https://doi.org/10.1186/s42269-020-00374-0

Bulletin of the National Research Centre

RESEARCH Open Access

Ameliorative effect of foliar application of calcium on vegetative growth and mineral contents of olive trees Kalmata and Manzanillo cultivars irrigated with saline water

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Abstract

Background: This work was carried out through 2017 and 2018 seasons on tow olive cultivars (Kalmata and Manzanillo). Trees were 15 years old, grown in sandy soil, planted at 5 × 5 m apart, and irrigated with saline water through drip irrigation system. This investigation aimed to improve vegetative growth and its mineral contents of the tow olive cultivars. Trees were sprayed with calcium at 0.5% as calcium chloride (21% Ca) and chelated calcium.

Results: The results revealed that there were significant differences with calcium source treatment regarding vegetative growth and leaf mineral contents.

Conclusions: Results proved that olive trees sprayed at the end of December with 0.5% calcium as chelated calcium was the promising treatment for good vegetative growth and leaf mineral contents.

Keywords: Olive (*Olea europea*), Kalamata, Manzanillo, Calcium chloride, Chelated calcium, Vegetative grow parameters and mineral contents

Introduction

Olive (*Olea europaea* L.) is one of the fundamental tree crops in the Mediterranean Basin, which is one of the regions affected by water scarcity (Chartzoulakis et al. 2001). It is known that water is essential for agricultural production. There is a lack of pure water in many new reclaimed area. It is estimated that by 2025, around 2 billion people will be affected by absolute water scarcity (Riemenschneider et al. 2016). Large quantities of pure water supplies will be diverted from agriculture to meet the growing water demand in the civil life and industry sectors (Hamdi et al. 1995; Correia, 1999). As a consequence, in some new reclaimed area, the only source of irrigation water is either recycled wastewater or saline groundwater, exposing the irrigated trees to salinity stress (Oron et al. 2002).

Salinity is considered as one of the most important factors of abiotic stress (Slama et al. 2015; Himabindu et al. 2016). High levels of salts especially in the form NaCl which consider the first responsible for soil salinity and the main factor caused damage on many plant physiological processes (Yang et al. 2009). In order to avoid bad effects of salt stress, Tuna et al. (2007) recommended to use calcium element.

Calcium element is considered as one of the main macronutrients in plants and acts as signaling molecule. Calcium contributed in the regulation of plant growth and development and the enhancement of

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abiotic stress tolerance (Khan et al. 2010 and Cao et al. 2017). Calcium element is considered as secondary messenger that plays an important role as signaling molecule in mediating mechanisms contributes in recognition and response to abiotic stresses in plants. Under salt stress, plant cells either accumulate calcium or release intracellular cytosolic calcium, which work as a signaling molecule and adjust a range of physiological processes to modify salt stress (Kader et al. 2007; Kader and Lindberg, 2008; Kader and Lindberg, 2010). Also, it is known that calcium chained the sodium element entering plant cells, and this contributes to reducing the negative effects of salinity (Kader and Lindberg, 2008; Hussain et al. 2010). Additionally, calcium is considered as an essential element for potasium/sodium and calcium/sodium selectivity, and reduced the negative effects of salinity by regulating ion transport in plants (Renault, 2005).

Ca mineral is relatively insoluble in soil in this state and is considered a leachable nutrient, which reduces the calcium uptake by plants. With regard to uptake and mobility of Ca in plants, Ca uptake is passive which means it does not require energy input. Ca mobility occurs fundamentally in the xylem, flow with the movement of water. Thus, uptake of Ca is related directly to the rate of transpiration in plant. Accumulation of salinity might also be a limiting mobility of calcium in plants which led to deficiency of calcium due to its effect on decreasing uptake of water by the plant. Deficiency of Ca will appear in younger leaves and in fruits due to its low rate of transpiration. Hence, it is necessary to have a constant supply of calcium to continue to grow (Kadir 2004).

However, calcium is considered as an immobile element. So, foliar absorption is considered the most efficient method to supply secondary macronutrients such as calcium nutrients (Gaussoin et al. 2009). Efficiency of foliar application with Ca depends on the source of Ca and applied dosage. In this regard, foliar application of calcium chloride was more efficient than that of calcium oxide and chelate calcium (Almeida et al. 2016). $CaCl_2$ is highly soluble in water and is deliquescent. It can be used on plants as a source of Ca and Cl, and plays an important role in photosynthesis and other cellular processes (Wahid et al. 2007; Rab and Haq, 2012).

