
*International Journal of Plant & Soil Science*

***31(2): 1-7, 2019; Article no.IJPSS.53049***
***ISSN: 2320-7035***

# Evaluation of Soil Constituents and Water Quality on the Growth Rate of Olive Trees (*Olea europaea* L.) in Albaha Region, South-Western Saudi Arabia

**Saad Howladar[1,2*]**

[1]*Department of Biology, Faculty of Science, University of Albaha, Albaha, Saudi Arabia.*
[2]*Department of Biology, College of Science, University of Jeddah, Jeddah, Saudi Arabia.*

***Author's contribution***

*The sole author designed, analysed, interpreted and prepared the manuscript.*

***Article Information***

DOI: 10.9734/IJPSS/2019/v31i230204
*Editor(s):*
(1) Dr. Alejandro Hurtado Salazar, Professor, Departamento de Produccion Agropecuaria, Universidad de Caldas, Colombia.
(2) Dr. Hon H. Ho, Biology, State University of New York, New York, USA.
(3) Dr. Olanrewaju Folusho Olotuah, Professor, Department of Plant Science and Biotechnology, Adekunle Ajasin University, Nigeria.
*Reviewers:*
(1) Muhammad Raziq Rahimi Kooh, Universiti Brunei Darussalam, Brunei.
(2) Christian R. Encina-Zelada, National Agrarian University La Molina, Perú.
(3) Guizhou Liu, Chinese Academy of Sciences, China.
Complete Peer review History: http://www.sdiarticle4.com/review-history/53049

***Original Research Article***

***Received 10 October 2019***
***Accepted 15 December 2019***
***Published 21 December 2019***

## ABSTRACT

The study aimed at evaluating the influence of the physicochemical properties of soil and water on the growth rate of olive trees (*Olea europaea* L.) at twelve locations at Albaha region, south-western Saudi Arabia. The studied locations demonstrated clear variation in soil contents. They showed deficiency in organic matter contents while they were significantly different in their soil salinity. Soil samples had no significant variations in their nitrogen contents and had moderate amount of phosphorous. Soil from Farm No.2a contained significantly high amount of calcium (2470 mg/kg) while Farm No.1b had high iron (690 mg/kg) content. Soil pH values of all the areas were in the neutral range. Water samples were not chemically contaminated and showed negative test for total coliform except water sample from farm No. 1 which had a positive test. The variations in growth rate and health among the studied trees could be attributed to the variations in physicochemical properties of soil and water at the studied locations.

*Keywords: Organic matter; micro and macro nutrients; water analysis.*

**Corresponding author: E-mail: smhowladar@uj.edu.sa;*

## 1. INTRODUCTION

*Olea europaea* L. (Oleaceae), belonging to the olive complex, both wild and cultivated olive are largely distributed in this area. Farmers in this region rely on private ground water wells and water reservoir dams as main resources for irrigation of their crops. According to our knowledge, there are no studies on soil properties and quality of water and background levels of contaminants that may be presented in water used for irrigation of olive trees at Albaha region. In addition, at this time, there are no regulations governing individual water wells at Albaha region. Macronutrients and micronutrients in the soil are important factors controlling growth rate and yields of the crops [1]. Many studies have reported the importance of the soil elements on growth, development, yield and plant metabolism [2,3]. One of their main roles is to activate some of the enzymes in the cell [4]. Many investigations were carried out in the world for evaluating the vegetation and production of olive oil under full irrigation conditions [5,6]. Some researchers have reported diverse results on the impact of the irrigation practice on olive oil quality [7,8,5]. In semiarid and arid regions, irrigation of olive trees improves crop yield. This agricultural practice may increase problems such as salinization of agricultural soil [6]. It is the quality of water used for irrigation, which affects the quality and health of the olive trees and consequently the fruits and oil yield [9].

The aims of this study were to evaluate the impacts of the macronutrient and micronutrient contents of the soil samples from different locations on the growth rate (vigour's shoot growth) of the olive trees (*O. europaea* L.). In addition, to check if the level of chemical contaminants in the water used for olive crops irrigation might exceed the standard values that may pose any negative effect on the olive trees.

### 1.1 Study Areas

The study was carried out at twelve location sites (Farm No.1a, Farm No.1b, Amdaan forest, Barhrah forest, Albudani area, Al Khulb Park, Mishari Prince Park, Farm No. 2a, Farm No. 2b, Almrasa area) in Albaha province. The studied locations were randomly chosen representing different geographic areas.

