Environment and Natural Resources Journal 2020; 18(1): 44-54

Effects of Volcanic Zeolite Tuff on Olive (*Olea Europaea* L.) Growth and Soil Chemistry under a Constant Water Level: Five Years' Monitoring Experience

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ARTICLE INFO

Received: 11 Apr 2019
Received in revised: 18 Jul 2019
Accepted: 26 Jul 2019
Published online: 9 Sep 2019
DOI: 10.32526/ennrj.18.1.2020.05

Keywords:
Nutrients/ Plant water status/ Soil amendment/ Volcanic zeolite tuff/ Olive tree

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ABSTRACT

This study investigated the effects of using fine and coarse volcanic zeolite tuff on the growth of olive (*Olea europaea* L.) trees and the silty clay soil in which they were grown. Olive trees were grown in four different soil treatments: silty clay soil (S1, control), silty clay soil covered with coarse volcanic zeolite tuff (S2), silty clay soil mixed with fine volcanic zeolite tuff (S3), and silty clay soil mixed with fine volcanic zeolite tuff covered with coarse volcanic zeolite tuff (S4). The morphological and physiological characteristics of the olive plants were then monitored over a 5-year period from 2012 to 2016, and the leaf and soil chemistry were analyzed at the end of the monitoring period. It was found that the addition of volcanic zeolite tuff (treatments S2, S3, and S4) had a positive effect on shoot length (relative increases of 10%, 21%, and 29%, respectively), plant height (0.53%, 1.29%, and 3.5%), plant weight (13%, 22%, and 32.26%), number of branches (14%, 27%, and 41.5%), number of leaves (9%, 22%, and 43%), trunk diameter (9%, 22%, and 29%), and shoot diameter (12%, 22%, and 36%), as well as the relative water content (15%, 22%, and 36%) and leaf water potential (16%, 26%, and 32%) compared with the control treatment (S1). Furthermore, the contents of N and P in the plant leaves, and most of the soil chemical parameters measured significantly increased following the addition of volcanic zeolite tuff. These results highlight the benefits of using volcanic zeolite tuff as a natural, readily available, and low-cost material for soil amendment due to its large effects on plant growth and soil fertility.

1. INTRODUCTION

Jordan is ranked as the second and eighth largest exporter of table olives and olive oil, respectively. Olive oil production is an important source of income to over 180,000 Jordanian families and contributes over 150 million US dollars to the national economy (ILO, 2014).

In recent decades, olive tree (*Olea europea* L.) plantations have transitioned from traditional rain-fed to irrigated production systems. Most olive plantations occur in the Middle East and North Africa (MENA) region, in which most countries are suffering from a scarcity of water. Consequently, water management and soil amendment are key solutions to minimizing soil moisture evaporation and enhancing plant nutrient uptake, which may increase plant yield and ensure the sustainability of this tree in arid and semi-arid regions. Water conservation leads to better management of the environmental resources, support the ecological systems especially in the arid areas, and reduce the drought stress on human communities and the agriculture.

Several different approaches can be taken to conserve soil moisture and reduce the effects of water stress, such as the addition of crop residues, mulch plants, waste, straw, stubble, and synthetic materials like hydro-plus zeolites to the soil (Silberbush et al., 1993). Recently, there has been a noticeable trend toward using natural materials to augment soil

Citation: Al-Tabbal JA, Al-Mefleh NK, Al-Zboon KK, Tadros MJ. Effects of volcanic zeolite tuff on olive (*Olea Europaea* L.) growth and soil chemistry under a constant water level: five years' monitoring experience. Environ. Nat. Resour. J. 2020;18(1):44-54. DOI: 10.32526/ennrj.18.1.2020.05

fertility, such as waste materials, gypsum, earthworms, and natural volcanic zeolite tuff.

Zeolitic tuff which is a normally volcanogenic sedimentary mineral made basically out of aluminosilicates is widely distributed in Jordan (Almjadleh et al., 2014). The mineral has a three dimensional precious stone cross section, with approximately bound cations, equipped for hydrating and getting dried out without changing the gem structure (Ramesh and Reddy, 2011). The unique three dimensional porous structure gives natural zeolites various application possibilities. Zeolite may help in total procedure in the soil that assumes an extensive job in improving the soil physical qualities, for example, pressure driven conductivity, penetration and ventilation (Mirzaei et al., 2015) just as in improving the carbon sequestration in soil (Lal, 2015).

