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Research Article

Impact of Manganese Soil and Foliar Fertilizers on Olive Trees Productivity in Al-Qurayat and Sakaka Cities in Kingdom of Saudi Arabia

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Abstract

Different fertilizers such as mineral, organic, nano- and bio-fertlizers are used to improve olive production all over the world. This study was aimed to address the impact of manganese (Mn) soil and foliar fertilizers on the olive fruit production, twigs and seedlings growth in two pre-selected regions cultivated with olive trees in Al-Qurayat and Sakaka cities, KSA. The olive trees in the two pre-selected regions were fertilized by soil (fertilizer A: Mn 2.5%) and foliar (fertilizer B: Mn 0.6%) starting from early December, 2021 till the middle February, 2022. Soil samples from the pre-selected regions were collected to determine the soil elements by using Inductively Coupled Plasma Emission Spectrometer (ICP 6200). The results showed that upon using the fertilizer A to fertilize olive trees in both of Al-Qurayat and Sakaka pre-selected regions, an increase in olive fruits production, increase olive twigs and seedlings growth were reported when compared to those fertilized with fertilizer B or non-fertilized. In addition, analysis of soil samples elements showed that Fe, Mg and Mn levels in Al-Qurayat soil samples were higher than their levels in Sakaka samples. Collectively, applying fertilizer A led to increase olive fruit productivity, olive twigs and seedlings growth more than fertilizer B utilization.

Keywords: Olives; Fruits; Twigs; Seedlings; Soil; Foliar; Fertilizers; Manganese; Al-Qurayat; Sakaka

Introduction

Olive tree (*Olea europaea* L.) is one of the most important agricultural crops belongs to family *Oleaceae* with an economic value worldwide. Around 98% of olive trees cultivation was concentrated in the Mediterranean and Middle East countries (Ghanbari., *et al*. 2012; Tekaya., *et al*. 2016) [1,2]. These trees range from 10 to 40 feet in height with numerous branches having lance-shaped leaves. Paired leaves measuring 4–10 cm long and 1–3 cm wide arranged in alternative positions on the twig (Rugini., *et al*. 2016) [3]. The olives fruit is a small drupe 1–2.5 cm long, thinner-fleshed and harvested in the green to purple stage (Kiritsakis and Shahidi, 2017) [4]. The maintenance of olive groves is important for the soil conservation and environmental biodiversity (Duarte., *et al*. 2008) [5].

Olives are used in pharmaceutical products, cosmetics, medicine and food industry (Erbay and Icier, 2010) [6]. Olives have beneficial effects on human health due to the richness of bioactive compounds including vitamins, flavanoids, and phenolics (Soleas., *et al*. 1997) [7]. Olives showed antioxidant and anticancer activities due to its chemical compositions (De Marino., *et al*. 2014; Abdel-Farid., *et al*. 2020) [8,9]. Olive trees need several macro- and micronutrients from its surrounding environment for their development and growth (Grusak., *et al*. 2016) [10]. Fertilization considered one of the most important and critical factors for rapid plant growth. Olive trees have to be fertilized to maintain proper tree nutritional status and not impair growth or production (Erel., *et al*. 2018) [11]. Supplemental soil and foliar fertilizers can improve olive yields, correct their mineral status, and enhance crop quality (Erel., *et al*. 2013; Haytova, 2013) [12,13]. These fertilizers may play an important role in fertilization programs of containerized olive nursery plants. Even though, fertilization has an important for olive plants, over-fertilization has a potential negative effect on

olive yield and quality (Erel., *et al*. 2013; Haberman., *et al*. 2019) [12,14], the environment (Segal., *et al*. 2011) [15].