## 2. MATERIALS AND METHODS

### 2.1 Soil Analysis

Three soil samples from different depths were randomly taken from each location and then mixed well to form a composite soil sample. They were air-dried to constant weight, ground and sieved to 2 mm prior to chemical analysis. Soil water extracts (1:5) were prepared for the determination of electrical conductivity (EC) and pH using a digital pH-meter (pH/ORP/Ion/ Conductivity meter SG78). Walkley–Black method further modified by Yeomans & Bremner [10] was used for determining the organic carbon content, and the total nitrogen was analyzed by Kjeldahl method [11]. For metal analysis, 0.25 g of a sample was digested by a microwave oven (Anton-Paar PE Multiwave 3000) with 4 mL $HNO_3$ (65%), 1 mL HCl (36%), 2 mL $H_2O_2$ (30% w/v) and 1 mL deionized $H_2O$ (Milli-Q quality). The digested samples were analysed with the inductively coupled plasma-optical emission spectrometry (ICP-OES, 7000 DV, Perkin Elmer, USA).

### 2.2 Water Analysis

#### 2.2.1 Sample collection and analysis

Five water samples were collected from different private water wells used for irrigation of olive oil trees during the month of June – 2018. The sites from where water samples were collected are Almrasa, Barhrah, Algema, Farm No. 1 and Farm No. 2 at Albaha region. The water samples were collected in clean polyethylene bottles (150 ml capacity). Bottles were cleaned first with distilled water and were rinsed two times with the water intended for sampling.

Each bottle was filled completely and placed in cartoon box and taken back to the laboratory. The water samples were submitted to Allehyan water station laboratories and were analyzed for levels of normal chemicals and the physical characteristics of the water.

#### 2.2.2 Chemical analysis

pH was measured using a pH meter (HANNA, HI 9125). Conductivity and total dissolved salts were measured using a calibrated Conductivity Meter (HANNA, Conductivity meter). Turbidity measurements were conducted using a portable turbidity meter (LaMotte 2020E). Chloride, nitrate-N, sulfate and major cations were determined according to standard methods for the examination of water and wastewater [12].

#### 2.2.3 Total coliform bacteria test

USEPA method 1604 the Membrane-Filter technique was used to test the total coliform bacteria. In this technique a fine porosity filter (47 mm pore sized cellulose ester membrane) that retain bacteria was utilized, which was placed in a petri dish (15 mm size) on a pad with growth enrichment media (MI Agar) and was incubated for 48 hours at 35ºC. The bacteria grown were inspected for the presence of dome-shaped colonies with a gold-green sheen.

## 2.3 Statistical Analysis

The experiments were performed in triplicates, and the average values and standard deviations were calculated using SPSS 21.0 for Windows (SPSS Inc, Chicago, IL, USA). Statistical comparisons were estimated by one-way ANOVA and Duncan's multiple-range tests at $p < 0.05$.

## 3. RESULTS AND DISCUSSION

## 3.1 Soil Analysis

### 3.1.1 pH, electrical conductivity, organic matter and calcium carbonate contents

Table 1 displays the pH, electrical conductivity, organic matter and calcium carbonate contents of the tested soil samples from the studied locations. The recorded pH values were in the range of 6.6-7.7. It was clear that the tested soil pH values of all the areas were in the neutral range. Soti et al. [13] have reported that the mineral nutrients are readily available to plants when soil pH is near neutral (pH = 6.5 –7.5) and soil pH is an important factor for plant growth, as it affects nutrient availability, nutrient toxicity and has a direct effect on the protoplasm of plant root cells.

Statistical analysis revealed significant variations among the locations in their soil salinity. The obtained results of electrical conductivity (EC) were ranging from 0.3 to 4.6 dS/m. Most of the studied locations were free from salinity hazards. The soil samples from Farm No. 2a showed significantly high level of salinity as compared with the other collected samples. This could be due to irrigation water and dissolving soil minerals and kinds of the used fertilizers. If more salt is applied in the irrigation water than is leached or taken off in harvested plants the soil becomes more saline, and eventually will cease to support agricultural production. Poor water management on irrigated crop land has resulted in 10 –15% of all irrigated land suffering some degree of water logging and salinization. In fact, water logging and salinization alone represent a significant threat to the world's productivity capacity [14]. However, some plants can only be grown without yield damage in soils with EC below 2 dS/m while others can be grown without much yield reduction in any soil up to EC of 16 dS/m.