Natural zeolite was shown to improve soils and reduce the harmful effects of water stress in arid and semi-arid area (Ghanbari and Ariafar, 2013) due to their ability to improve water storage, making it available for plant growth and production (Manivannan et al., 2007; Zhang et al., 2007). Because of the excess of negative charge on the surface of zeolite, which results from isomorphic replacement of silicon by aluminum in the primary structural units, natural zeolites belong to the group of cationic exchangers and thus it tends to be utilized to improve the soil (Najafi-Ghiri, 2014). Natural zeolite-enriched soils increased water holding capacity by (18-19%) and cation exchange capacity by 30-40% (Jakkula and Wani, 2018). The utilization of zeolite in dry season periods significantly affects fundamental oil yield of Medicinal Peppermint (Ghanbari and Ariafar, 2013). The expansion of zeolite had a constructive outcome on physicomorpological qualities of Moldsvian Balm (Gholizadeh et al., 2010).

Several studies have reported the positive impact of volcanic zeolite tuff additions on plant growth (Bybordi and Ebrahimian, 2013; Ozbahce et al., 2015), plant yield (Ozbahce et al., 2015), soil moisture content (Al-Busaidi et al., 2008), soil nutrient levels (Perez-Caballero et al., 2008), improve soil physio-chemical properties, and the soil biota (Da Silva et al., 1993; Giuffrida and Consoli, 2015). The addition of zeolites to soil helps to control soil pH and improve ammonium retention (Jakkula and Wani, 2018). Due to its superior adsorbent properties, Jordanian volcanic zeolite tuff has been used successfully in many engineering applications, such as water decontamination (Al-Zouby et al., 2017), heavy metal removal (Al-zboon et al., 2016), gas adsorption (Al-Harahsheh et al., 2014), and soil amendment (Al-Tabbal et al., 2016). Zeolite can hold supplements in the root zone of plants until required. This prompts increasingly effective utilization of N and K manures, utilizing less compost for a similar yield or use of same measure of compost for longer enduring and creating higher yields (Gamze, 2007; Khodaei-Joghan and Asilan, 2012).

A few studies have evaluated the benefits of using Jordanian natural volcanic zeolite tuff on plant growth and soil properties in the agricultural field, and those that have only measured short-term plant growth in crops such as salvia (*Salvia officinalis*) (Owais et al., 2013), tomato (*Solanum lycopersicum*) (Al-Qarallah et al., 2013), and cucumber (*Cucumis sativus*) (Manolov et al., 2005).

Therefore, this paper investigated the effects of natural volcanic zeolite tuff as a low-cost natural material on the morphological and physiological characteristics of olive trees, as well as the soil and leaf chemistry over a 5-year monitoring period. The comprehensive monitoring procedure, long monitoring period (5 years), analysis of plant growth (olive tree), and suite of parameters that were considered are key strengths of this research.

2. METHODOLOGY

2.1 Soil treatments

A pot experiment was conducted in an open field at Al-Huson University College of Al Al-Balqa' Applied University in the northern part of Jordan (32°27′N, 35°27′E). This site is at an altitude of 650 m and receives an average annual rainfall of 450 mm. The research was conducted using the olive cultivar "Nabali baladi", which is widely planted in orchards and nurseries. One-year-old transplants of this cultivar were obtained from a government nursery (Faisal Nursery) and planted in 20-l pots filled with different media. Growth was then measured over five successive seasons from 2012 to 2016. The soil taxonomy system can be classified as vertisol (Chromoxeret).

Four different soil media were used as treatments: The control soil was silty clay texture (S1), silty clay soil covered with coarse volcanic zeolite tuff (S2), silty clay soil mixed with fine volcanic zeolite tuff (S3), and silty clay soil mixed with fine volcanic zeolite tuff covered with coarse volcanic zeolite tuff (S4). The coarse volcanic zeolite tuff cover with size of 6-20 mm was added on the soil surface to a depth of 5 cm, whereas the fine volcanic zeolite tuff with size of <0.06 mm was mixed with the soil at a 1:3 ratio. In the fine volcanic zeolite tuff+ coarse volcanic zeolite tuff treatment, a total of 4 kg of volcanic zeolite tuff was added on the soil surface. X-ray fluorescence (XRF) analyses have previously shown that the volcanic zeolite tuff material consists of 44.56% SiO_2, 11.74% Al_2O_3, 10.78% Fe_2O_3, 10.46% CaO, 8.81% MgO, 1.5% K_2O, 0.52% P_2O, 2.63% TiO_2, 1.87% Na_2O, and 0.11% MnO (Al-zboon et al., 2016). The volcanic zeolite tuff had an average bulk density of 1872 kg/m^3 and a water absorption ratio of 12.7% (Al-zboon and Al-Zouby, 2015; Al-zboon and Al-Zouby, 2017). Silty clay is generally brownish gray, with soft and creamy texture, flow shape and with clay content more than 40% with field capacity equal 35 % (10% sand, 49.4 silt, and 40.6 clay).

