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Influence of foliar spray with some calcium sources on flowering, fruit set, yield and fruit quality of olive Kalmata and Manzanillo cultivars under salt stress

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Abstract

Background: This work was carried out through 2017 and 2018 seasons on Kalmata and Manzanillo olive cultivars. Trees were 15 years old, grown in sandy soil and planted at 5 × 5 m apart irrigated with saline water through drip irrigation system. This investigation aimed to improve flowering, fruit set, yield and fruit quality 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 number of inflorescences/shoot, no. of total flowers/inflorescences, sex expression, initial fruit set, final fruit set (%) and yield/kg (tree) and decreasing fruit drop (%) of olive oil Kalmata and Manzanillo cultivars compared with unsprayed in both seasons.

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 flowering, fruit set, yield and fruit quality.

Keywords: Olive (*Olea europaea* L.), Kalamata, Manzanillo, Calcium chloride, Chelated calcium, Flowering, Fruit set, Yield and fruit quality

Background

Olive (*Olea europaea* L.) considered is one of the oldest cultivated trees in the history of the world about 8000 years ago. In Egypt, table olive cultivars play an important function in economics of the growers where most of the olive production is consumed as pickling products. Plant growth and fruit production are all expected to be influenced by levels of available nutrients and soil properties. Flowering and fruit set are the main processes influencing the productivity of fruit trees that are especially important for the olive, in which there is a clearly accurate relationship between vegetative and reproductive growth (Lavee 2006). Thereby, poor fruit

set, high fruit shedding and consequently poor yields are considered critical factors for growing table cultivars.

Olive trees existing in Mediterranean climate are almost grown in semiarid regions, where rainfall considered rare and irregular which responsible of low yields. Olive trees mainly grown around the Mediterranean Basin have been conventional cultivated in dry lands (Orgaz and Fereres 2004), lack of water requirements for the growth and productivity of olive tree cultivated in dry lands leading to the use of low-quality water resources. Olive trees are considered moderately tolerant to salinity (Maas and Hoffman 1977; FAO 1985; Rugini and Fedeli 1990). For that reason, high concentrations of salts in irrigation water cause a decrease in nutrient that may be due to both dysfunctions of membrane selectivity and ionic competitive interactions (Kozłowski 1997) which led to ionic imbalance (Zhu

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2001; Munns 2002). The accumulation of Na^+ and Cl^- ions to toxic levels in plants decrease the absorption of potassium, magnesium and calcium (Daas-Ghrib et al. 2011; Farissi et al. 2014). Ca^{2+} is also assumed to play an important role in retention mechanisms and sodium exclusion, which may be considered responsible for survival under salt stress conditions (Melgar et al. 2006; Tattini and Traversi 2008).

Calcium element is considered a secondary plant nutrient and acts as signaling molecule and plays a very important function in nutrition and plant growth, as well as in cell wall precipitation. Ca^{2+} element considered a multifunctional nutrient in plant physiology, which influences the availability nutrient and its uptake and has a role raising strength and thickness of cell wall. Ca^{2+} element levels affect the strength of plant stem and fruit quality. Ca^{2+} element considered a crucial regulator of growth and development in plants. Calcium ion sharing in many growing processes and nearly involves in all plant development aspects (Harper et al. 2004; Hetherington and Brownlee 2004; Hirschi 2004; Reddy and Reddy 2004; Bothwell and Ng 2005).

Ca^{2+} element renowned by its protective function in most abiotic stresses: salt stress drought, heat, cold, and heavy metals (Khan et al. 2010; Liu et al. 2014). Ca^{2+} is found to be crucial in altering the ion selectivity absorption and in enhancing salt tolerance in many species (Rengel 1992; Zhu 2003). Under salt stress, plant cells either accumulate calcium or releasing intracellular cytosolic calcium, which working as a signaling molecule and adjust a range of physiological processes to modify salt stress (Kader et al. 2007; Kader and Lindberg 2008, 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 considered essential element for potassium/sodium and calcium/sodium selectivity and reducing the negative effects of salinity by regulating ion transport in plants (Renault 2005). Application of calcium alleviated adverse effects of salinity on plants, sodium formed competition with calcium ion on the cell wall, therefore high levels of calcium protected cell membrane from adverse effects of salinity (Busch 1995). Various studies indicate that Ca^{2+} reduced peroxidation of lipid, increased activity of antioxidant enzyme and improve osmotic adjustment of cell membranes (Hernandez et al. 2003; Amor et al. 2010). Whereas Ca^{2+} at moderate concentration reducing oxidative damage produced by sodium chloride in *Cakile maritima* (Amor et al. 2010) and Ca^{2+} at high concentration improved salt tolerance in *Nitraria tangutorum* (Liu et

al. 2014). These reports show that calcium has different effects in inducing salt stress tolerance that may depend upon the species or concentration of calcium applied.