Best management protocol for olive trees fertilization depends on the effectiveness of fertilizer composition as well as their method of application. Studies have been conducted on olive trees in regard to nutrient fertilization showed that Mn was just one of the main constituents in fertilizers (DelRı´co., *et al*. 2003; Tekaya., *et al*. 2016) [2,16]. In addition, potassium (K) has been reported as an important nutrient in olive. In this regard, K-fertilized olive trees showed increased growth and yields (Centeno and Campo, 2011) [17]. Furthermore, boron (B) application as a fertilizer is promising for olive productivity, quality and fruit set (Arrobas., *et al*. 2010; Larbi., *et al*. 2011) [18,19]. The importance of N in olive fertilization has been reported. Rodrigues., *et al*. (2011) [20] showed a significant decrease in olive yield when N was eliminated from the fertilization crops. In addition, Jasrotia., *et al*. (1999) [21] also found a significant olive production with increasing N fertilizer rates. Sarrwy., *et al*. (2010) [22] reported a remarkable improvement in leaf mineral status, yield and fruit quality after the application of potassium nitrate in comparison with control trees probably due to the higher needs of N than P in olive nutrition. Centeno and Campo (2011) reported an increase in olive yield after the application of N to the soil, and P and K as foliar sprays. It has been reported that mineral fertilization (NPK) improved olive seedlings parameters under greenhouse condition including vegetative, rooting growth and leaf mineral content (Hagagg., *et al*. 2018) [23].

Manganese (Mn) is essential micronutrient and play important role in plant growth and development. It is related indirectly to chlorophyll formation, photosynthesis and involved in various enzymes synthesis (Fischer., *et al*. 2015; Farzadfar., *et al*. 2017) [24,25]. It activates important metabolic reactions, involved in the oxidation-reduction reactions and electron transport systems (Amao and Ohashi, 2008; Millaleo., *et al*. 2010) [26,27].

Aljouf district located in the North of Kingdom of Saudi Arabia (KSA) is the most important city in the Gulf region producing 68% of olive oil in KSA where more than 15,000,000 trees are cultivated there (http://www.aljouf.com.sa/en_products.aspx). The present study aimed to evaluate the impact of soil and foliar fertilization with Mn feeding application on olive fruit production, olive twigs and seedlings growth in pre-selected olive trees in Al-Qurayat and Sakaka cities of KSA.

Materials and Methods

Chemical fertilizers

Two types of manganese (Mn) fertilizers were used in this study. Fertilizer (A) composed of Mn 2.5%. Fertilizer (B) composed of Mn 0.6%. Fertilizer (A) was used as a soil mineral fertilizer and applied in irrigation water from the beginning till the end of the experiment. Fertilizer (B) was used as a foliar mineral fertilizer and applied in irrigation water and then after 15 days added as foliar on the olive trees leaves.

Experimental sites characterization

The experiments were conducted in two different regions Al-Qurayat and Sakakah located in the north of KSA. This study was conducted in the two regions due to the difference in climate such as temperatures and humidity. Curves of weather in Al-Qurayyat and Sakaka cities were represented in figure 1. The two pre-selected farms were chosen because they are similar to the quality of their soil, the same variety and the age of the trees.

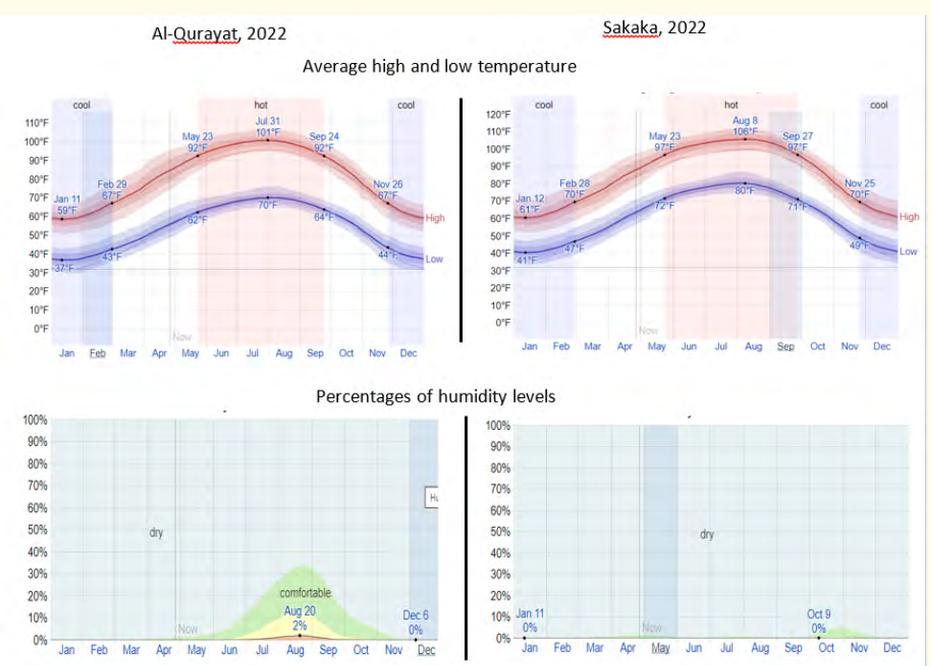

Figure 1: Average temperature and percentages of humidity levels in Al-Qurayat and Sakaka cities in KSA.