The treatments were arranged in a randomized complete block design (RCBD) with four replications. Gravimetric determinations of the water contents of the soil were made by weighing soil samples before and after oven drying to a constant weight at 80 °C. These values were then used to calibrate all measurements of moisture content of the substrates in the pots. Field capacity (FC) was determined 48 h after irrigation, and was calculated according to the equation of Paquin and Mehuys (1980). The level of water was then maintained at between 50% and 70% of FC by manual irrigation and was checked by weighing individual pots each day to maintain the required level of moisture.

At the beginning of the experiment, all trees had a uniform height of 1 m. To enhance root development, the trees were irrigated to the pot capacity for 1 month prior to starting the experiment.

2.2 Plant water status

The two most important indicators of water deficit in plants are the relative water content (RWC) and leaf water potential.

2.2.1 Relative water content

Relative water content was measured in five leaves per plant that were detached from a similar position along the shoots, using three replicate trees per treatment. Following cutting, the petiole of each leaf was immediately immersed in distilled water inside a glass tube. The tube was then sealed, placed in a cold container, and transported to the laboratory, where the increased weight of the tube was used to determine the leaf fresh weight (FW). After 48 h in dim light, the leaf was again weighed to obtain the turgid weight (TW). The dry weight (DW) was then measured after oven drying at 80 °C for 48 h and RWC was calculated as (Ozbahce et al., 2015):

$$\mathrm{RWC} = \left(\frac{\mathrm{FW} - \mathrm{DW}}{\mathrm{TW} - \mathrm{DW}}\right) \times 100$$

2.2.2 Leaf water potential

Leaf water potential (Ψ_w) was measured in the third and fourth fully expanded leaves per plant, with three replicates per treatment. Measurements were made immediately after removing the leaves at midday (12.00) using a Sholander pressure chamber (Model 600; PMS Instruments Co. Corvallis, OR, USA).

2.3 Soil and plant chemistry

At the end of the 5-year experimental period, soil samples were taken at two depths (0-30 cm) from each treatment, air-dried at room temperature, and ground to pass through a 2-mm sieve. These samples were then analyzed for pH, electrical conductivity (EC), Na, Ca, Mg, N, P, K, exchangeable sodium percentage (ESP), sodium adsorption ratio (SAR), total cations, $CaCO_3$, and organic matter. These analyses were carried out according to the standard methods of soil analysis (Van, 2002). Leaves were also collected from the middle of new shoots (fully matured) and analyzed for the nutrients N, P, K, Ca, Mg, and Na according to the Official Methods of Analysis of HORWIZ (2000).

2.4 Morphological indicators

The trunk diameter (approximately 10 cm above the soil surface), number of branches per plant, main shoot diameters, and main shoot lengths (labeled shoot) were monitored annually from the year of planting (2012) to the end of 2016, while measurements of plant height were made from the second year onward. Plant weight (trunk, shoot, and leaves), the number of leaves per plant, and the fresh weight of roots were measured at the end of the 5-year period.

2.5 Statistical analysis

The data for each season were statistically analyzed using analysis of variance (ANOVA) followed by Fisher's Least Significant Difference

(LSD) test using SAS statistical software (SAS, 2004).

3. RESULTS

3.1 The growth of olive tree

The effect of adding volcanic zeolite tuff materials as a mixture and as cover on the soil surface on olive plant characteristics was determined over the 5-year monitoring period. The study clearly demonstrated that the addition of volcanic zeolite tuff material (treatments S2, S3, and S4) improved the vegetative growth characteristics of olive trees compared with the control (S1), with significant effects on shoot length (Figure 1), shoot diameter (Figure 2), trunk diameter (Figure 3), plant height (Figure 4), number of branches (Figure 5), number of leaves (Figure 6) and plant weight (Figure 7). The treatment in which the soil was mixed with fine volcanic zeolite tuff and covered with coarse volcanic zeolite tuff (S4) had a greater effect on all growth characteristics than the treatments in which the soil was covered with coarse volcanic zeolite tuff (S2) or mixed with fine tuff (S3).

The maximum shoot length at the end of experimental period was 64.6 cm for plants in the S4 treatment, with the S2, S3, and S4 treatments increasing the shoot length by 10%, 21%, and 29%, respectively, compared with the control (S1). Similar trends were observed for the other vegetative parameters measured, with the S4 treatment having the greatest effect, and treatments S2, S3, and S4 increasing plant height by 0.53%, 1.29%, and 3.5%; plant weight by 13%, 22%, and 32.26%; the number of branches by 14%, 27%, and 41.5%; the number of leaves by 9%, 22%, and 43%; trunk diameter by 12%, 20%, and 29%; and shoot diameter by12%, 22%, and 36%, respectively, at the end of the experiment. Thus, the impact of the treatments on the vegetative growth of olive trees can be ranked as S4>S3>S2>S1. These differences in growth parameters were observed over all of the experimental periods.