The amounts of organic matter (0.5 - 0.9%) in the collected soil samples from the studied locations were not significantly different ($p < 0.05$). There was deficiency of organic matter contents in the studied locations. It was observed that the olive trees of Algema forest and Almarasa area were not healthy, vigorous trees. This could be attributed to the extremely deficient of organic matter (0.6%) in these areas. However, the organic matter concentration within a soil is the resulting balance between formation and decomposition and depends largely on interactions between inherent soil properties (e.g. texture and mineralogy), climate, management, and the nature of the inputs [15].

Soil samples from Farm No.1a and Mishari Prince Park showed significantly ($p < 0.05$) high amount of calcium carbonate when compared with the samples from the other locations. High level of calcium carbonate content was expected since the arid regions had high concentrations of free calcium carbonate [16].

### 3.1.2 Micro nutrients

Table 2 shows the Fe, Mn, Zn and Cu contents of the collected soil samples in the studied locations. All the locations had high contents (above 150 mg/kg) of Fe except Farm No.2b (85 mg/kg). The soil from Farm No.1b had significantly high amount (690 mg/kg) of Fe; it was eightfold that of Farm No.2b. The recorded results were expected since the iron is the fourth most abundant element on earth, and soil typically contains 1% – 5% total iron [17]. Iron is an essential micronutrient for plants because of it plays critical role in metabolic processes such as DNA synthesis, respiration, and photosynthesis. Further, many metabolic pathways are activated by iron, and it is a prosthetic group constituent of many enzymes [18]. Significantly high amount of manganese (63.6 mg/kg) was detected in the soil sample from Al Khulb Park. The soil samples from Farm No.1a, Amdaan forest, and Barhrah forest were not significantly different in their manganese contents. Manganese plays an important role in oxidation and reduction processes in plants, such as the electron transport in photosynthesis. It also has played a role in chlorophyll production, and acts as an activating factor which causes the activation more than 35 different enzymes [19]. The soil from Al Khulb Park contained significantly high level of zinc (418 mg/kg) when compared with other locations which showed no significant variation in their zinc contents. Zinc is involved in many physiological functions and its inadequate supply will reduce crop yields. Its deficiencies can affect plant by stunting its growth, decreasing number of tillers, chlorosis and smaller leaves, increasing crop maturity period, spikelet sterility and inferior quality of harvested products [20]. Copper content was in the range of 64 - 242 mg/kg. Soil samples from Farm No.1b had significantly high Cu content as compared with the other studied locations. Soil samples from Almrasa area and Amdaan forest had nearly equal amount of copper content. The variability of copper concentration among the studied locations may be due to soil type and other characteristics such texture, acidity and organic matter content [21]. Copper is an essential element for various metabolic processes in plants. It is required only in trace amounts and becomes toxic at high concentrations [22].

### 3.1.3 Macro nutrients

The concentrations of nitrogen, phosphorus, potassium and calcium in the soil samples from different locations are shown in Table 3. No significant variations were observed among the collected soil samples in their nitrogen content. It was clear that the soil from all locations were relatively poor in nitrogen content (0.03 -0.04%). Most of the examined olive trees (*O. europaea* L.) from different locations were not healthy and less vigorous. This could be attributed to the deficiency of nitrogen in the soil. However, Boussadia et al. [23] have reported that nitrogen-deficient plants had significant lower leaf nitrogen and chlorophyll a contents in two olive (*O. europaea* L.) cultivars ('Meski' and 'Koroneiki'). They also showed a significant reduction in their photosynthetic capacity. This indicates that the low nitrogen content inhibit photosynthesis in nitrogen-deprived olive plants.

Nitrogen is primarily required for increasing plant growth and crop yield more than any other nutrients. The absence of N in the plants is often associated with slow growth, reduced leaf size, yellowing; short branches, premature fall colour and leaf drop, and increase the likelihood of some diseases. Much of the N in soils is stored within the soil humus in forms that plants cannot be easily accessed (Galloway et al., 2004).