Plant roots absorb calcium from the soil solution in the form of Ca^{2+} ions (Clarkson 1993; White 2001) Ca mineral, relatively insoluble in soil in this state and considered a leachable nutrient. Which reduce the calcium uptake by plants. With regard to uptake and mobility of Ca in plants, Ca uptake is passive which means not require energy input. Ca mobility occurs fundamentally in the xylem, flow with the movement of water. Thus, uptake of Ca related directly to the rate of transpiration in plant. Accumulation of salinity might also 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. Thence, it is necessary to have a constant supply of calcium to continue growing. (Kadir 2004).

However, 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 an inorganic mineral structure hardly diffuses from the leaf surface into the plant because of high weight molecular structure. Chelating agents describe a kind of organic chemical complex that can encapsulate certain metallic salts and then release these metallic salts slowly to become available for up take by plants (Marschner 1995; Zocchi and Mignani 1995).

Thence 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 be easily release their ions to affect the plant (Zocchi and Mignani 1995). Natural chelates as mid-molecular weight compounds like amino acids that 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 current study was therefore initiated to investigate the influence of foliar application of calcium chloride and calcium chelate on the yield and fruit quality characteristics olive Kalmata and Manzanillo cultivars.

Methods

The present study was conducted during two successive seasons, 2017 and 2018, on 15-year-old olive trees Kalamata and Manzanillo cvs. grown in a private orchard located at Ismailia governorate, Egypt. The trees spaced 5 × 5 m apart (168 trees/feddan) in a sandy soil (Table 1). The trees received the same cultural practices according to the recommendations of the Ministry of Agriculture. The trees irrigated by drip irrigation system depending on wells in irrigation (Table 2). The trees were almost similar in vigor, free from any visible pathogenic symptoms and at the same bearing phase. Complete block randomized design was applied. Three treatments were applied in five replicates (one tree for each replicate); all of the 15 trees conducted in this study were vigorous and similar in growth and canopy.

Experimental design

The treatments will be arranged in a randomized complete block design (RCBD), the experiment contained three treatments were applied in five replicates (one tree for each replicate). The normal horticulture practices that used in the farm were applied to all Kalamata and Manzanillo olive trees.

Experimental material

- 1 Calcium chloride is a chemical compound with the formula CaCl. It is a common substance found in rocks as the minerals calcite and aragonite (most notably as limestone, which is a type of sedimentary rock built mainly of calcite).
- 2 Chelated calcium: the chelating agents used in this experiment were natural chelates 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 on two olives (Kalamata and Manzanillo cvs), this experiment included three treatments as follows:

- T0: Control.
- T1: CaCl (0.5%).
- T2: Calcium chelate (0.5%).

Table 1 Effect of foliar spray with some calcium sources on flowering of olive Kalamata and Manzanillo cultivars

	No. of inflorescences/shoot		No. of total flowers/inflorescences		Sex expression	
	2017	2018	2017	2018	2017	2018
<i>Kalamata</i>						
Control	11.00b	9.00b	17.50b	6.33b	70.22b	44.17b
CaCl ₂	16.50a	13.83a	23.50a	21.50a	77.96a	76.56a
Chelated Ca	15.75a	14.87a	21.75a	21.67a	79.98a	78.90a
<i>Manzanillo</i>						
Control	10.56a	7.23b	20.57a	8.57b	61.77b	53.62c
CaCl ₂	12.58a	13.03a	23.33a	12.33a	63.14ab	59.00b
Chelated Ca	11.33a	12.43a	23.93a	13.67a	73.75a	66.33a

Table 2 Effect of foliar spray with some calcium sources on fruit set and yield of olive Kalamata and Manzanillo cultivars