3.2 Relative water content and leaf water potential

The addition of tuff (treatments S2, S3, and S4) significantly increased the RWC and leaf water potential of the leaves compared with the control (S1), resulting in 15%, 22%, and 36% increases in RWC, respectively (Figure 8) and 16%, 26%, and 32% increases in leaf water potential, respectively, compared with S1 (Figure 9).

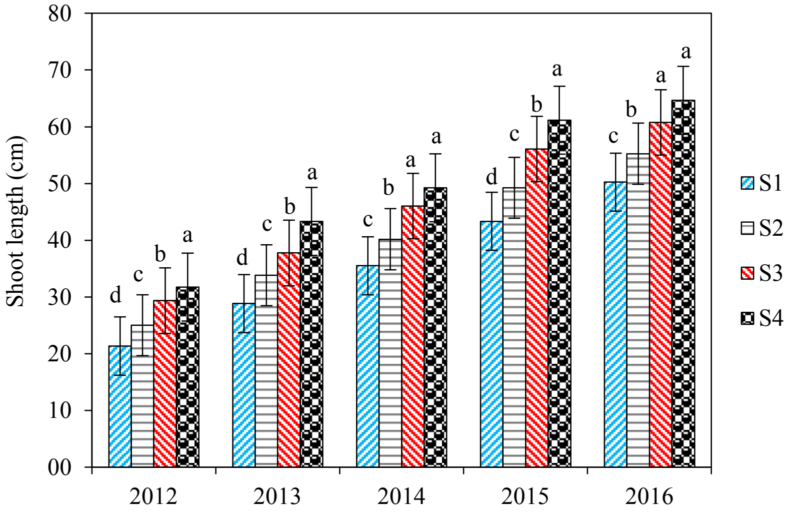

Figure 1. Shoot length of olive trees grown in in four different soil treatments, bars (indicate for standard error) with the same letters are not significantly different at p <0.05.

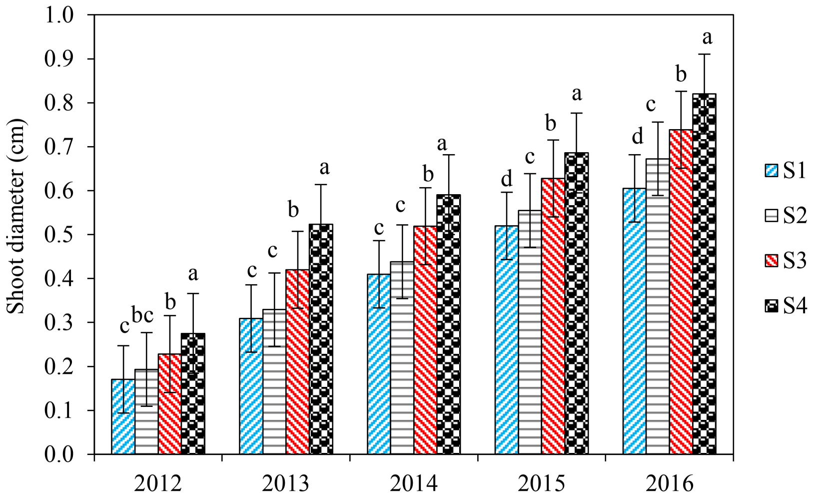

Figure 2. Shoot diameter of olive trees grown in in four different soil treatments, bars (indicate for standard error) with the same letters are not significantly different at $p<0.05$.

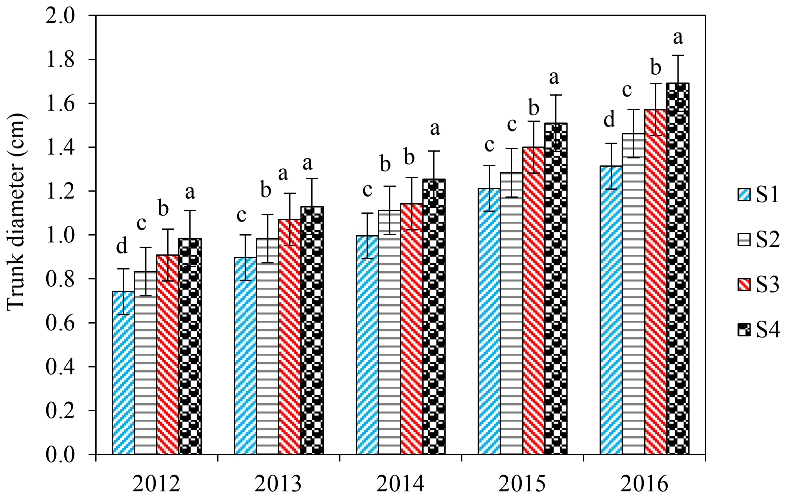

Figure 3. Trunk diameter of olive trees grown in in four different soil treatments, bars (indicate for standard error) with the same letters are not significantly different at $p<0.05$.

