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The Potential of the Application of Olive Cake and Stone Cutting Waste for Soil Amendment

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Abstract

The recycling of waste is considered an attractive solution for the high amounts of waste generated worldwide. Some waste including olive waste and stone cutting waste present considerable environmental challenges for environmental planners and local communities. Due to their impacts on the environment and human health, this paper investigates the recycling of olive cake (OC) and stone cutting sludge (SCS) and their use for soil amendment. It evaluates their effect on soil pH, soil permeability, and maize growth. Thirteen different treatments containing clay soil (CS), OC, and SCS with different proportions to be used as maize seed growing media. The media were placed in pots and each treatment had three replicates with a randomized complete block design and was irrigated with fresh water. OC had high permeability, low pH, while SCS had low permeability and alkaline ph. The growing media which contained CS and SCS at 70:30 (w/w) ratio (T8) exhibited an increase in the number of leaves (8.7 %), plant height (5.5 %), stem diameter (34.3 %), shoot fresh weight (18.2 %), shoot dry weight (23.5 %), fresh root weight (4.29 %), dry root weight (38.10 %), leaf length (31.9 %), and leaf width (4.86%), while OC application resulted in significant reductions in all the above-mentioned parameters. In the treatments containing the three mixtures (CS, OC, and SCS), stone cutting sludge countered the negative effects of OC and enhanced the performance of the mixed soil, resulting in significant improvements of the growth indicators.

The obtained results highlighted the potential of using waste as a soil amendment technique instead of the disposal of waste. This could decrease the destructive impact of waste on the environment and reduce the costs of transportation and disposal.

Keywords: Olive Cake, Stone Cutting Waste, Soil Amendments, Maize, Recycling.

1. Introduction

A high increase in the global population has led to a corresponding high demand for food. An intensive use of land for continuous cropping has been adopted to meet the increasing demand for food. Intensive land use activities, in addition to soil erosion, nutrient leaching, and low rainfall have considerably reduced soil fertility (Moges and Holden, 2008). To compensate for soil exhaustion, fertilizers are often applied intensively, which has numerous negative impacts on the environment, such as contributing to acid rain and global warming, ground water contamination, air pollution, soil acidity, and eutrophication in surface water (Al-Tabbal and Al-Zboon, 2012). Soil amendment is an attractive route for improving soil fertility through the improvement of soil characteristics, in turn providing a suitable environment for root growth (McGeehan, 2012). The recycling of waste to be used in soil amendment can reduce the environmental loads of such waste and contribute to soil fertility and food production (Petersen et al., 2003). Several organic (compost, manure, sawdust, wood chips) (Lima et al., 2009; Breton et al., 2016.) and inorganic materials (gravel, tire waste) (Braun and Flückiger, 1998; William and Shenker, 2016) have been used to amend soils. Soil amendment may enhance soil physical properties (water retention, aeration, water infiltration, permeability, porosity, and texture), adjust soil acidity, and increase soil organic contents (Tester, 1990).

Chan et al. (2008) investigated the impact of biochar produced from poultry litter as soil amendment on the yield of radish and soil characteristics. They reported that yield increased by 42 % and 96 % with the biochar application rates of 10 and 50 t ha^{-1}, respectively. Soil Carbon (C), Nitrogen (N), pH, and Phosphorus (P) increased significantly following the amendment. The application of different organic wastes (municipal biosolids, food waste compost, composted hog manure solids, mined peat moss) in soil amendment resulted in considerable increases in soil water retention and a marginal increase in organic matter, while soil bulk density decreased significantly (Zebarth et al., 1999).

Olive Cake (OC) is a byproduct of olive fruit milling with an average production rate of 0.4 kg of cake per kg of olive fruit. More than 50,000 tons of OC is produced annually in Jordan (Al-Zboon, 2017). Today, this material is stored in open ditches for long periods and is left to dry, which results in an unpleasant odor, risks to groundwater and the attraction and spread of flies. After drying, OC is often used for energy production, particularly in rural areas. OC has a high organic matter content with volatile solid contents >82 % (Al-Zboon, 2017). Therefore, OC can be used for soil amendment, particularly in soils poor in organic matter such as the soils of arid and semi-arid regions. Compost OC is used as soil amendment with the application rates of 2 %,

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4 %, and 8 %,; the soil organic matter content increased by 1.25 %–4.54 % depending on soil type. Moreover, it resulted in an increase in water penetration, water-holding capacity, and accumulated water intake (Al-Widyan et al., 2005).