Experimental protocol

In Al-Qurayyat region: the farm has 5,000 olive trees of a 20-year-old Nepalese variety. Three random and spaced squares (200 meters) were taken, each box contained: 50 trees without fertilizer, 50 trees fertilized by a soil mineral fertilizer 2.5% of Mn (fertilizer A) and 50 trees fertilized by a foliar mineral fertilizer 0.6% Mn (fertilizer B). In Sakaka region: the farm has 4,000 olive trees of a 20-year-old Nepalese variety. Three random and spaced squares (200 meters) were taken, each box contained: 50 trees without fertilizer, 50 trees fertilized fertilizer A and 50 trees fertilized by fertilizer B. Soil and foliar fertilizations started at early December, 2019 till the middle February, 2020 in both regions, respectively. The results were obtained starting from early March, 2020 to late May, 2020 to determine the growth of twigs and seedlings. In addition, olive fruits were harvested and weighed from trees during October, 2020.

Crop harvest

Fifty pre-selected trees with similar canopy sizes were used in this experiment in each region of the study. The pre-selected trees were harvested in October 2020. A knapsack portable shaker-machine was used to pull the fruits down, and sheets on the floor were laid to recover them. Thereafter, the weights of olives were recorded per tree.

Measurements of olive twigs and seedlings

Olive twigs and seedlings were measured by caliber starting from March, 8 till May, 30/2020. Six twigs and seedlings were measured at every time point.

Determination of soil elements

Soil samples collected from the two pre-selected regions in Al-Qurayat and Sakaka cities were ground and passed through a 20 mesh sieve to obtain very fine particles. Five grams of an air-dried sieved sample were placed in an Erlenmeyer flask and 20 mL of the extracting solution (0.05 N HCl + 0.025 N H_2SO_4) was added and stirred for 20 minutes. The resulting solution was filtered and diluted to 50 mL with the extracting solution. The analytical reagent blanks were prepared and these contained only the acids. The above mentioned procedure is in accordance with Mehlich-I extraction. The microwave digestion of soil and plant samples was done in accordance with EPA Method 3052. This method is applicable to the microwave assisted acid digestion of siliceous matrices, organic matrices and other complex matrices prior to analysis protocol. This method is provided as a rapid multi-element. Sample weights were approximately 0.1 g. To each sample, 9 mL of concentrated nitric acid and 3 mL of concentrated hydrofluoric acid were added. The Micronutrient and NPK elements of soil samples after treatment were determined by using the Inductively Coupled Plasma Emission Spectrometer (ICP 6200).

Statistical analysis

The results were presented with the mean and standard deviations. All data were subjected to statistical analysis using Duncan multiple test range and analysis of variance (ANOVA).

Results

Utilization of fertilizer A increased the production of olive fruits

The olive fruits were harvested from the trees cultivated in the two pre-selected regions in Al-Qurayat and Sakaka in October, 2022. The results showed that the olive trees in Al-Qurayat regions which fertilized with soil fertilizer (Fertilizer A; Mn 2.5%) produced the highest quantity of olive fruits when compared to the non-fertilized or fertilized trees with foliar fertilizer (fertilizer B; Mn 0.6%). Interestingly, the same results obtained after harvesting the olive fruits from the olive trees which fertilized with fertilizer A and B in Sakaka region (Table 1).

Table 1: Quantities of olive fruits harvested from the pre-selected olive trees (Kg) without fertilizer, with fertilizer (A) and (B) in Al-Qurayat and Sakaka cities in Kingdom of Saudi Arabia (KSA).