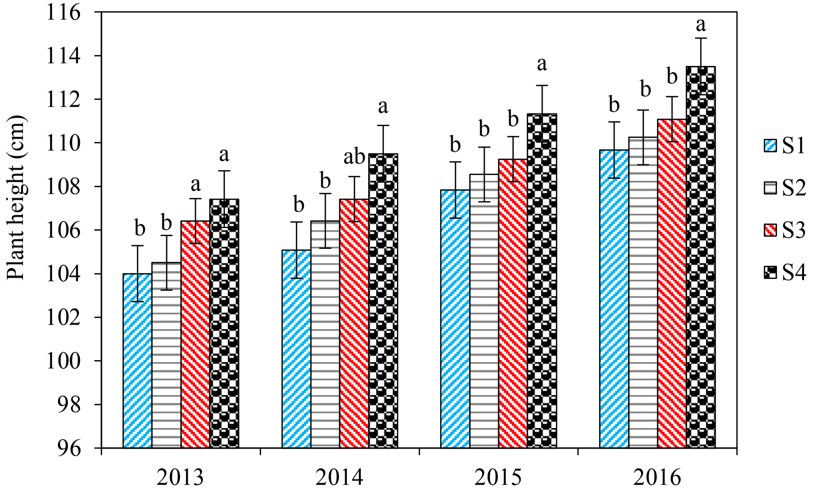

Figure 4. Plant height of olive trees grown in in four different soil treatments, bars (indicate for standard error) with the same letters are not significantly different at $p<0.05$.

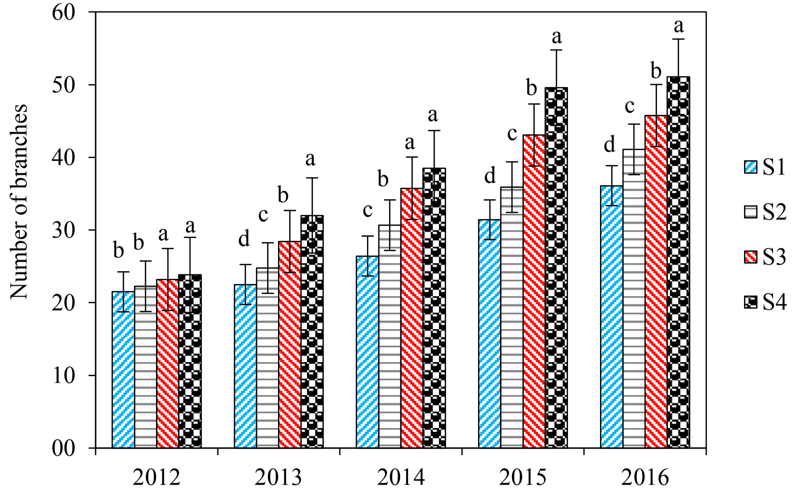

Figure 5. Number of branches of olive trees grown in in four different soil treatments, bars (indicate for standard error) with the same letters are not significantly different at $p<0.05$.

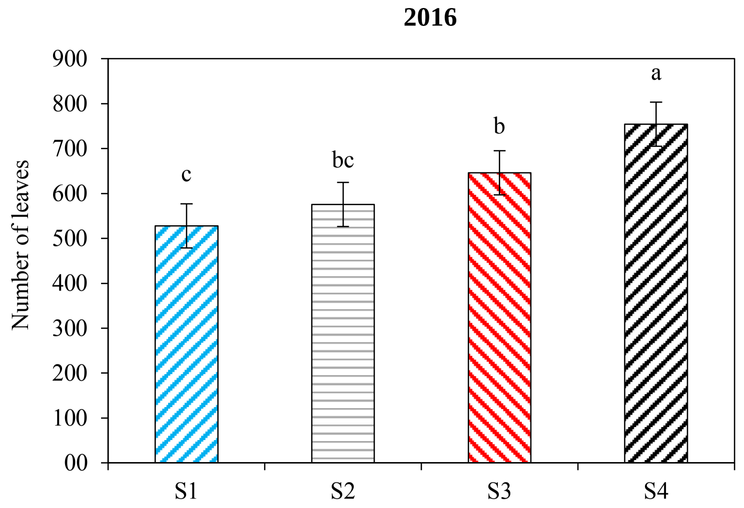

Figure 6. Number of leaves of olive trees grown in in four different soil treatments, bars (indicate for standard error) with the same letters are not significantly different at p<0.05.