The leaf fertilizers which are inorganic mineral structures hardly diffuse from the leaf surface into the plant because of high-weight molecular structure. Chelating agents describes a kind of organic chemical complex that can encapsulate certain metallic salts and then release these metallic salts slowly to become available for uptake by plants (Marschner 1995, Zocchi and Mignani, 1995). Hence, synthetic portent, like EDTA (ethylene diamine tetra acetic acid) and EDDHA (ethylene diamino–hydroxyphenylacetic acid) which has the ability of making strong chelate is almost used in plant-growing medium. Foliar fertilizers as chelate should be easily absorbed by the plants rapidly transported and should easily release their ions to affect the plant (Zocchi and Mignani, 1995). Natural chelates as mid-molecular-weight compounds, like amino acids, have long organic chains diffuse easily to cell cytoplasm according to their chemical structure. These chelates are not phytotoxic to plants (Ferguson and Drobak 1988).

The purpose of this study was to investigate the use of foliar application of calcium chloride and calcium chelate on vegetative growth and leaf mineral contents of olive Kalmata and Manzanillo cultivars.

Materials and methods

This study was carried out during two successive seasons (2017 and 2018) in a private orchard located at Ismailia Governorate, Egypt. The study was conducted on 15-year-old olive trees of Kalamata and Manzanillo cvs., planted at 5 × 5 m apart grown in sandy soil, under drip irrigation system and uniform in shape, and received the common horticultural practices. The orchard soil analysis is given in Table 1, and water irrigation analysis is given in Table 2 according to procedures which are outlined by (Wild et al. 1985).

Experimental design

The treatments will be arranged in a randomized complete block design (RCBD); the experiment contains

Table 1 Some physical and chemical analysis of the orchard soil

Parameters	Depth of simple(cm)		
	Surface sample	30 cm depth	60 cm depth
pH	8.02	8.70	8.11
EC(dSm-1)	3.80	0.80	1.70
	Soluble cations (meq\l)		
Ca++	6.00	2.50	3.00
Mg++	4.00	1.50	1.50
Na+	28.60	4.40	12.90
K+	0.12	0.14	0.78
	Soluble anions (meq\l)		
$CO3^-$	–	–	–
$HCO3^-$	4.40	2.40	2.00
Cl^-	27.20	5.00	13.00
$SO4^=$	7.12	1.14	3.18

Table 2 Chemical characteristics of water weal used for the present study

Parameters	Values
pH	7.49
EC(dSm^{-1})	4.40
	Soluble cations (meq\l)
Ca^{++}	7.50
Mg^{++}	5.00
Na^{+}	33.1
K^{+}	0.16
	Soluble anions (meq\l)
$CO3^{=}$	–
$HCO3^{-}$	1.60
Cl^{-}	40.00
$SO4^{=}$	4.16

three treatments, and each contains three replicates and the replicate is represented by one tree.

Experimental material

1- Calcium chloride is a chemical compound with the formula $CaCl_2$. It is a common substance found in rocks as the minerals calcite and aragonite (most notably known as limestone, which is a type of sedimentary rock built mainly of calcite).
2- Chelated calcium is the chelating agent used in this experiment and is a natural chelate as mid-molecular-weight compounds like amino acids that have long organic chains diffuse easily to cell cytoplasm according to their chemical structure.

Treatments

Effect of spraying with two sources of calcium; this experiment included tow treatments as follows:

T1: Control.
T2: Ca Cl (0.5%)
T3: Calcium chelate (0.5%)
All treatments were applied at the end of December.

Measurements

1- Vegetative parameters:

a. Leaf area (cm^2) according to (Ahmed and Morsy, 1999) using the following equilibration: Leaf area = 0.53 (length × width) + 1.66.
b. Total chlorophyll content was estimated in intact flag leaves using a portable chlorophyll meter (CCM-200, Opti-Sciences, England).
c. C/N ratio: total carbohydrate in shoot according to Yemm and Folkes, 1953. Nitrogen in shoot using the modified micro-Kjeldahl method as lined by Pregl (1945). C/N ratio was calculated.

2- Leaf mineral contents:

Leave sample from each tree/replicate was separately oven dried at 70 °C till constant weight, and then grounded for determination the following nutrient elements (percentage as dry weight):

N—using the modified micro-Kjeldahl method as lined by Pregl (1945).

P—was estimated as described by Chapman and Pratt (1961).

K—flamephotometerically determined according to Brown and Lilleland (1946).