The soil samples from the studied locations had moderate amount of phosphorous (29 -277 mg/kg). The amount of phosphorous in the soil samples from Al Khulb Park was nearly tenfold that of Mishari Prince Park. The highest level of phosphorus was detected in the soil samples from four locations, Al Khulb park (277 mg/kg), Algema forest (251 mg/kg), Farm No.1b (231 mg/kg) and Alchukran forest park (204 mg/kg).

Phosphorous (P) is highly needed to establish and maintain crops especially in calcareous soils, where its natural availability is very low. It is considered an essential nutrient for plant growth and development and its deficiency is representing a major constraint to crop production worldwide [24].

**Table 1. pH electrical conductivity, organic matter and calcium carbonate contents in the collected soil samples from the studied locations**

| Location | pH | ECe (dS/m) | O.M (%) | $CaCO_3$ (%) |
|---|---|---|---|---|
| Farm No.1a | $7.4 \pm 0.0^{a}$ | $2.1 \pm 0.2^{cd}$ | $0.8 \pm 0.2^{a}$ | $5.6 \pm 3.7^{a}$ |
| Amdaan forest | $7.4 \pm 0.0^{a}$ | $0.4 \pm 0.0^{d}$ | $0.7 \pm 0.1^{a}$ | $1.4 \pm 1.1^{b}$ |
| Barhrah forest | $6.7 \pm 0.4^{b}$ | $0.4 \pm 0.0^{d}$ | $0.8 \pm 0.1^{a}$ | $0.8 \pm 0.5^{b}$ |
| Albudani area | $6.6 \pm 0.3^{b}$ | $0.3 \pm 0.1^{d}$ | $0.9 \pm 0.2^{a}$ | $1.2 \pm 0.8^{b}$ |
| Al Khulb park | $7.2 \pm 0.1^{a}$ | $0.6 \pm 0.1^{cd}$ | $0.8 \pm 0.1^{a}$ | $0.4 \pm 0.1^{b}$ |
| Mishari Prince Park | $7.6 \pm 0.1^{a}$ | $0.6 \pm 0.2^{cd}$ | $0.7 \pm 0.3^{a}$ | $5.4 \pm 4.3^{a}$ |
| Farm No. 2a | $7.4 \pm 0.2^{a}$ | $4.6 \pm 1.6^{a}$ | $0.5 \pm 0.1^{a}$ | $2.3 \pm 2.4^{ab}$ |
| Farm No. 2b | $7.5 \pm 0.4^{a}$ | $1.4 \pm 0.6^{c}$ | $0.8 \pm 0.3^{a}$ | $1.7 \pm 1.3^{b}$ |
| Almrasa area | $7.5 \pm 0.1^{a}$ | $0.9 \pm 0.3^{cd}$ | $0.6 \pm 0.2^{a}$ | $2.8 \pm 0.7^{ab}$ |
| Algema forest | $7.6 \pm 0.2^{a}$ | $0.4 \pm 0.1^{d}$ | $0.6 \pm 0.2^{a}$ | $1.1 \pm 0.5^{b}$ |
| Alchukran forest park | $7.4 \pm 0.1^{a}$ | $0.4 \pm 0.1^{d}$ | $0.8 \pm 0.1^{a}$ | $1.3 \pm 1^{b}$ |
| Farm No.1b | $7.7 \pm 0.1^{a}$ | $3.2 \pm 0.3^{b}$ | $0.7 \pm 0.2^{a}$ | $1.3 \pm 0.0^{b}$ |

*Values are mean ± SD, n = 3. Values in columns with different letters are significantly different ($p < 0.05$)*