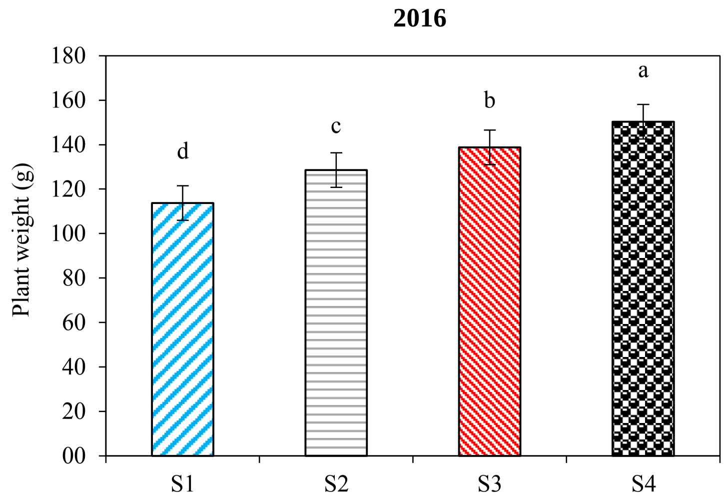

Figure 7. Plant weight of olive trees grown in in four different soil treatments, bars (indicate for standard error) with the same letters are not significantly different at p<0.05.

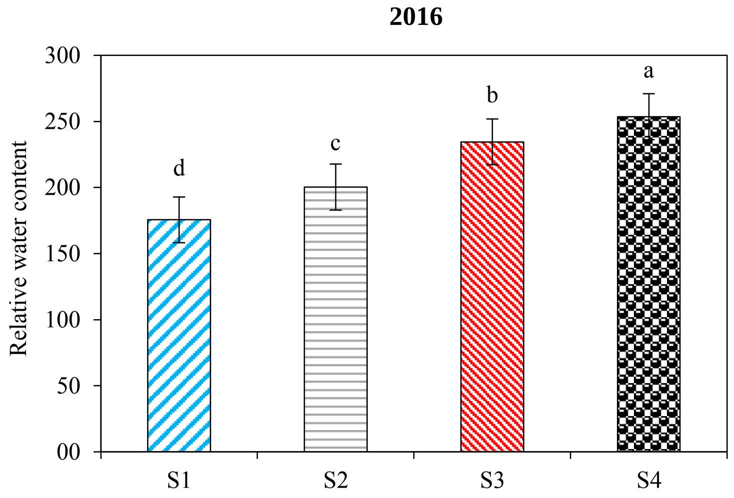

Figure 8. Relative water content of olive leaves grown in in four different soil treatments, bars (indicate for standard error) with the same letters are not significantly different at p<0.05.

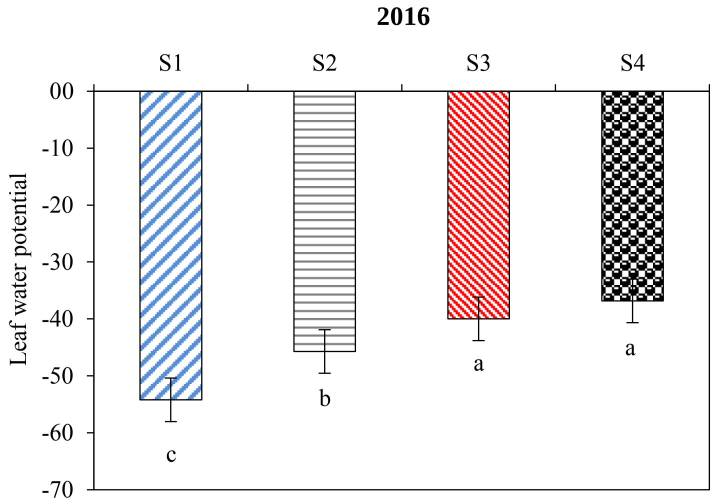

Figure 9. Leaf water potential of olive leaves grown in in four different soil treatments, bars (indicate for standard error) with the same letters are not significantly different at p<0.05.

3.3 Plant leaf chemistry

There were significant increases in the N, P, and Na contents of leaves in plants grown in volcanic zeolite tuff-treated soil, with the S4 treatment leading to 16.8%, 28.6%, and 116% increases, respectively, compared with S1 (Table 1). However, there were no significant differences in the contents of K, Ca, and Mg between treatments.

Table 1. The chemical characteristics of the plant under different soil treatments at the end of the experiment.

Treatment	N	P	K	Na	Ca	Mg
	%	%	%	%	%	%
S4	1.095^a	0.018^a	0.348^a	0.080^a	2.115^c	0.402
S3	1.086^a	0.014^b	0.339^a	0.063^b	2.305^b	0.407^a
S2	1.052^a	0.013^b	0.342^a	0.040^c	2.474^a	0.398^a
S1	0.937^b	0.014^b	0.363^a	0.037^d	2.429^{ab}	0.381^a
F value	**	**	ns	**	ns	ns
C.V. (%)	4.09	8.2	9.52	9.98	9.19	9.02

*,**, ns indicate significant difference at $p \leq 0.05$, $p \leq 0.01$ and non-significant difference, respectively.

