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

Laila F. Hagagg*, Mohamed A. Merwad, Mohamed M. F. Shahin and Eman S. El-Hady

Abstract

Background: This work was carried out through 2017 and 2018 seasons on two olive cultivars (Kalmata and Manzanillo). Trees were 15 years old, grown in sandy soil, planted at 5 x 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 two 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 growth 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...
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 potassium/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). CaCl₂ 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 (Marchner 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 sample(cm) |
| pH          | Surface sample 30 cm depth 60 cm depth |
| EC(dSm⁻¹)   | 8.02 8.70 8.11 |
| 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 |
| SO₄²⁻       | 7.12 1.14 3.18 |
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 CaCl₂. 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 (cm²) 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—flamephotometrically determined according to Brown and Lillemo (1946).

Fe, Zn, and Mn as ppm were spectrophotometrically 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 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      |
| SO₄²⁻               | 4.16       |
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 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 cm²  | 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        |
| CaCl₂          | 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       |
| CaCl₂          | 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       |

### 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 |
| Kalmata        |     |      |     |      |      |      |
| Control        | 1.11b| 1.31b| 0.043c|0.027b|1.05b  |1.22c |1.14c |1.26c |
| CaCl₂          | 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 |
| CaCl₂          | 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|
| CaCl₂          | 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|
| CaCl₂          | 237.73a| 138.37b| 24.12a |14.19a | 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 micro-nutrients. 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; Ca²⁺: Calcium ion

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**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.

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

**Ethics approval and consent to participate**

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The authors declare that they have no competing interests.

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