Fe, Zn, and Mn as ppm were spectrophotometerically determined using atomic absorption (model, spectronic 21 D) as described by Jackson (1973).

Statistical analysis

All obtained data during 2017 and 2018 experimental seasons were subjected to analysis of variances (ANOVA) according to Snedecor and Cochran (1980) using MSTAT program. Least significant ranges (LSR) were used to compare between means of treatments according to Duncan (1955) at probability of 5%.

Results

The presented data in Table 3 indicate that all calcium source had significant effect on leaf area, total chlorophyll, and C/N ratio of olive Kalmata and Manzanillo cultivars than unsprayed in both seasons.

Concerning Kalmata cultivar, sprayed trees with chelated Ca significantly increased leaf area (4.80 and 4.94), total chlorophyll in leaves (94.27 and 97.90), and C/N ratio in leaves (13.53 and 12.41) agonist (4.00 and 4.10) leaf area (72.27 and 82.21), total chlorophyll in leaves, and (6.15 and 6.46) C/N ratio in leaves for control treatment in the 1st and 2nd seasons, respectively.

As for Manzanillo cultivar, the obtained results show that the highest values of leaf area (4.50 and 4.79), total chlorophyll in leaves (86.10 and 92.21), and C/N ratio in leaves (15.95 and 18.07) were obtained with the tree recorded sprayed with chelated Ca agonist leaf area (4.11

Table 3 Effect of foliar spray with some calcium sources on leaf area, total chlorophyll and C/N ratio of olive Kalmata and Manzanillo cultivars

	Leaf area cm^2		Total chlorophyll (SPAD units)		C/N ratio	
	2017	2018	2017	2018	2017	2018
	Kalmata					
Control	4.00c	4.10c	72.27c	82.21c	6.15c	6.46c
$CaCl_2$	4.25b	4 .52b	84.3b	91.07b	11.35b	9.92b
Chelated Ca	4.80a	4. 94a	94.27a	97.9a	13.53a	12.41a
	Manzanillo					
Control	4.11b	4.08b	82.44b	87.43b	12.53b	12.00c
$CaCl_2$	4.29ab	4.73a	86.07a	96.17a	14.58a	15.32b
Chelated Ca	4.50a	4.79a	86.10a	96.21a	15.95a	18.07a

and 4.08), total chlorophyll in leaves (82.44 and 87.43), and C/N ratio in leaves (12.53 and 12.00) for unsprayed tree in the 1st and 2nd seasons, respectively

Data in Table 4 clearly reveal that spraying the trees of olive Kalmata and Manzanillo cultivars with tow calcium sources promotes significant leaf N, P, K, and Ca percentages than unsprayed trees in both seasons.

As for Kalmata cv., the data show that sprayed trees with chelated Ca had significant effect on all macro elements content in leaves than sprayed with CaCl2 in both growing seasons, whereas insignificant effect was recorded with olive trees sprayed with CaCl2 with regard to P content in the 2nd season and K content in the 1st season. The highest values of N% (1.67 and 1.62), P% (0.072, 0.063), K% (1.19 and 1.87), and Ca (1.24 and 1.57) came from the trees recorded sprayed with chelated Ca in the first and second seasons, respectively. The least values of N% (1.11 and 1.31), P% (0.043, 0.027), K% (1.05 and 1.22), and Ca (1.14 and 1.26) resulted from the trees which unsprayed the first and second seasons, respectively. The trees recorded were sprayed with CaCl2 and gave intermediate values.

With regard to Manzanillo cv., data indicate that sprayed trees with chelated Ca gave the highest values of N (1.83%), P (0.081%), K (1.17%), and Ca (1.21%) in the 1st season, while sprayed with CaCl2 gave the highest values of N (1.77%), P (0.081%), K (1.23%), and Ca (1.481%) in the 2nd season

The presented results in Table 5 indicated that sprayed tree with tow calcium sources had significant effect on Fe, Zn, and Mn content (ppm) in leaves in both Kalmata and Manzanillo cultivars in both experimental seasons.

As for Kalmata cv., the highest values of Fe (298.67 and 194.33) and Zn% (25.29 and 30.52) in the 1st and 2nd seasons, respectively, were obtained with the tree which sprayed with chelated Ca, while Mn (26.94 and 15.37 ppm) was obtained by the trees recorded sprayed with CaCl2 in the 1st and 2nd seasons, respectively. On the other hand, the lower most values of Fe ppm (272.37 and 103.53), Zn ppm (23.60 and 26.07), and Mn ppm% (21.17 and 10.78) came from unsprayed tree in the first and second seasons, respectively.