3.4 Soil chemistry

Treatment of the soil with volcanic zeolite tuff resulted in an increase in ECe, $CaCO_3$, K, P, SAR, Na, Mg, and Ca, with treatment S4 resulting in the greatest differences from the control (S1), followed by S3 and S2 (Table 2). By contrast, there were no significant differences in the pH and organic matter content between treatments. The soil pH values ranged from 7.73 to 7.78, which are within the most preferable range (6.5-8.5) for agricultural soils, while the organic matter contents ranged from (0.49-0.58%). Based on the pH and ECe values, the soil can be characterized as moderately alkaline (pH=7.5) and unsaline (ECe<0.4 S/m).

4. DISCUSSION

All of the soil amendments used in this study had a significant effect on the morphological traits of olive plants. Plant weight, shoot length, shoot diameter, trunk diameter, the number of branches, plant height, and the number of leaves were significantly higher in plants that were grown in amended soils compared with the control (S1), with the combined fine and coarse tuff treatment (S4) having a larger effect than the fine tuff treatment (S3) and the coarse tuff treatment (S2) alone. The change in plant weight was caused by an increase in the vegetative components such as the number of leaves, number of branches, trunk diameter, and plant height. The observed increase in vegetative growth and plant height in plants grown in the amended soils (S2-S4) indicates that they were not subjected to water stress unlike the control plants (S1). It is known that plants that are not affected by drought stress have an increased plant height as a result of an increase in cell division and assimilate transport, which leads to an increased number of nodes and internode lengths (Wright et al., 1995).

The addition of volcanic zeolite tuff improved the water and nutrient contents of the soil, which explains the improvement in all of the growth parameters measured. The high porosity of volcanic zeolite tuff increases its water holding capacity and allows water to be released when required by plants (Mumpton, 1999). Zeolites are able to lose and gain water reversibly, without any change in their crystal structure, allowing them to be used as fertilizers, stabilizers, and chelators (Perez-Caballero et al., 2008). A layer of coarse tuff covering the soil acts as a mulching material that maintains the humidity at the soil surface and prevents airflow, keeping the moisture in the soil and helping plants to produce more leaves, which results in an improvement in other morphological traits. The RWC of the leaves was considerably higher in olive plants that were grown in amended soils (S2-S4) compared with the control (S1). Leaf RWC is closely related to cell volume and is considered an important criterion of plant water status that indicates the level of water stress in the leaves (Merah, 2001), and the balance between water supply to the leaf and transpiration rate (Farquhar et al., 1989). Thus, leaf RWC reflects

Table 2. The chemical characteristics of the soil treatments at the end of the experiment

Treatment	ECe	pH	OM	$CaCO_3$	N	K	P	ESP	SAR	Na	Mg	Ca
	S/m		%	%	%	mg/kg	mg/kg	%		mg/kg	mg/kg	mg/kg
S4	0.178^{a}	7.78^{a}	0.49^{a}	14.25^{a}	0.11^{a}	265.48^{a}	0.3096^{a}	3.80^{a}	3.60^{a}	31.35^{a}	58.368^{b}	93.386^{a}
S3	0.174^{ab}	7.78^{a}	0.52^{a}	13.35^{b}	0.09^{b}	249.45^{b}	0.2683^{b}	3.57^{a}	3.44^{a}	30.13^{a}	58.854^{a}	94.588^{a}
S2	0.166^{b}	7.73^{a}	0.58^{a}	13.37^{b}	0.08^{b}	247.50^{b}	0.2683^{b}	3.25^{ab}	3.20^{b}	27.73^{b}	55.692^{d}	94.588^{a}
S1	0.152^{c}	7.78^{a}	0.54^{a}	12.98^{b}	0.09^{b}	240.85^{c}	0.2476^{b}	2.82^{b}	2.90^{c}	24.64^{c}	56.665^{c}	87.775^{b}
F value	**	ns	ns	*	**	**	*	ns	**	**	**	**
C.V. (%)	2.62	2.47	9.18	2.65	7.06	0.95	5.93	11.04	2.66	2.77	0.16	1.41

*, **, ns indicate significant difference at $p \leq 0.05$, $p \leq 0.01$ and non-significant difference, respectively.