**Table 2. Micro nutrients (mg/kg) of the collected soil samples from the studied locations**

| Location | Fe | Mn | Zn | Cu |
|---|---|---|---|---|
| Farm No.1a | 197 ± 24[de] | 19.5 ± 7.4[cd] | 203 ± 23[b] | 139 ± 25[b] |
| Amdaan forest | 296 ± 108[bcd] | 17.1 ± 2.2[cd] | 181 ± 14[b] | 135 ± 59[b] |
| Barhrah forest | 162 ± 28[ef] | 19.1 ± 8.5[cd] | 196 ± 17[b] | 75 ± 5[bc] |
| Albudani area | 324 ± 70[bc] | 31 ± 13.3[bc] | 180 ± 13[b] | 64 ± 5[c] |
| Al Khulb park | 228 ± 39[cde] | 63.6 ± 17.6[a] | 418 ± 325[a] | 119 ± 12[bc] |
| Mishari Prince Park | 206 ± 80[de] | 26.1 ± 9.9[bcd] | 157 ± 4[b] | 91 ± 57[bc] |
| Farm No. 2a | 148 ± 87[ef] | 51.2 ± 46.5[ab] | 232 ± 75[b] | 83 ± 8[bc] |
| Farm No. 2b | 85 ± 5[f] | 10.2 ± 0.8[cd] | 169 ± 2[b] | 66 ± 3[c] |
| Almrasa area | 200 ± 10[de] | 38.7 ± 3.3[abc] | 176 ± 9[b] | 136 ± 7[b] |
| Algema forest | 200 ± 41[de] | 0.0 ± 0.0[d] | 162 ± 6[b] | 79 ± 68[bc] |
| Alchukran forest park | 388 ± 26[b] | 8.8 ± 2.2[cd] | 179 ± 7[b] | 99 ± 37[bc] |
| Farm No.1b | 690 ± 67[a] | 25.5 ± 1.3[bcd] | 229 ± 9[b] | 242 ± 5[a] |

*Values are mean ± SD, n = 3. Values in columns with different letters are significantly different ($p < 0.05$)*

**Table 3. Macro nutrient contents of the collected soil samples from the studied locations**

| Location | N (%) | P (mg/kg) | K (mg/kg) | Ca (mg/kg) |
|---|---|---|---|---|
| Farm No.1a | 0.04 ± 0.01[a] | 151 ± 39[bcd] | 46.4 ± 2.2[b] | 650 ± 50[bc] |
| Amdaan forest | 0.04 ± 0.01[a] | 47 ± 18[de] | 27.9 ± 3.2[bcd] | 400 ± 100[c] |
| Barhrah forest | 0.04 ± 0.01[a] | 102 ± 25[cde] | 25.7 ± 14.7[bcd] | 317 ± 29[c] |
| Albudani area | 0.04 ± 0.01[a] | 63 ± 20[de] | 15.5 ± 2.8[cd] | 267 ± 29[c] |
| Al Khulb park | 0.04 ± 0.00[a] | 277 ± 31[a] | 68.1 ± 28.6[a] | 600 ± 100[c] |
| Mishari prince park | 0.03 ± 0.01[a] | 29 ± 12[e] | 21.4 ± 2.8[cd] | 517 ± 144[c] |
| Farm No. 2a | 0.03 ± 0.01[a] | 93 ± 85[cde] | 18.4 ± 6.8[cd] | 2470 ± 1998[a] |
| Farm No. 2b | 0.04 ± 0.02[a] | 46 ± 25[de] | 11 ± 1.8[d] | 867 ± 404[bc] |
| Almrasa area | 0.03 ± 0.01[a] | 110 ± 51[cde] | 32 ± 4.8[bcd] | 550 ± 87[c] |
| Algema forest | 0.03 ± 0.01[a] | 251 ± 114[ab] | 26.3 ± 10.2[bcd] | 400 ± 50[c] |
| Alchukran forest park | 0.04 ± 0.01[a] | 204 ± 103[abc] | 35 ± 15.2b[c] | 300 ± 100[c] |
| Farm No.1b | 0.03 ± 0.01[a] | 231 ± 96[ab] | 82.5 ± 2.7[a] | 1700 ± 265[ab] |

*Values are mean ± SD, n = 3. Values in columns with different letters are significantly different ($p < 0.05$)*

**Table 4. Physicochemical characteristics of water samples**

| Analysis type(Unit) | Almrasa | Barhrah | Algema | Farm No.1 | Farm No.2 | Standard values |
|---|---|---|---|---|---|---|
| pH(S.U) | 6.89 | 7.08 | 7.39 | 7.12 | 6.75 | 6.5-8.5 |
| T.D.S(mg/L) | 334 | 94 | 455 | 155 | 342 | 1000 |
| $Cl_2$(mg/L) | 0 | 0 | 0 | 0 | 0 | 1.0-0.5 |
| Turbidity(N.T.U) | 0.45 | 0.83 | 0.27 | 0.6 | 0.25 | 5 |
| Al(mg/L) | 0.016 | 0.026 | 0.04 | 0.061 | 0.012 | 0.2 |
| Fe(mg/L) | 0.03 | 0.01 | 0.02 | 0.23 | 0.11 | 0.3 |
| $SO_4$(mg/L) | 47 | 26 | 82 | 37 | 31 | 250 |
| $NH_3$(mg/L) | 0.03 | 0.04 | 0 | 0.01 | 0.01 | 1.5 |
| $NO_3$(mg/L) | 19.47 | 2.21 | 11.51 | 2.21 | 1.77 | 45 |
| $NO_2$(mg/L) | 0.103 | 0.005 | 0.014 | 0.008 | 0.002 | 3 |
| $SiO_2$(mg/L) | 29.2 | 2.8 | 21.6 | 7.2 | 0.001 | 100 |