In Jordan, stone cutting waste is considered a major environmental problem and is only associated with the construction sector. High quantities of slurry water containing solid particles are generated from stone cutting. This water is often collected and stored in open basins for long periods to condensate the solids (sludge), while the supernatant water is recycled inside the plant. The generated sludge is disposed-off in uncontrolled sites or in landfills which have numerous environmental effects on surface water and groundwater, in addition to harming flora, polluting soils, altering the natural drainage, and negatively affecting and disrupting the aesthetic appearance of environments (Al-Zboon et al., 2010). Stone cutting sludge (SCS) consists mainly of Calcium Oxide (CaO), Magnesium Oxide (MgO), Aluminum Oxide (Al_2O_3), and Iron (III) Oxide (Fe_2O_3), which means that it can be a great potential source of nutrients for the soil (Al-Zboon and Al-Zou'by, 2014). Carrao and Castelli (2008) reported that the application of stone sludge mixtures, at suitable proportions (40–50 %) relative to soil weight, may result in greater water retention. The addition of 20–40 % sludge to porous acidic soils could enrich them with potassium, magnesium, phosphorus, and numerous other micro-elements, which are beneficial to vegetable production. Tozsin et al. (2014) reported that the application of marble cutting waste as soil amendment increased the soil pH from 4.71 to 5.88, and increased the hazelnut yield by approximately 43 %. Furthermore, Pérez-Sirvent et al. (2011) observed that the addition of marble cutting sludge to soils contaminated with heavy metals modified the soil pH and enhanced the adsorption and precipitation of the metals, subsequently minimizing their mobility and toxicity. From an environmental and economic perspective, the recycling of waste is an efficient process for the reducing of the negative effects of waste on the environment, and for reducing the cost of waste management, and costs of crop production, while at the same time increasing the value addition from byproducts.

Both materials (OC and SCS) present serious environmental challenges in Jordan. The control of waste represents a heavy economic and environmental burden on their owners, municipalities, and local communities. Recycling is considered the optimal strategy for reducing waste quantities, the cost of waste management, in addition to adding values and creating job opportunities. To achieve the aforementioned goals, the present study was conducted and is aimed at investigating the impact of using OC and SCS waste as a soil amendment on maize (Zea mays) growth.

2. Materials and Methodology

2.1. Materials

In the present study, two types of waste are used for the soil amendment including OC and SCS. The control soils were collected from a field experimental station at Al-Huson University Collage, Al-Balqa Applied University. The soil samples were taken from the upper 25 cm zone, and were air-dried, and sieved through a 5-mm sieve. Naturally, dried OC was collected from a local three-phase centrifuge-system olive mill. A dried SCS sample was obtained from a local plant in Irbid area. An X-Ray fluorescence (XRF) spectrometer (SHIMADZU-XRF-1800) was used to determine the chemical composition of both materials (OC and SCS). Water content was determined by drying the samples in a drying oven at 105°C, and the water content was calculated as follows:

% Soil water conten

$$= \frac{(Weight\ of\ Wet\ soil - Weight\ of\ dry\ soil)}{Weight\ of\ dry\ soil} x100 \ldots\ldots.1$$

The organic contents of the sample were determined by measuring the sample volatility after being burnt in a muffle furnace at 550°C for four hours. A Euro EA 3000 elemental analyzer (Euro Vector, Milano, Italy) was used to determine the mass fraction of C, hydrogen (H_2), N, and oxygen (O_2) in the OC sample.

2.2. Experimental Layout

The experiments were carried out in a controlled environment in a greenhouse. Plastic pots with a diameter of 30 cm and a depth of 45 cm were used to plant Zea mays seeds after being filled with various media. The pots were divided into thirteen treatments according to different soil mixtures as shown in Table 1.