Regarding Manzanillo cv., the data show that sprayed trees with chelated Ca recorded the maximum concentration of Fe (265.50 and 171.21 ppm) in both season

Table 4 Effect of foliar spray with some calcium sources on nitrogen (N), phosphor (P), potassium (K), and calcium (Ca) contents in leaves of olive Kalmata and Manzanillo cultivars

	N%		P%		K%		Ca%	
	2017	2018	2017	2018	2017	2018	2017	2018
	Kalmata							
Control	1.11b	1.31b	0.043c	0.027b	1.05b	1.22c	1.14c	1.26c
$CaCl_2$	1.23b	1.43b	0.063b	0.062a	1.16a	1.50b	1.19b	1.40b
Chelated Ca	1.67a	1.62a	0.072a	0.063a	1.19a	1.87a	1.24a	1.57a
	Manzanillo							
Control	1.39c	1.42b	0.014b	0.018b	0.98b	0.93c	1.08b	1.11c
$CaCl_2$	1.60b	1.77a	0.068a	0.081a	1.15a	1.23a	1.18a	1.48a
Chelated Ca	1.83a	1.63a	0.081a	0.064a	1.17a	1.13b	1.21a	1.31b

Table 5 Effect of foliar spray with some calcium sources on iron (Fe), zinc (Zn), and manganese (Mn) contents in leaves of olive Kalmata and Manzanillo cultivars

	Fe ppm		Zn ppm		Mn ppm	
	2017	2018	2017	2018	2017	2018
Kalmata						
Control	272.37c	103.53c	23.60c	26.07c	21.17b	10.78b
$CaCl_2$	284.33b	165.00b	24.48b	27.95b	26.97a	15.37a
Chelated Ca	298.67a	194.33a	25.29a	30.52a	26.34a	14.68a
Manzanillo						
Control	207.21b	120.60c	21.40b	12.60c	30.40b	29.00c
$CaCl_2$	237.73a	138.37b	24.12a	18.19a	34.58a	33.26a
Chelated Ca	265.50a	171.21a	25.33a	15.50b	34.08a	31.48b

and Zn (25.33 ppm) in the 1st season, while sprayed tree with CaCl2 gave the maximum concentration of Zn (18.19 ppm) in the 2nd season and Mn (24.58 and 33.26 ppm) in the both experimental seasons.

Discussion

The obtained results are in agreement with those obtained by Saour (2005), Bedrech and Farag (2015), El-Said (2015), and Omran (2013) which demonstrated that foliar applications with CaCo3 significantly increased vegetative growth characteristics. Also, Hagagg et al. 2019 indicated that foliar application of calcium carbonate at 7% on mid-December on 15-year-old Kalamata and Manzanillo olive trees increased vegetative growth, leaf pigments, and mineral content. In this respect, Youssef et al. 2017 reported that foliar application of calcium chloride at 20 mM on lettuce significantly increased vegetative growth parameters (plant length, head diameter, fresh and dry weights of head, number of leaves/head, average leaf area, and leaf area index), chlorophyll (a, b, and total), leaf relative water content, leaf membrane stability index, and macro- and micronutrients. The beneficial effect of calcium in increasing growth might be due to the higher availability of photosynthesis, and these chemicals are also associated with hormone metabolism which promotes synthesis of auxin, essential for growth (Kazemi, 2014).

Conclusions

Results proved that olive trees sprayed at the end of December with 0.5% calcium as chelated calcium was the promising treatment for good vegetative growth and leaf mineral contents.

Abbreviations

Ca: Calcium; Ca^+: Calcium ion

Acknowledgements

Not applicable

Authors' contributions

This work was carried out in collaboration between all authors. Author L.F.H. designed the study, wrote the protocol, managed the fieldworks, and reviewed the final draft of manuscript; Author M.F.M.Sh. managed the literature searches, created the tabled field data for the statistical analyses, prepared the samples for analyses, and wrote the first draft of the manuscript. Author M.M.A. participated in the fieldworks, collected field samples, and created the tabled data for statistical analyses. Author E. S. El conducted the field applications, created the tabled field data for the statistical analyses, prepared the samples for analyses, conducted the physical and chemical analyses, and performed the statistical analyses. All authors read and approved the final manuscript.

Funding

Not applicable

Availability of data and materials

The datasets generated and/or analyzed during the current study are included in this published study.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Received: 10 May 2020 Accepted: 2 July 2020
Published online: 29 July 2020

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