the metabolic activity in tissues (Flower and Ludlow, 1986), which declines significantly under water stress. When there is a low water content in the soil and roots, plants are unable to compensate for water losses through transpiration, resulting in a reduction in leaf RWC (Shalhevet, 1993; Singh and Singh, 1995; Gadallah, 2000). Therefore, the high RWC that was observed in plants grown in soils treated with volcanic zeolite tuff and volcanic zeolite tuff cover indicates that there was sufficient water in the soils and roots, which contrasts with the lower RWC found in the control treatment. This demonstrates the high impact that volcanic zeolite tuff treatment and volcanic zeolite tuff cover have on water content and subsequently RWC, supporting previous findings (Eskandari Zanjani et al., 2012). Similarly, leaf water potential also tended to be higher in plants that were grown in amended soils, which, combined with the higher RWC, resulted in a higher stomatal conductance and photosynthetic rate. The findings of the present study support those of previous studies, which have suggested that mulching with various materials sequesters water and prevents evaporative water loss from the soil (Hartman et al., 2000; Yamanaka et al., 2004; Sinkevičienė et al., 2009), which, in turn, enhances the photosynthetic rate in the leaves of plants grown under these conditions (Ni et al., 2016). Qin et al. (2015) found that soil mulching reduced evaporation, increased the water potential, and subsequently modified soil temperature, increasing the yields and water use efficiencies of maize (*Zea mays*) and wheat (*Triticum aestivum*) by up to 60%. The positive effect of volcanic zeolite tuff on plant growth and yield can be attributed to its high affinity for nutrients, and high capability of improving N absorption (Bybordi and Ebrahimian, 2013) and the P content of the soil (Pirzad and Mohammadzade, 2014) by preventing nutrient leaching (Gholamhoseini et al., 2012). It has also previously been shown that zeolite amendment improves the nutrient use efficiency of plants by improving the use of N compounds, increasing P availability, reducing leaching losses of exchangeable cations, especially K^+, and acting as a slow-release source of nutrients that are made available when the plant needs them (Barbarick et al., 1990; Bernardi et al., 2008).

Many studies have demonstrated a positive effect of using zeolite on plant leaves, and a favorable effect on the main nutrients (N, P, K, and Ca) in leaves and fruits (Jakab and Jakab, 2010). For example, Ozbahce et al. (2015) found that zeolite significantly affected the N, K, Zn, Mn, and Cu contents in leaf samples, which increased with increasing rates of zeolite application, and Perez-Caballero et al. (2008) similarly found that the levels of K and N in olive tree leaves increased following the addition of zeolite to the soil due to the absorption of NH_4^+ by the zeolites and the reduced losses of NO_3^- through leaching.

Chemical analysis of the volcanic zeolite tuff indicated that it is rich in Mg, Na, K, and Ca, which explains the increase in the concentrations of these elements in the treated soils. The high ECe values in the treated soils could be attributed to the increase in the concentrations of Na and Mg due to the ability of zeolite to enhance the water and salt holding capacity of soil (Al-Busaidi et al., 2008). A similar result was obtained by Ghazavi (2015), who reported 21.6% and 33% increases in soil ECe following the addition of 10% and 20% zeolite, respectively, to the control soil. The concentrations of the main cations (Ca, Na, and K) were also significantly higher in volcanic zeolite tuff-treated soils than the control soil, whereas the addition of volcanic zeolite tuff had no significant effect on the soil pH. Jakab and Jakab (2010) showed that zeolite volcanic tuff improves N maintenance and increases the mobile K content of soil two to three fold, which explains the increase in nutrients that occurred in the treated soil. Similarly, Perez-Caballero et al. (2008) found that soil K and N contents increased significantly as the application rate of zeolite increased from 0 to 4 kg/m^2, particularly at >3 kg/m^3. Ghorbani and Agha babaei (2008) found that the addition of zeolite to the soil at low rates (<1:20) decreased the soil salinity at an initial water NaCl salinity of 15 dS/m, while a higher rate of zeolite application significantly increased the EC.

5. CONCLUSION

Five years monitoring period of olive trees indicated that amendment of the soil with volcanic zeolite tuff especially fine volcanic zeolite tuff increased both relative water content and leaf water potential. Amended soils also had higher levels of EC, $CaCO_3$, N, K, P, SAR, Na, Mg, and Ca compared with the control soil, while plants that were grown on these soils had higher contents of N, P, and Na in their leaves. Based on the observed changes in physiological parameters and chemistry, it is considered that the amendment of soil with fine and coarse volcanic zeolite tuff ameliorates reduced olive growth under moisture stress by conserving water, increasing nutrient levels in the soil, and preventing nutrient leaching. The outcomes of this research may help in better utilization of water resources in the agricultural sector, optimize the utilization of ZT as a natural material, improve soil fertility, enhance food productivity, subsequently increase the farmers' income, and improve their life.

ACKNOWLEDGEMENTS

We acknowledge the Scientific Research Fund for funding this project, the National Agricultural Research Center (NARC), for their help in chemical analysis and Al-Balqa Applied University for providing the required land for olive cultivation. The authors would like to thank the Jordan University of Science and Technology for supporting this research.

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