	Initial fruit set (%)		Final fruit set (%)		Fruit drop (%)		Yield (kg/tree)	
	2017	2018	2017	2018	2017	2018	2017	2018
<i>Kalamata</i>								
Control	25.63b	32.57a	16.07b	22.89a	31.77a	34.34a	19.41c	24.00c
CaCl ₂	34.26a	35.83a	24.55a	23.52a	23.85b	29.72ab	41.33b	33.67b
Chelated Ca	37.26a	37.14a	25.10a	26.55a	25.39b	28.61b	50.67a	57.67a
<i>Manzanillo</i>								
Control	28.91b	26.94b	17.95c	14.01b	37.93c	48.60a	24.00b	19.00b
CaCl ₂	37.50a	69.71a	22.19b	29.66a	48.39a	24.60b	45.00a	27.38a
Chelated Ca	42.06a	80.12a	27.53a	32.64a	41.16b	22.07b	45.33a	31.56a

Calcium chloride (0.5%) and calcium chelate (0.5%) were applied as foliar spray at the end of December. Calcium chloride and calcium chelate were prepared from analytical grade chemicals. A back-held spray pump was used for foliar application of the chemicals. After each treatment, the pump was washed thoroughly. A teaspoon of commercial washing powder was added as a wetting agent. Tap water containing a comparable amount of wetting agent was sprayed on the plants in the controlled treatment. All foliar spraying was carried out early in the morning.

The number of flower clusters per plant, number of fruits per cluster, and number of fruits per plant were determined for three plants in the middle row of the plot. For this purpose, the number of flower clusters per plant, number of fruits per cluster, and number of fruits per plant were counted and divided by the total number of plants. The total yield for each treatment was calculated by weighing the fruit picked in each plot and converting the weight to yield per acre. The average fruit weight was estimated by weighing 100 fruits in each treatment, with the help of an electronic balance measuring in grams to the third decimal place, and then converting to average fruit weight.

Measurements

1 Flowering parameters:

- Ten (1-year-old) shoots were chosen at random and labeled on each tree for each season's during full bloom (late April) to count the total number of inflorescences per shoot and number of flowers per inflorescences.
- Sex expression: the percentage of perfect flowers to the total number of flowers was calculated in previously the thirty inflorescences at balloon stage for each replicate.
- Initial fruit set (%): Fruit set was calculated after 21 days from full blooming, Mofeed (2002).
- Final fruit set (%): Fruit set was calculated at the beginning phase of ripening.
- Fruit drop (%): Fruit drop was measured for the selected trees by chosen 4 small branches/tree in the 4 directions, we was wrap the branches in a net bag and we was collected the drop fruits every 15 days and count it. During the last observation, we counted the number of olives still on the branch.
- Yield (kg/tree): average yield (kg) per tree was recorded at harvesting date for every replicate tree from each treatment.

2 Fruit parameters:

Hundred fruits per each tree were randomly selected and used to determine the following physical characteristics:

lower-alpha Fruit weight (g): The average fruit weight (g) was determined by weighing the sample of each studied tree.

- 1 Fruit volume (cm³): Average fruit volume (ml) was determined from the volume of water displaced method.
- 2 Pulp/seed ratio: stones were extracted to determine stone weight (gm), flesh/fruit weight and flesh/stone ratio.
- 3 Oil %: Oil content percentage in dry weight was extracted by Soxhlet apparatus from the dry fruit samples using petroleum ether (60–80) as a solvent for 16 h according to the method described by A.O.A.C (1995).

Statistical analysis

All obtained data during both 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

Data in Table 1 indicate that, there were significant differences with calcium source and control treatment regarding number of inflorescences/shoot, No of total flowers/inflorescences and Sex expression of olive Kalmata and Manzanillo cultivars than unsprayed in both seasons.

Concerning Kalmata cultivar, sprayed trees with CaCl₂ recorded the highest values of number of inflorescences/shoot (16.50) and No of total flowers/inflorescences (23.50) in the 1st season, while sprayed with Chelated Ca recorded the highest values of number of inflorescences/shoot (14.87) and No of total flowers/inflorescences (21.67) in the 2nd season and Sex expression (79.98 and 78.90) in both season against (11.00 and 9.00) number of inflorescences/shoot, (17.50 and 6.33) No of total flowers/inflorescences and (70.22 and 44.17) Sex expression for control treatment in the 1st and 2nd seasons, respectively.

As for Manzanillo cultivar, such data in the same Table 1 showed that, in general treated trees with chelated Ca recorded the highest values of highest values of No of total flowers/inflorescences (23.93 and 13.67) and Sex expression (73.75 and 66.33). While sprayed trees with CaCl₂ recorded the highest values of No of

inflorescences/shoot (12.58 and 13.03) against (10.56 and 7.23) number of inflorescences/shoot, (20.57 and 8.57) No of total flowers/inflorescences and (61.77 and 53.62) Sex expression in the 1st and 2nd seasons, respectively.