Table 1. Soil mixtures for different treatments(Dry-weight basis)

Treatment	Clay soil (%)	Olive cake (%)	Stone cutting sludge (%)
T1	100	0	0
T2	90	10	0
T3	80	20	0
T4	70	30	0
T5	60	40	0
T6	90	0	10
T7	80	0	20
T8	70	0	30
T9	60	0	40
T10	90	5	5
T11	80	10	10
T12	70	15	15
T13	60	20	20

The treatments were arranged based on a randomized complete block design with three replicates. The plants were irrigated daily using tap water to maintain the water-holding capacity at 80 %. Material permeability was determined using a constant-head test according to the standard test method for permeability in granular soils (ASTM D2434-68). pH was measured using an Ino Lab pH meter model (Model 7110, WTW Ino Labs, Germany).

2.3. Morphological Data Collection

The morphological parameters were recorded sixty days after sowing the maize *(Zea mays)* plants. The fresh weights of roots and shoots were measured and recorded in addition to the following measurements: the number of leaves per plant was determined by the visual counting of the leaves in a plant per pot (Tanko and Hassan, 2016); plant height (cm) was measured sixty days after being planted from the ground surface to the tip of the plant (Sabiel et al., 2014); stem diameter (mm) was measured using a vernier caliper at 10 cm above the ground level (Sabiel et al., 2014); leaf length was measured to the nearest millimeter from the leaf tip to the point at which the lamina is attached to the petiole (Sezer et al., 209); and the leaf width was measured from edge to edge at the widest part of the leaf lamina (Sezer et al., 2009). Roots and shoots were then dried at 105°C for dry-weight measurements.

2.4. Statistical Analysis

Analysis of variance, using randomized complete block design, was estimated for all the characters evaluated on SAS (SAS, 2008). The results are the means of three replicates. Data were statistically examined by the analysis of variance, and the least significant difference test was used to determine the significance of the differences between treatments.

3. Results

3.1. Properties of the Amendment Materials

OC and SCS had particle sizes ranging from 0.035 (N.400) to 16 mm (5/8) and from 0.50 to 177 µm (N.80) with an average size of 5.66 mm and 9.0 µm, respectively. The water contents of the OC and SCS samples were 11.6 % and 4.3 %, with soil content of 88.4 % and 95.7 % respectively. The average volatile organic matter content in the OC samples was 82.1 %.

The XRF analyses revealed that SCS contained a high level of CaO (54.7%), which indicates a carbonate origin of the stones (Table 2). OC had higher LOI lost on ignition (LOI) (80.4 %) than SCS (42.3 %) due to the high volatility of the organic matter in the OC samples, while SCS mostly had inorganic constituents. In addition, a higher Silicone dioxide (SiO_2) concentration was detected in the OC samples than in the SCS samples. High volatile organic compounds in OC (82.4 %) demonstrated its potential benefits as a source of organic matter, and that it could be used to improve the soil fertility and plant growth. The average element fractions in the OC samples were: C (50.1 %), O_2 (41.2 %), H_2 (6.3 %), N_2 (2.3and sulfur (0.1 %).

Table 2. Results of XRF analyses of the olive cake and stone cutting waste samples

Parameter	Olive cake	stone cutting sludge
	Average %	
CaO	7.65	54.7
SiO_2	6.45	0.85
Al_2O_3	1.37	0.20
K_2O	0.97	ND$^+$
Fe_2O_3	0.90	0.10
MgO	0.60	0.90
Na_2O	0.19	ND$^+$
SO_3	0.16	0.10
LOI*	80.4	42.3

**: loss on ignition, + not detected*

pH values of the different soils in the present study are presented in table (3). OC was acidic, while SCS and the control soil were alkaline. The acidity of OC could be useful in neutralizing alkaline soils, which is the case for most soils in Jordan.