Area	Olive quantities (Kg)		
	Without fertilizer	Fertilizer (A)	Fertilizer (B)
Qurayat-KSA	22.9 ± 6	48 ± 13.9	36.2 ± 7.2
Sakaka-KSA	17.9 ± 3.9	40.3 ± 5.8	30.3 ± 5.1

The values represented mean ± SD; P value < 0.05 was statistically significant. Fertilizer (A): Manganese (Mn) 2.5%, Fertilizer (B): Mn 0.6%. Olive fruits were harvested manually in Al-Qurayat and Sakaka from 10 to 20 October.

Fertilizer A increased the growth of the olive twigs in olive trees

Starting from March, 8 till May, 30/2022, the growth of the olive twigs was determined in all the pre-selected areas that cultivated with olive trees in Al-Qurayat and Sakaka cities. The results showed that starting from March, 8 till April, 11, there were no significant increase in growth of the olive twigs in all trees, which either treated with fertilizer A, B, without fertilizers in Al-Qurayat region, however, from April, 29 toll May, 30/2022 a significant increase in the growth of olive twigs in the olive trees which fertilized with fertilizer A was reported when compared to the fertilized olive tree fertilized with fertilizer B or non-fertilized olive trees. In addition, a significant increase was noticed in the growth of the olive twigs, which fertilized with fertilizer B but less than those which fertilized with fertilizer A, when compared to the non-fertilized olive trees (Figure 2). As shown in figure 3, the results showed that same pattern in the olive trees which fertilized with fertilizer A or B in Sakaka region.

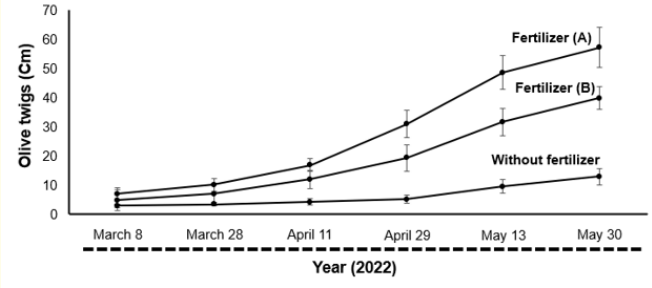

Figure 2: The growth of olive twigs without fertilizer, with fertilizer (A): (Mn 2.5%), fertilizer (B): (Mn 0.6%) in Qurayat-KSA.

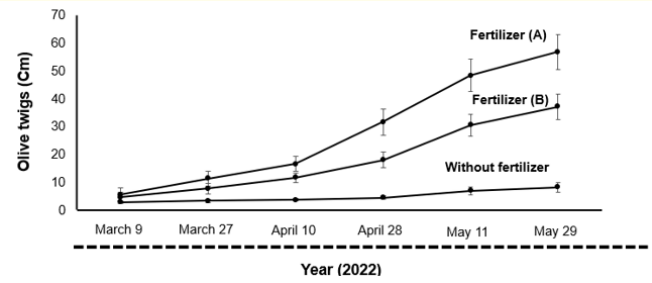

Figure 3: The growth of olive twigs without fertilizer, with fertilizer (A): (Mn 2.5%), fertilizer (B): (Mn 0.6%) in Sakaka-KSA.

The growth of olive seedlings significantly increased post fertilizing with fertilizer A

As shown in figure 4, starting from March, 8 till May, 30/2020, the growth of the olive seedlings was determined in all the olive trees in the selected regions in Al-Qurayat and Sakaka cities. The results showed that starting from March, 8 till April, 11; there were no significant increase in the growth of olive seedlings in trees that fertilized with fertilizer A or with fertilizer B when compared to non-fertilized olive trees in Al-Qurayat region. However, from April, 29 toll May, 30, a significant increase in the growth olive seedlings in the olive trees which fertilized with fertilizer A was reported when compared to the non-fertilized olive trees. Additionally, a significant increase was noticed in the growth of the olive seedlings in the trees, which fertilized with fertilizer B but less than those which fertilized with fertilizer A. The results showed that same pattern in the olive trees which fertilized with fertilizer A or B in Sakaka region (Figure 5).