Results in Table 2 showed that foliar application of both Ca source were led to significant increases in initial fruit set, final fruit set (%), Fruit drop (%) and yield/kg (tree) of olive Kalmata and Manzanillo cultivars than control treatment in both season, except initial fruit set, final fruit set (%) in the 1st season for Kalmata cultivar.

As for Kalmata cv. The data show that, sprayed trees with Chelated Ca gave the highest values of initial fruit set % (37.26 and 37.14), yield/tree (50.67 and 57.67 kg/tree) in both seasons and final fruit set (25.10%) in the 1st season and lowest fruit drop in the 2nd season (28.61%) against (25.63 and 32.57) initial fruit set, (16.07 and 22.89%) Final fruit set (%), (19.41 and 24.00) yield kg/tree and highest fruit drop (31.77 and 34.34%) in the 1st and 2nd seasons, respectively.

Also, sprayed Manzanillo tree with Chelated Ca was the best treatment for increasing initial fruit set, final fruit set (%) and yield/kg (tree) and decreasing fruit drop (%) than sprayed with CaCl₂ or control treatments.

Data in Table 3 indicated that, sprayed olive trees with different source of Ca had significant effect on fruit weight, fruit volume, pulp/seed ratio and oil percentage in fruit in both Kalmata and Manzanillo cultivars than unsprayed tree in the two tested seasons, except fruit weight with Kalmata cultivar in both seasons.

Treated Kalmata cv. with CaCl₂ gave the highest values of fruit volume (5.40 and 5.27 cm³) and oil percentage (47.60 and 40.33%), while sprayed with Chelated Ca gave the highest values of Pulp/seed ratio (5.78 and 5.85) against fruit volume (4.87 and 4.68 cm³), Pulp/seed ratio (2.36 and 2.44) and oil percentage in fruit (40.47 and 35.60%) for control treatment in the 1st and 2nd seasons, respectively.

As for Manzanillo cv., control treatment (unsprayed trees) gave the highest values of fruit weight and fruit volume in both seasons, while sprayed trees with Chelated Ca gave the maximum percentage of oil in fruit (49.27 and 50.67%) against (32.67 and 37.00%) for unsprayed trees, in addition, treated trees with CaCl₂ recorded (43.87 and 44.53% in the 1st and 2nd seasons, respectively.

Discussion

The beneficial effect of calcium in increasing fruit set 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 fruit set and 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 flowering, fruit set, yield and fruit quality.

Abbreviations

Ca: Calcium; Ca⁺: Calcium ion.

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Authors' contributions

This work was carried out in collaboration between all authors. Author LFH designed the study, wrote the protocol, managed the field works and reviewed the final draft of manuscript; Author MFMSH managed the literature searches, tabled the field data for the statistical analyses, prepared the samples for analyses and wrote the first draft of the manuscript. Author MMA participated in the field works, collected field samples and tabled the data for statistical analyses. Author ESEI conducted the field applications, tabled the field data for the statistical analyses, prepared the samples for analyses, conducted the physical and chemical analyses, performed the statistical analyses. All authors have read and approved the manuscript.

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Table 3 Effect of foliar spray with some calcium sources on fruit quality and oil percentage of olive Kalmata and Manzanillo cultivars

	Fruit weight (g)		Fruit volume (cm ³)		Pulp/seed ratio		Oil (%dry W)	
	2017	2018	2017	2018	2017	2018	2017	2018
<i>Kalmata</i>								
Control	5.19a	4.87a	4.87b	4.68b	2.36c	2.44b	40.47b	35.60b
CaCl ₂	5.42a	5.52a	5.40a	5.27a	4.16b	5.44a	47.60a	40.33a
Chelated Ca	5.24a	5.41a	5.06a	4.99a	5.78a	5.85a	47.53a	39.13a
<i>Manzanillo</i>								
Control	4.87a	5.54a	4.30a	5.20a	3.52c	2.68b	32.67c	37.00c
CaCl ₂	4.13b	4.27b	3.82b	4.12b	4.35b	3.57a	43.87b	44.53b
Chelated Ca	4.49ab	4.50b	4.20ab	4.23b	4.97a	2.86ab	49.27a	50.67a

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.

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