Scientia Horticulturae 162 (2013) 55–62

Contents lists available at ScienceDirect

Scientia Horticulturae

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

Potassium utilization efficiency of three olive cultivars grown in a hydroponic system

A. Saykhul[a], T. Chatzistathis[a,*], C. Chatzissavvidis[b], S. Koundouras[c], I. Therios[a], K. Dimassi[a]

[a] Laboratory of Pomology, Department of Horticulture, School of Agriculture, Aristotle University of Thessaloniki, 54124, Greece
[b] Laboratory of Pomology, Department of Agricultural Development, Democritus University of Thrace, 68200 Orestiada, Greece
[c] Laboratory of Viticulture, Department of Horticulture, School of Agriculture, Aristotle University of Thessaloniki, 54124, Greece

ARTICLE INFO

Article history:
Received 22 May 2013
Received in revised form 18 July 2013
Accepted 26 July 2013

Keywords:
Olive (*Olea europaea* L.)
Potassium
'Koroneiki'
'Kalamon'
'Arbequina'

ABSTRACT

A hydroponic experiment was carried out in an experimental greenhouse in order to investigate if K level in nutrient solution affected the efficient use of K (KUE) of three olive cultivars, as well as if genotypic differences concerning KUE among them for the same K level existed. For that purpose, the effect of K concentration on growth, nutrient uptake and utilization efficiency, as well as on physiological functions (stomatal conductance, photosynthetic rate, transpiration and water use efficiency) of the olive cultivars 'Koroneiki', 'Kalamon' and 'Arbequina' was studied. Rooted leafy cuttings of these olive cultivars were grown for 55 days in 1:1 sand:perlite mixture and were irrigated with 50% modified Hoagland nutrient solutions, differing between them only in K concentration (0.50, 1, 5 and 20 mM KCl). Potassium concentration in nutrient solution influenced the growth of the cultivars 'Kalamon' and 'Arbequina', but not that of 'Koroneiki'. The influence of K concentration on macro and micronutrient uptake was in most cases non significant. Stomatal conductance was greater in the T4 treatment (at 35, 45 or 55 DAIT), compared to T1, T2 and T3, for all genotypes. However, only the photosynthetic rates of 'Kalamon' and 'Arbequina' (and not that of 'Koroneiki') were found to follow the tendency of greater stomata opening (at 35, 45 or 55 DAIT). The highest rate was observed in the treatment of 20 mM KCl in 'Kalamon', while the lowest one was found in the treatment of 1 mM KCl in 'Arbequina'; therefore, the reaction of photosynthetic operation of olive plants to K mineral nutrition was strongly K, as well as genotype dependent. Transpiration rates on the 35th and on the 45th day of the experiment were significantly affected by K mineral nutrition, in all olive cultivars. Regarding water use efficiency (WUE), the K treatment effect was significant only in 'Koroneiki' on the 35th day and in 'Kalamon' on the 45th day. No difference between treatments was recorded in all cultivars concerning WUE on the 55th day, though genotypic differences were significant ('Kalamon' was less water use efficient, compared to the other genotypes). Finally, 'Koroneiki' was more K-efficient than 'Arbequina' and 'Kalamon', especially in high K concentrations (5 and 20 mM KCl), so it should be preferred for cultivation in groves receiving rich K fertilizations.

1. Introduction

Potassium plays a key role in many physiological functions (stomata opening and photosynthesis, translocation of photosynthates, polypeptide synthesis and meristematic growth, enzyme activation, charge balancing and neutralizing functions, osmoregulation, stress resistance, quality improvement of fruits etc.) (Mengel and Kirkby, 2001; Epstein and Bloom, 2005; Arquero et al., 2006). With the increasing crop production the global consumption of K has increased at an average rate of 4.4% per year over the period 1999–2005 (IFA, 2005) and this tendency is increasing. With increasing world population, high costs of crop production, and issues related to environmental pollution, the need for breeding and selecting more efficient or tolerant cultivars to sustain or improve crop production on low productive soils has gained the momentum (Fageria and Baligar, 2003).

Efficient use of nutrients is the relative ability of plants to produce maximal amounts of dry matter or yield for each increment of nutrient accumulated. Potassium efficiency is defined as plants' ability to produce high dry matter, yields and/or grain yields under deficient K levels, with efficient internal and/or external use efficiencies (Yang et al., 2003). Nutrient-efficient genotypes are important in modern agriculture because they can produce greater yields on soils where the effectiveness of fertilizers may

* Corresponding author.
E-mail address: chchatzi@in.gr (T. Chatzistathis).

0304-4238/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.scienta.2013.07.036

be limited by chemical and biological reactions, topsoil drying, subsoil constraints and/or disease interactions (Graham and Rengel, 1993; Lynch, 1998; Rengel and Marschner, 2005). Growing nutrient-efficient genotypes of crop plants on soils of low nutrient availability represents an environmentally friendly approach that would reduce land degradation by (i) reducing the use of machinery and (ii) minimizing application of chemicals on agricultural land (Thongbai et al., 1993).