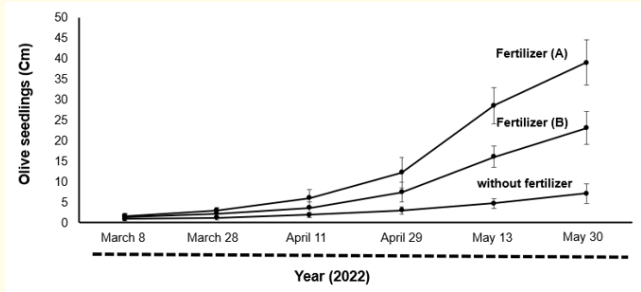

Figure 4: The growth of olive seedlings without fertilizer, with fertilizer (A): (Mn 2.5%), fertilizer (B): (Mn 0.6%) in Qurayat-KSA.

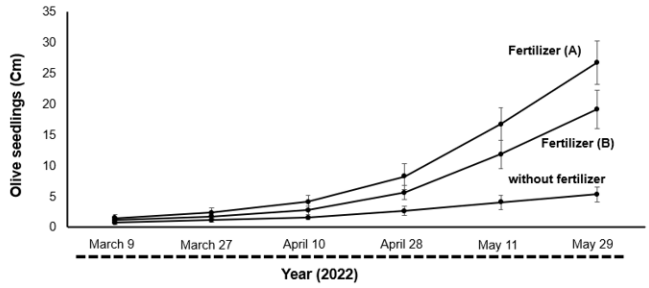

Figure 5: The growth of olive seedlings without fertilizer, with fertilizer (A): (Mn 2.5%), fertilizer (B): (Mn 0.6%) in Sakaka-KSA.

Soil elements in the pre-selected regions in Al-Qurayat and Sakaka cities

Further, we have determined the levels of different elements in the soil samples obtained from two pre-selected regions in Al-Qurayat and Sakaka cities (Figure 6). The results showed that, the analysis of soil elements which collected from Al-Qurayat and Sakaka soil samples showed that the nitrogen (N), potassium (K), sodium (Na) and calcium (Ca) were almost closed in their levels. However, the levels of iron (Fe) and magnesium (Mg) in the soil samples that collected from Al-Qurayat was significantly higher than its level in the soil sample that obtained from Sakaka region. Furthermore, the analysis showed that the concentration of boron (B), copper (Cu), manganese (Mn), phosphorous (P), and zinc (Zn) were close in the soil samples obtained from Al-Qurayat and Sakaka (Figure 6).

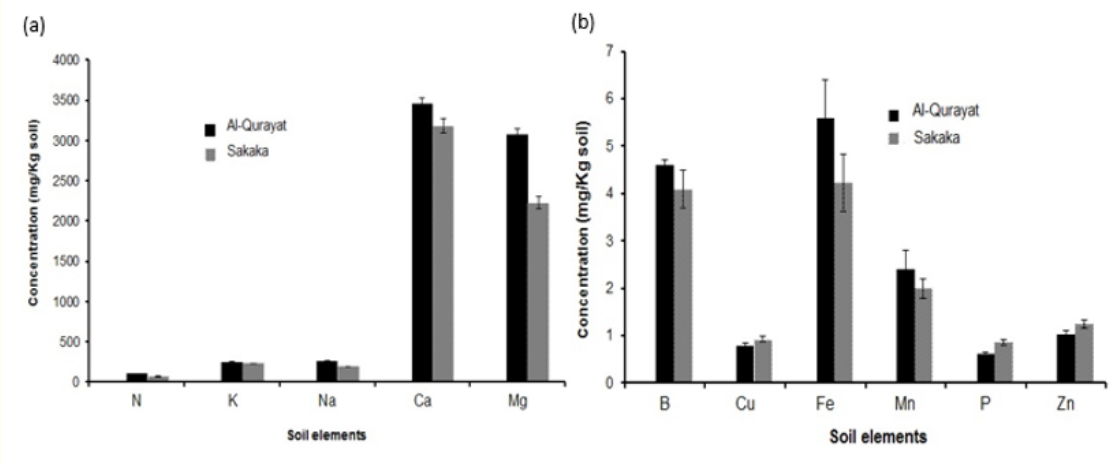

Figure 6: The analysis of elements in soil samples collected from Qurayat and Sakaka-KSA. a. Nitrogen (N), potassium (K), sodium (Na), calcium (Ca), and magnesium (Mg), b. Boron (B), copper (Cu), iron (Fe), manganese (Mn), phosphrous (P) and zinc (Zn) elements.