Table 3. pH values for different soil samples

Treatment	pH
T1	7.7
T2	7.29
T3	6.91
T4	6.52
T5	6.5
T6	8.12
T7	8.15
T8	8.22
T9	8.26
T10	7.73
T11	7.37
T12	7.18
T13	7.19

The results of the permeability experiment revealed that the OC samples had high filtration rates, which were three and eight times higher than those in CS and SCS, respectively (Table 4). Based on the permeability results, CS, OC, and SCS, are be classified as slow, rapid, and very slow permeability (FAO, 2017). Al-Widyan et al. (2005) observed that the addition of OC to the soil increased its infiltration rate by 20, 24, and 27 % with the OC application loads of 2, 4, and 8 %, respectively after sixty-two minutes. Adequate permeability in the soil enhances soil aeration, biological activity, water infiltration, root development, and subsequently, plant growth. In contrast, low permeability causes disconnected soil channels, alters water filtration, and holds water within the top layer making it unavailable in the root zone, in addition to resulting in poor aeration. Very high permeability increases water filtration, decreases water availability for plants, and results in wastage of water resources. OC utilization considerably improved the permeability of CS and SCS, which makes it a potential material to increase soil infiltration, when applied at suitable rates.

Table 4. Permeability and filtration rate of various selected soil mixture.

Treatment	Permeability cm/min.
Olive cake	0.068
Stone cutting	0.0084
T1 (100:0:0)	0.0196
T5 (60:40:0)	0.0476
T9 (60:0: 40)	0.00939

3.2. Morphological characteristics of maize

The morphological parameters (number of leaves, plant height, stem diameter, fresh and dry weight of shoots, fresh and dry weight of roots, leaf length, leaf width, and shoot to root ratio) for all treatments are illustrated in Figures 1 to 10. Significant differences ($p \leq 0.05$) were observed among all treatments and for all morphological parameters, as illustrated in Table 5.

Table 5. Analyses of variance for growth parameters of maize (Zea Mays L.) plants grown in different mixtures of media (clay soil, olive cake and stone cutting).

Source of variation	Number of leaves	Plant height (cm)	Stem diameter (cm)	Fresh weight of shoot (g)	Dry weight of shoot (g)	Fresh weight of root (g)	Dry weight of root (g)	Leaf length (cm)	Leaf width (cm)	Shoot to root ratio
Treatment	17.87 **	863.8 **	0.25 **	609.6 **	38.92 **	20.93 **	0.89 **	1223 **	4.005 **	5.87 **
Error	0.58	13.47	0.03	25.57	1.7	0.84	0.04	4.34	0.035	0.78

*** indicates significant difference at 5 % probability.*

3.2.1. Number of Leaves

The number of leaves was significantly influenced by the growing medium, as illustrated in Figure 1. The effect was positive for some treatments and negative for others. The positive effects were found for plants grown in pots containing a combination of clay soil (CS) and SCS compared to control treatment (CS) with the highest number of leaves obtained from the treatment containing a combination of CS and SCS at the proportion of 70 % : 30 % (Figure 1). The number of leaves decreased progressively for all treatments that contained OC compared to the control treatment and the reduction was more obvious as he OC proportion increased to 40 % in the growing media. The reduction percentage for this treatment was 68.35 % compared with the control.

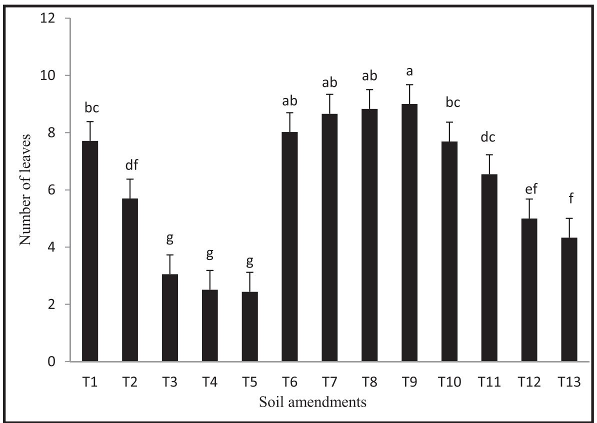

Figure 1. Effect of olive cake and stone cutting waste as soil amendment on the number of leaves of maize. Columns denoted by a different letter indicate significantly different values at P ≤ % 0.05 in one-way ANOVA.

