film), using cylindrical pots (0.34 m diameter and 0.3 m height) adequately equipped with flowerpot saucers, each containing 20 dm^3 of soil, collected in the same location. The soil was a fine, mixed, subactive, thermic Chromic Haploxererts (Cassi et al., 2006), with the following physical and chemical characteristics: sand (2 > Ø > 0.02 mm) 29.5%, silt 37.5%, clay (Ø < 2 μ) 33.0%; pH 7.6; total N (Kjeldahl method) 1.48 g kg^{-1}, available P_2O_5 (Olsen method) 25.9 mg kg^{-1}, exchangeable K_2O (ammonium acetate method) 249 mg kg^{-1}, organic matter (Walkley–Blackmethod) 33.7 g kg^{-1}, total limestone 14 g kg^{-1}, active limestone 4.5 g kg^{-1}; saturated paste extract electrical conductivity (ECe) 0.90 dS m^{-1}; ESP 2.0%; bulk density 1.24 kg dm^{-3}; soil moisture at field capacity (FC) 31.8% and at wilting point (−1.5 MPa, Richard Pressure Plate Extractor) 15.3% (w/w) of soil dry weight. The FC was measured at the beginning of the experiment by saturating pots with tap water. The water content of the covered pots after the drainage stopped was assumed to be FC.

Weather data were measured in the greenhouse by an automatic weather station including a pyranometer (model CM 4, Kipp and Zonen, Delft, The Netherlands), thermistor (model E001, Tecno.El, Rome, Italy), hygrometer (C-83_N Rotronic, Zurich, Switzerland) and anemometer (model VT 0805B, SIAP Bologna, Villanova di Castelnaso-BO, Italy), for measuring solar radiation, air temperature, relative humidity and wind speed, respectively. Data were collected by the electronic system operated through a data-logger (model Kampus, Tecno.El, Rome, Italy) connected via modem to a PC.

2.2. Experimental design and crop management

The following treatments were compared: two genotypes of wild rocket (*D. tenuifolia* and *D. muralis*) and six soil salinity levels, obtained by accurately mixing to the soil, before sowing, 0.0, 0.5, 1.0, 2.0, 3.5 and 5.5 g dm^{-3} of NaCl + $CaCl_2$ 1:1 (on a weight basis), indicated with S_1, S_2, S_3, S_4, S_5 and S_6, respectively. A completly randomized block experimental design with 4 replicates was adopted. Each plot consisted of three pots. Before sowing, the soil of each pot was fertilised with 1.78 and 2.26 g of diammonium phosphate and urea, respectively. The wild rocket was sown on February 1^{st} 2007 and 2008. Fifteen days after sowing (DAS), thinning was performed by leaving five plants per pot, arranged in an homogeneous manner with respect to the pot surface. Each year three growing cycles were performed by exploiting the ability of this species to re-growth after harvest. The harvests (on March 20^{th}, April 23^{th}, May 25^{th} 2007, and on March 25^{th}, April 28^{th}, May 30^{th} 2008) were performed cutting off leaves 1cm above the collar with a knife. Evapotranspiration (ET) was estimated by the water balance method by weighing every days the pots that were considered as a weight lysimeter, and utilizing the following equation (Ünlükara et al., 2010):

$$ET = \frac{(W_n - W_{n+1}) + \left(W_I - W_{Dp}\right)}{\rho_w}$$

where, *ET* is the daily evapotranspiration (L), W_n and W_{n+1} are pot weights in two consecutive days (kg), W_I is the amount of applied water (kg), W_{Dp} is the amount of drainage water (kg), ρ_w is water bulk density (1 kg L^{-1}). As the weights of the pots were taken daily and weight loss from each day was calculated using their preceding weights only, possible error due to the plant weight increase was indeed very little and negligible (Ghaemi and Rafiee, 2016).