The potassium content in the studied soil samples was very low (11-82.5 mg/kg). However, the earth crust on average and similar soils contain large amounts of K bearing minerals that often satisfy the plant demand but in some cases the K in those minerals is of low availability to plants leading then to K deficiency in crops. But crops may differ in their ability to grow under conditions of low K availability [25].

As shown from Table 4, the soil from Farm No. 2a contained extremely high amount (2470 ± 1998 mg/kg) of calcium as compared with the calcium content in the soil samples from

Albudani area (267 mg/kg). The other studied locations had moderate amount (317 -867 mg/kg) of calcium content. Calcium is used in large amounts by plants second only to N and K. It is involved in cell elongation and division, membrane permeability, and activation of several critical enzymes [26].

## 3.2 Water Analysis

### 3.2.1 Physicochemical characteristics

The results of the physicochemical analysis for the selected water samples are presented in Table 4. The physico-chemical analysis of the collected water samples showed values in the standard range and indicates no chemical contamination in all the samples. So, the water used for irrigation of olive trees crops in the selected farms and other areas is suitable for irrigation and may not have any negative effect on the growth or the production of these trees.

The measured values for the physical and chemical characteristics of the selected samples showed values in the range of the standard values.

### 3.2.2 Total coliform bacteria test

The total coliform bacteria test is a primary indicator of "potability" and suitability for consumption. This test measures the concentration of total coliform bacteria associated with the possible presence of disease causing organisms. The total coliform test for most samples showed negative observation after 48 hours incubation, except only one sample taken from the research farm No. 1 site showed positive test for total coliform test.

## 4. CONCLUSION

The studied twelve locations in Albaha region, south-western Saudi Arabia showed clear variations in organic matter, pH, electrical conductivity and micro and macro nutrient contents of the soil. These variations had remarkable effects on the growth rate and health of the olive trees. The collected water samples from the locations had no chemical or biological contaminants, except samples from Farm No. 1.

## ACKNOWLEDGEMENTS

This project was funded by chair of Sheikh Said Ben Ali Alangari for Olive's research at Albaha University, Albaha, Saudi Arabia. The Author also acknowledge with thanks Albaha University for the technical and logistic support.

## COMPETING INTERESTS

Author has declared that no competing interests exist.

## REFERENCES

1. Srinivasan K, Poongothai S. Macro-nutrients and micronutrients relation to soil characteristics of wellington reservoir, Tamilnadu, India; 2013.
2. He ZL, Yang XE. Role of soil rhizobacteria in phytoremediation of heavy metal contaminated soils. Journal of Zhejiang University Science B. 2007;8(3):192-207.
3. Subbarao GV, Ito O, Berry WL, Wheeler RM. Sodium a functional plant nutrient. Critical Reviews in Plant Sciences. 2003;22(5):391-416.
4. Akenga P, Salim A, Onditi A, Yusuf A, Waudo W. Determination of selected micro and macronutrients in sugarcane growing soils at Kakamega North District, Kenya. IOSR Journal of Applied Chemistry. 2014; 7(7):34-41.
5. Palese AM, Nuzzo V, Favati F, Pietrafesa A, Celano G, Xiloyannis C. Effects of water deficit on the vegetative response, yield and oil quality of olive trees (*Olea europaea* L., cv Coratina) grown under intensive cultivation. Scientia Horticulturae. 2010;125(3):222-229.
6. Peragón JM, Delgado A, Pérez-Latorre FJ. A GIS-based quality assessment model for olive tree irrigation water in southern Spain. Agricultural Water Management. 2015;148:232-240.
7. Tognetti R, d'Andria R, Sacchi R, Lavini A, Morelli G, Alvino A. Deficit irrigation affects seasonal changes in leaf physiology and oil quality of Olea europaea (cultivars Frantoio and Leccino). Annals of Applied Biology. 2007;150(2):169-186.
8. Gómez-Rico A, Salvador MD, Fregapane G. Virgin olive oil and olive fruit minor constituents as affected by irrigation management based on SWP and TDF as compared to ETc in medium-density young olive orchards (*Olea europaea* L. cv. Cornicabra and Morisca). Food Research International. 2009;42(8):1067-1076.
9. Peragón JM, Pérez-Latorre FJ, Delgado A, Tóth T. Best management irrigation