3.2.2. Plant Height

OC exerted adverse effects on all other growth attributes. Plant height decreased progressively as OC concentration increased in the growth media (Figure 2). The most adverse effect was observed from the treatment that contained 40 % of OC resulting in a reduction in the plant height by 85.54 %. However, mixing SCS with OC mitigated the negative effects of OC. When comparing the treatment which contained OC only with the treatment that has the same percentage of OC mixed with SCS, it becomes clear that the treatment with SCS showed clear positive effects in improving the plant height.

3.2.3. Stem Diameter

The growing media exhibited significant differences for stem diameter. T8 that contained CS and SCS (70 % : 30) produced the highest stem diameter compared to other treatments (Figure 3). Plants grown in media that contained OC exhibited considerable decline in stem diameter. Maximum reduction was noted in T5, which resulted in 79 % reduction in stem diameter compared with T1 (control).

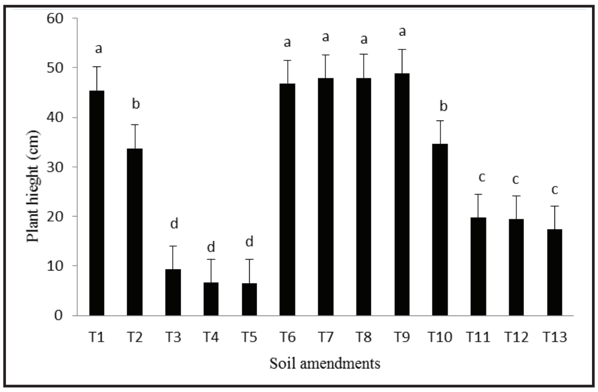

Figure 2. Effect of olive cake and stone cutting waste as soil amendment on plant height of maize. Columns denoted by a different letter indicate significantly different values at P ≤ % 0.05 in one-way ANOVA.

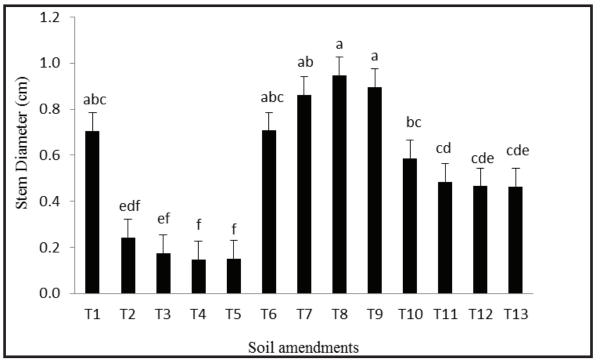

Figure 3. Effect of olive cake and stone cutting waste as soil amendment on stem diameter of maize. Columns denoted by a different letter indicate significantly different values at P ≤ % 0.05 in one-way ANOVA.

3.2.4. Leaf Length and Width

OC caused a significant reduction up to 79.4 % and 60.19 % in leaf length and leaf width, respectively, as compared to control plants (Figure 4 Figure 5). However, this inhibition was alleviated in the presence of SCS, the length and width of leaf in the combination treatment of CS, OC, and SCS decreased to 65 % and 56 %, respectively.

3.2.5. Fresh and Dry Weight of Shoot

The effects of OC and SCS on plant growth expressed as the fresh and dry weights of shoots are shown in Figures 6 and 7. The fresh and dry weights of shoots after treatments containing OC with CS alone remarkably decreased. The decrease was the highest in T5 while the fresh and dry weights of shoot after the treatment that contained SCS in addition to CS increased. The highest SCS–mediated OC stress alleviation was recorded in T13 (60 % CS: 20 % SCS: 20 % OC), in which the application of SCS improved the shoot fresh and dry weight by 557 % and 605 %, respectively compared with that in T3 (80 % CS: 20 % OC).