Olive varieties could be differently influenced by ecological factors and therefore nutrient uptake and utilization efficiency may dramatically change. Under these conditions the macro or micronutrient requirement of varieties are quite different. Furthermore, many varieties may differently respond to nutrient deficiency or toxicity stress (Therios and Misopolinos, 1988; Therios and Sakellariadis, 1988; Marschner, 1995; Chartzoulakis et al., 2002a,b; Loupassaki et al., 2002). Particularly, K mineral nutrition is a very important issue in Mediterranean basin because low rainfall, mainly during growing season (spring–summer), may negatively affect K availability in soil and K uptake by plants. Under so harsh conditions of limited K availability genotypes of the same species may differently respond to K stress; it has been found that significant differences concerning K uptake and utilization, as well as adjustment to K deficiency among genotypes (K-efficient and inefficient cultivars) exist in watermelon and cotton plants (Wang and Chen, 2012; Ul-Hassan et al., 2012; Fan et al., 2013; Oosterhuis et al., 2013). Despite the fact that significant differences in K uptake and utilization efficiency (KUE) have been found among genotypes: (i) of cotton and (ii) recently of watermelon plants (Fan et al., 2013), almost nothing has been studied and published on KUE among olive cultivars.

In our study it has been hypothesized that the level of K in growing medium affects the efficient use of K by three genotypes and that genotypic differences among them concerning KUE existed for the same K level. Therefore, the aims of our research were to investigate if: (i) K concentration in the nutrient solution affected the KUE of the olive cultivars 'Koroneiki', 'Kalamon' and 'Arbequina', (ii) genotypic differences concerning KUE existed between the three genotypes for the same K level (under K deficiency, sufficiency and over-sufficiency conditions). In order to facilitate the reader have a more profound insight on this topic, plant growth parameters, physiological functions (stomata opening, photosynthetic and transpiration rates and water use efficiency), as well as nutrient uptake were also determined. These three cultivars have been chosen for study since they are three of the most important and commonly used for cultivation in the olive growing areas of Greece. More specifically, 'Koroneiki' is a widely cultivated oil producing cultivar (it produces a high oleuropein content olive oil), 'Kalamon' is a table olive producing genotype, while 'Arbequina' is a dual purpose (for oil, as well as for table olives production) cultivar, which during last years is used more and more for the establishment of intensive olive plantations in Greece.

2. Materials and methods

2.1. Experimental conditions and K treatments

The experiment was carried out in the experimental greenhouse of the laboratory of Pomology, situated in the farm of the Aristotle University of Thessaloniki (40.53° N, 22.99° E), from early May to late June 2009, with an average temperature of 30 °C. Juvenile rooted leafy cuttings (about two-month old) of three olive cultivars were grown in plastic bags containing perlite, inside the experimental greenhouse. Each plant with its bag was placed into a metallic container and the extra space was filled with perlite. There was a narrow and small Cu pipe at the bottom of each metallic container joined with a rubber pipe, used as outlet for the draining solution. Each rubber pipe was connected with a 2 L plastic bottle covered with aluminum foil and containing 50% modified Hoagland nutrient solution (Hoagland and Arnon, 1950) with different K concentrations, by which the plants were irrigated, by raising the bottle, every second day. Each bottle contained 1200 ml of nutrient solution. Four treatments (0.50, 1, 5 and 20 mM KCl) were applied to plants.

2.2. Determination of nutrient concentrations in plant tissues and K use efficiency

The plants were divided into three parts (root, basal leaves and apical leaves). All the vegetal tissues were dried in a Heraeus oven at 75 °C for 48 h and were milled to pass through a 30-mesh sieve. Then, 0.5 g of fine powder of each sample was dry-ashed in a muffle furnace at 515 °C for 5 h. Afterwards, the ash was dissolved in 3 mL of 6N hydrochloric acid (HCl) and diluted with distilled water up to 50 mL. Total N was measured by the Kjeldahl method, while P in 470 nm using the vanado-molybdophosphate yellow method (Page et al., 1982). Finally, K, Ca and Mg concentrations were determined by atomic absorption spectroscopy (Perkin-Elmer 2380 Waltham, MA, USA). Multiplying the concentration of each nutrient (mg/g dry weight) found in each plant part by the dry weight of the corresponding plant part, the content (absolute quantity) of each nutrient existed in each plant part at the end of the experiment was calculated. By addition of the nutrient contents of different plant parts, the total nutrient content (mg) per plant, thus the total nutrient uptake per plant, was computed. Potassium use efficiency (KUE) was calculated at the end of the experiment (55th day), and it was defined as the amount of biomass produced per unit of nutrient (Chapin and Van Cleve, 1991).

2.3. Measurements of gas exchange parameters and determination of water use efficiency

Thirty five, 45 and 55 days from the initiation of the experiment, photosynthesis, transpiration, stomatal conductance and internal CO_2 concentration were measured using the photosynthesis measuring instrument 'LC PRO portable gas exchange system' (ADC BioScientific Ltd, Hoddesdon UK). All gas exchange measurements were carried out in fully expanded leaves, located in the middle of the shoots. Measurements were performed the time period from 10.00 to 12.00 o'clock at natural light intensity, greater than 700 $\mu mol\ m^{-2}\ s^{-1}$, while leaf temperature varied from 24 °C to 25 °C. Finally, water use efficiency was determined as $\mu mol\ CO_2$ per mol H_2O.

2.4. Statistical analysis

The experimental layout was a Randomized Block Design (RBC) with four K treatments, three cultivars and five replicates per treatment (i.e. total number of experimental plants: 60). The data were subjected to analysis of variance (ANOVA), using the SPSS (17.0 for Windows) statistical package (SPSS, Inc., Chicago, IL). For comparison of means between K treatments and olive cultivars, the Tukey's Multiple Range Test for $P \leq 0.05$ was used.

3. Results

3.1. Plant growth parameters

Shoot elongation was more or less independent of KCl concentration for the cultivar 'Koroneiki', but statistically significant differences existed for 'Kalamon' and 'Arbequina' among K treatments. The maximum shoot elongation was found in 'Koroneiki',