practices assessed by a GIS-based decision tool for reducing salinization risks in olive orchards. Agricultural Water Management. 2018;202:33-41.
10. Yeomans JC, Bremner JM. A rapid and precise method for routine determination of organic carbon in soil. Communications in Soil Science and Plant Analysis. 1988; 19(13):1467-1476.
11. Bremner JM. Total nitrogen. In: (Eds.): Sparks, D.L. Methods of soil analysis: Chemical methods. Soil Sci. Soc. Am., Madison, WI. 1996;1085-1086.
12. Rice EW, Baird RB, Eaton AD. Standard Methods for the Examination of Water and Wastewater, 3rd edition, American Public Health Association, American Water Works Association, Water Environmental Federation; 2017.
13. Soti PG, Jayachandran K, Koptur S, Volin JC. Effect of soil pH on growth, nutrient uptake, and mycorrhizal colonization in exotic invasive *Lygodium microphyllum*. Plant Ecology. 2015;216(7): 989-998.
14. Corwin DL, Lesch SM. Apparent soil electrical conductivity measurements in agriculture. Computers and Electronics in Agriculture. 2005;46(1-3):11-43.
15. Oldfield EE, Wood SA, Bradford MA. Direct effects of soil organic matter on productivity mirror those observed with organic amendments. Plant and Soil. 2018; 423(1-2):363-373.
16. Machado R, Serralheiro R. Soil salinity: Effect on vegetable crop growth. Management practices to prevent and mitigate soil salinization. Horticulturae. 2017;3(2):30.
17. Incesu M, Yeşiloğlu T, Cimen B, Yilmaz B. Influences of different iron levels on plant growth and photosynthesis of W. Murcott mandarin grafted on two rootstocks under high pH conditions. Turkish Journal of Agriculture and Forestry. 2015;39(5):838-844.
18. Rout GR, Sahoo S. Role of iron in plant growth and metabolism. Reviews in Agricultural Science. 2015;3:1-24.
19. Mousavi SR, Shahsavari M, Rezaei M. A general overview on manganese (Mn) importance for crops production. Australian Journal of Basic and Applied Sciences. 2011;5(9):1799-1803.
20. Hafeez B, Khanif YM, Saleem M. Role of zinc in plant nutrition-a review. American Journal of Experimental Agriculture. 2013; 3(2):374.
21. Mourato MP, Martins LL, Cuypers A. Effect of copper on antioxidant enzyme activities and mineral nutrition of white lupin plants grown in nutrient solution. Journal of Plant Nutrition. 2009;32(11):1882-1900.
22. Azeez MO, Adesanwo OO, Adepetu JA. Effect of Copper (Cu) application on soil available nutrients and uptake. African Journal of Agricultural Research. 2015; 10(5):359-364.
23. Boussadia O, Steppe K, Zgallai H, El Hadj SB, Braham M, Lemeur R, Van Labeke MC. Effects of nitrogen deficiency on leaf photosynthesis, carbohydrate status and biomass production in two olive cultivars 'Meski' and 'Koroneiki'. Scientia Horticulturae. 2010;123(3):336-342.
24. AlKhader AM, Abu Rayyan AM. Effects of Phosphorus Fertilizer Type and Rate on Plant Growth and Heavy Metal Content in Lettuce (*Lactuca Sativa* L.) Grown on Calcareous Soil. Jordan Journal of Agricultural Sciences. 2014;173(3834):1-15.
25. Claassen N, Dessougi HEL, Trehan SP. Crop growth and potassium uptake as related to plant and soil properties. In International Symposium on importance of potassium in nutrient management on sustainable crop production in India. 2001; 102-123.
26. Njira KO, Nabwami J. A review of effects of nutrient elements on crop quality. African Journal of Food, Agriculture, Nutrition and Development. 2015;15(1):9777-9793.



*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*http://www.sdiarticle4.com/review-history/53049*