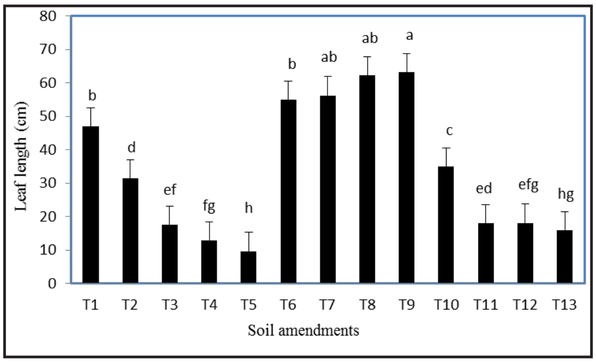

Figure 4. Effect of olive cake and stone cutting waste as soil amendment on leaf length of maize. Columns denoted by a different letter indicate significantly different values at P ≤ % 0.05 in one-way ANOVA.

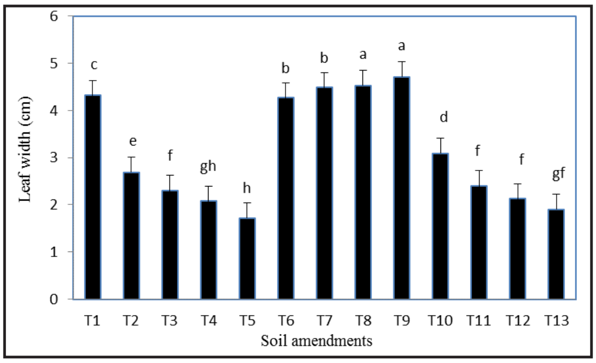

Figure 5. Effect of olive cake and stone cutting waste as soil amendment on leaf width of maize. Columns denoted by a different letter indicate significantly different values at P ≤ % 0.05 in one-way ANOVA.

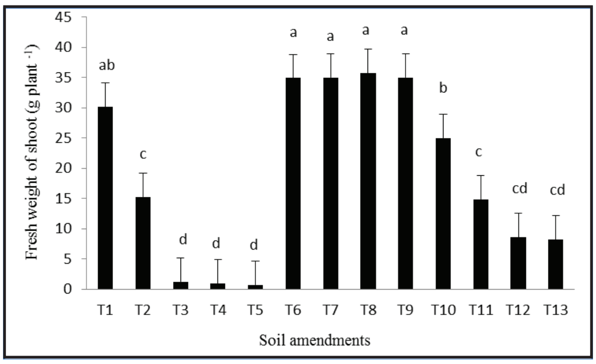

Figure 6. Effect of olive cake and stone cutting waste as soil amendment on shoot fresh weight of maize. Columns denoted by a different letter indicate significantly different values at P ≤ % 0.05 in one-way ANOVA.

3.2.6. Fresh and Dry Weight of Roots

The addition of OC to the growing media reduced the fresh and dry weights of roots, up to 70 % and 97 %, respectively, compared with the controls as shown in figures 8 and 9. Mixing SCS with both CS and OC mitigates the negative effects of OC in terms of the fresh and dry weights of roots. On the other hand, CS with SCS alone (CS and SCS, 70:30) increased the fresh and dry weights of roots by 8.42 % and 25 %, respectively compared to control.

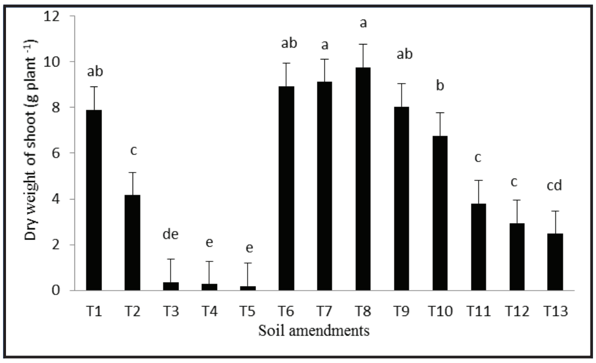

Figure 7. Effect of olive cake and stone cutting waste as soil amendment on dry weight of maize .Columns denoted by a different letter indicates significantly different values at P ≤ % 0.05 in one-way ANOVA.