Discussion

To improve the productivity of olive trees, farmers all over the world have to be using soil or foliar fertilizers (Paskovi´c., *et al*. 2019) [28]. Several types of fertilizers usually used for instance, organic (Akanni and Ojeniyi, 2008) [20], mineral (Usman, 2015) [29], nano- (Sheykhbaglou., *et al*. 2010; Bozorgi 2012) [30,31] and bio-fertilizers (Mosa., *et al*. 2014) [32]. Among these fertilizers mineral fertilizers are widely used to fertilize olive trees. These fertilizers mainly contain essential or micronutrients. Deficiency of one of the essential nutrients will adversely affect plant performance. Therefore, olives trees absorbed the essential nutrients from the soil such as N, P and K, which consider are the most important in terms of fertilization, particularly under condensed cultivation (Segal., *et al*. 2011; Erel., *et al*. 2018) [11,15]. Other essential nutrients such as Ca, Mg, and S are usually absorbed from the soil and rarely needed to be applied as mineral fertilizer (Ben-Gal, 2011) [33]. Other minerals such as Na and Cl are required by olives in very small amounts. Fe, Zn, Mn, and Cu are consider as microelements for olive trees nutrition and they required in very small amounts (Rodrigues., *et al*. 2012) [34]. To date, the majority of multi-nutrient fertilization studies on olive trees have been conducted where Mn was just one of the main constituents in fertilizers (DelRı´co., *et al*. 2003; Tekaya., *et al*. 2016) [2,16]. A previous study reported the role of Mn as a promising candidate for olive trees fertilization (Paskovi´c., *et al*. 2019) [28]. Mn has a fundamental role in photosynthesis (Fischer., *et al*. 2015) [24]. Few studies investigated the effects of Mn deficiency in olive plants (Chatzistathis., *et al*. 2010) [35]. It has been reported that over-fertilization or deficiencies of such these microelements in olives are uncommon (Zipori., *et al*. 2011; 2015) [36-38].

The present study reported the impact of Mn fertilizers that have been used as soil fertilizer (Mn 2.5%) and as foliar fertilizer (Mn 0.6%) on the olive fruits production, length of olive twigs and seedlings. This study showed that using Mn 2.5% as soil fertilizers increased the olive fruits production in both of the pre-selected olive trees that cultivated in Al-Qurayat and Sakaka cities when compared to their production that collected from non-fertilized or Mn 0.6% as foliar fertilizer under the same conditions. This result was in agreement with previous study showed that using minerals as soil fertilizers increase the productivity of olive fruits (Hagagg., *et al*. 2018; Paskovi´c., *et al*. 2019) [23,28]. These results also reported that the soil fertilizer (Mn 2.5%) was much effective than foliar fertilizer (Mn 0.6%) under the same conditions such as temperature, humidity and soil mineral constituents in both of the pre-selected regions in Al-Qurayat and Sakaka cities. Of note, the results showed that applying soil fertilizers on the olive trees in Al-Qurayat and Sakaka cities give almost the same results. Interestingly, consistent with the increase of olive fruit productivity post application of Mn 2.5% fertilizer in Al-Qurayat and Sakaka cities, the results showed that soil fertilizer (Mn 2.5%) significantly increased the length of olive twigs and seedlings when compared to the non-fertilized or Mn 0.6% foliar fertilized olive trees.

The analysis of elements in soil samples that collected from Al-Qurayat and Sakaka cities in the pre-selected regions that cultivated with olive trees, the levels of Fe, Mg and Mn were higher in samples collected from Al-Qurayat than their levels in samples obtained from Sakaka city. Even though, these minerals were higher in Al-Qurayat soil samples, they did not correlate with the significant increase in olive fruits production; increase the growth of olive twigs and seedlings. In summary, these data collectively showed that olive trees that fertilized with soil fertilizer (Mn 2.5%) provide an increase in olive fruit productivity, increase in both of olive twigs and seedlings when compared to foliar fertilizer (Mn 0.6%).

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