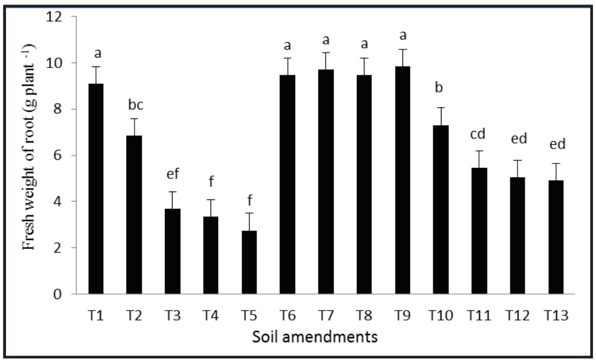

Figure 8. Effect of olive cake and stone cutting waste as soil amendment on root fresh weight of maize. Columns denoted by a different letter indicate significantly different values at P ≤ % 0.05 in one-way ANOVA.

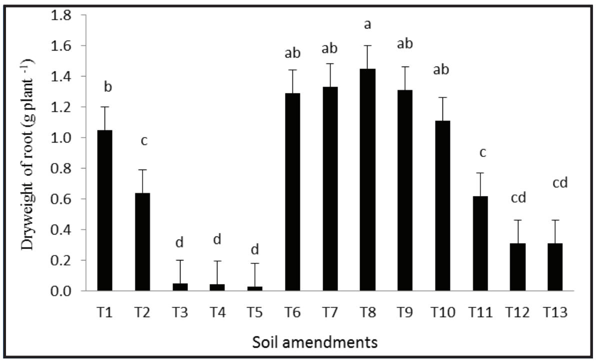

Figure 9. Effect of olive cake and stone cutting waste as soil amendment on root dry weight of maize. Columns denoted by a different letter indicate significantly different values at P ≤ % 0.05 in one-way ANOVA.

3.2.7. Shoot to Root Ratio

Shoot to root ratio decreased up to 92 % as a result of growing on CS containing OC alone (Figure 10). This reduction was decreased to 50 % when SCS mixed with previous media. The maximum alleviatory effect of SCS application on the growing media which contain OC was achieved when the concentration of SCS in the media increased to 20 %. However, an increase in shoot to root ratio was obtained in the growing media containing CS mixed with SCS only, reaching up to 15 % more than the control (CS).

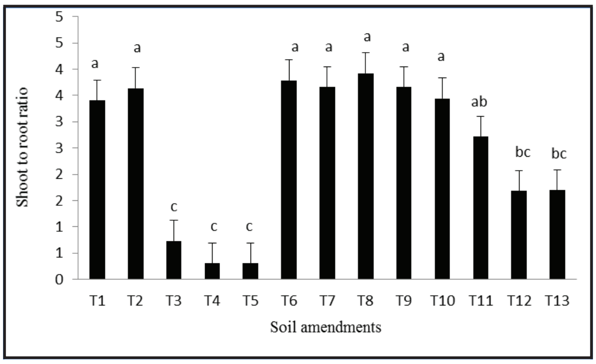

Figure 10. Effect of olive cake and stone cutting waste as soil amendment on shoot to root ratio of maize. Columns denoted by a different letter indicate significantly different values at P ≤ % 0.05in one-way ANOVA.

4. Discussion

The results of element analyses of the OC samples highlighted its importance as a bio-energy source in addition to its potential value as a source of organic matter. In the present study, OC significantly inhibited the growth of Zea mays. All application ratios of OC (10 %, 20 %, and 30 %) resulted significantly in lower growth parameters compared to the control soil, but greater reductions were achieved with higher percentages of OC in the mixtures. Olive mill waste has high phenolic, fatty acid, and ethanol compound contents, which have high lipophilicity and could alter the accessibility of nutrients within biological membranes which could explain the poor plant growth (El Hadrami et al., 2004; Tayeh et al., 2014; Pasten et al., 2017).

Moreover, the high infiltration rate of OC increases water loss, and could reduce the amount of water available to the plants (Abu-Rumman, 2016). Seferoglu (2011) reported that using olive fruit solid waste negatively influenced the germination of radish (Raphanus raphanistrum) and plant height in onions (Allium cepa) and radish (Raphanus raphanistrum), whereas it showed minor effects on onion germination and the plant height of faba beans (Vicia faba).

With regard to plant nutrient uptake, olive mill waste negatively influenced nutrient uptake rates in radish (Raphanus raphanistrum), while it positively influenced nutrient uptake rates in faba beans (Vicia faba) and onions (Allium cepa) at low application rates (20 t/ha). Higher application rates (40 t/ha) had adverse effects on all plants. Similarly, El Hadrami et al. (2004) reported that the addition of undiluted olive mill waste led considerably to the reduction of shoot and root weight and leaf extension, and significantly reduced yield in maize (Zea mays), chick peas (Cicer arietinum), tomatos (Solanum lycopersicum), and wheat (Triticum aestivum).

It has been reported that pH influences the solubility and availability of plant nutrients, and organic matter decomposition (McCauley et al., 2017). On the whole, soil pH near seven is the optimal pH for nutrient availability, crop tolerance, and soil microorganism activity (McCauley et al., 2017). Mixing OC with SCS resulted in a neutralized soil, which could decrease the negative effects of extreme pH on soil and plants.

Mixing CS and SCS at various proportions (T6-T9) and particularly at a ratio of 70:30 (T8) resulted in significant improvement of growth parameters compared to other treatments. Similarly, Tozsin et al. (2014) found that mixing marble waste with soil increased pH from 4.71 to 5.88, which resulted in the increase of hazelnut yield by 43 %. The increase in growth parameters for T9 (CS and SCS, 70:30), compared to the control soil, were 8.7 %, 5.5 %, 34.3 %, 18.2 % 23.5 %, 4.29 %, 38.10 %, 31.9 %, and 4.86 % for the number of leaves, plant height, stem diameter, fresh weight of shoot, dry weight of shoot, fresh weight of root, dry weight of root, leaf length, and leaf width, respectively. The increase in all morphological parameters in T6-T9 could be attributed to the presence of soluble nutrients in the treated soil (Ch'ng et al., 2014). The nutrients are essential for plant growth and development, and play key roles in various metabolic and physiological processes in plants, such as chlorophyll development, photosynthesis, starch synthesis, and phosphorylation (Dalcorso et al., 2014).

In the T10-T13 treatments, stone cutting waste countered and minimized the negative effects of OC, resulting in better growth of plants. Growing maize in pots containing a mixture of the three substances (CS, OC, and SCS) enhanced growth parameters compared with pots containing only a mixture of CS and OC. For example, in T13 (60:20:20) there were 4.3 leaves compared to 2.4 leaves in T5 (60:0:40), representing a 77.5 % increase. Plant height, stem diameter, fresh and dry weight of shoot, fresh and dry weight of root, leaf length, and width and shoot of root also increased. The improvement in plants' morphological parameters could be attributed to four reasons. T5 had a pH of 6.5, while stone cutting waste, which has good buffering capacity, increased pH in T13 to 7.19, which is more appropriate for plant growth. In addition to that, stone cutting waste decreased soil permeability, and subsequently increased the amount of water available to plants. Moreover, stone cutting waste added substantial amounts of nutrients to the soil as mentioned previously. Moreover, at higher pH rates (in the case of T13), the soil's capacity to adsorb phenol is low (Das et al., 2015), which could minimize the negative effects of phenol on plant growth.

5. Conclusions

OC and SCS have been assessed as potential materials for soil amendment for the production of Zea mays. Mixing OC and CS only at various proportions results in a decrease in key morphological parameters in Zea mays. Mixtures of OC and SCS, in addition to CS, at various proportions, facilitate suitable vegetative growth and plant productivity compared to OC alone or OC with CS. On the whole, stone cutting waste facilitates the recycling of OC for agricultural purposes.

The findings of the present study support the recycling of organic and industrial waste for soil amendment and food production.

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