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Evaluation of the effects of short-term amendment with olive mill pomace on some soil properties

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Abstract

The extraction of olive oil produces an enormous quantity of waste, such as olive mill wastewater (OMWW) and olive mill pomace (OMP), The majority of the agricultural wastes, including olive oil mill waste, are used as soil amendments due to their high nutritional value. The purpose of this study was to investigate the effects of the amendment with olive mill pomace from a 3-phase cold-pressed system on the characteristics of the soil pH, electrical conductivity (EC), and organic matter content (OM). The experiment was carried out using increasing rates of olive mill pomace (12.5%, 25%, 50%, 75%, and 100% w/w) plus the control untreated soil in microcosms under laboratory conditions. The results showed that the treatment of soil with olive mill pomace has a significant effect on soil properties (pH, EC, OM, OC, and $CaCO_3$) soil pH was decreased under OMP treatment, especially with high doses of PR4 and PR5, and the electrical conductivity of the soil (EC) was increased, as well as soil carbonate content. Moreover, the soil organic matter content and soil organic carbon content were highly increased under the treatment with OMP. As a result, we can consider the olive mill pomace as a soil fertilizer. Pretreatment of olive mill pomace to reduce acidic pH and salt content before use as a soil amendment is also recommended.

1. Introduction

From antiquity to the present, the olive industry is among the most traditional crop production, with important productive relevance for Mediterranean countries (Chatzistathis and Koutsos, 2017). Algeria is the ninth country producing olive oil in the world, about 4% of global production (Mekersi et al., 2021). There are various systems of olive oil extraction that are widespread throughout the world. The 3-phase separation technique is a more traditional extraction process described in this study. The principal by-product of the olive oil extraction process is the olive mill pomace (OMP) (Gómez-Muńoz et al., 2011). Due to the huge amount generated of OMP in a short period of time, it was generally characterized by acidic pH, a high level of salinity, and high organic matter content (OM), which represent a possible risk to the environment (Morillo et al., 2009; Chatzistathis et al., 2017).

The amendment of the agricultural soil by olive mill pomace has seemed to be operationally uncomplicated and economically achievable. Several researchers have focused on the use of raw or composted pomace on agricultural land for a short or long time (Abu-Rumman, 2016; Chartzoulakis et al., 2010; Aranda et al., 2015). Found that, due to its high amounts of minerals required for plant growth and development, such as potassium (K), nitrogen (N), phosphorous (P), magnesium (Mg), and organic matter, the olive mill pomace can be accepted as an effective fertilizer.

Moreover, organic matter is present in low quantities in most Mediterranean agricultural soils which are a limiting factor for plant growth and production (Mekki et al., 2013; Ben Rouina et al., 2014). For example, in, Tunisia due to the lack of organic matter in soils and the aridity climate, the authorities have decided to utilize olive mill by-products as soil organic fertilizers in the agriculture sector (Decree 1306 of February 26, 2013) (Meftah et al., 2019).

In this context, the study of the amendment of olive mill pomace on the characteristics of the soil is necessary to improve soil quality in the Mediterranean countries and ensure plant growth without negative effects on the soil. Several studies have been conducted on the long-term use of raw or composted olive mill pomace on agricultural land (Gómez-Muńoz et al., 2011; García-Ruiz et al., 2012; Aranda et al., 2016; Innangi et al., 2017;

Regni et al., 2017). As a result, due to its high quantities of nutrients necessary for plant growth and development, olive pomace can be regarded as an effective fertilizer.

Since most of the studies have focused only on the long-term effects of olive mill pomace on soil quality. It's needed to test the short-term effects of olive mill application on soil properties. Furthermore, it's also necessary to test different doses in order to provide the most realistic reflection of the natural conditions. The impact of OMP on the soil properties may also vary depending on the type and characteristic of OMP used, and the regional climate and, the application period. The effect of OMP on soil qualities varies based on the type and characteristics of OMP utilized, as well as the geographical climate and the time period of application. The present work is carried out to fill up some of the gaps in this subject's knowledge. This work aims to investigate the effects of the amendment of soil with various doses of olive mill pomace. The test doses are as follows (12.5%, 25%, 50% corresponding to doses recommended in several Mediterranean countries, and 75%, 100% w/w which could be reached in different areas. On soil pH, EC, OM, OC, $CaCO_3$, in order to improve their fertility, and better exploit the agricultural potential of this residue.

2. Materials and methods

In this study, we focused on olive pomace (OMP) obtained from a 3-phase cold-press olive oil mill in Baghaď, Khenchela, Algeria. Pomace samples were collected in November 2020 and immediately stored at 4°C until use. The soil used in this study was obtained from a natural grove at (0 - 40 cm) depth located in Khenchela (Algeria) (35° 29' 41'' N, 6° 55' 27'' E). The soil sample was oven dried overnight at 105°C. Before use in the experiment, it was mixed and sieved through a 2-mm sieve to remove gravel, roots, and stones. The selected soil had the following characteristics: 61% sand, 22% clay, 17% silt; pH (7.51), EC (0.24 mS cm^{-1}), % $CaCO_3$ (30.4), and OM (1.86 g kg^{-1}).

The experiments were performed with microcosms. The microcosms were 1 kg plastic containers with drains. The soil was divided into microcosms of 1000 g each. Olive pomace was added to the soil in increasing dosage as follows: PR1: 12.5% w/w, PR2: 25% w/w, PR3: 50% w/w, PR4: 75% w/w, and PR5: 100% w/w of olive pomace. The treatment with 50% olive pomace corresponded to the dose of 50–80 tones $^{-1}$ha $^{-1}$year legally allowed in several Mediterranean countries. In addition, the untreated soil (control) was used. The whole experiment was carried out with three replicates each under laboratory conditions for a short period (one week) Soil samples after the incubation period were sieved at (<2 mm) and stored at 4°C until further analysis.

At the end of the experiment, the olive pomace and soil were analyzed. For the physicochemical study, the raw olive pomace was dried in an oven at 105°C and crushed. The pH and electrical conductivity of OMP were analyzed using a pH meter and a conductivity meter according to the international method with a solid/water ratio of 1/5 (w/v) (Mathieu et al., 2003). Organic matter was determined by calcining the sample for 1 hour at 850°C in a muffle furnace (Aubert, 1978). Dichromate oxidation was used to measure organic carbon content by the Anne method (Aubert, 1978). Soil pH and EC were determined in the aqueous extract using ratios of 2:5 (w/v) for pH and 1:5 (w/v) for EC (Rodier et al., 2009). Total organic carbon was calculated using the method of Walkley and Black (Walkley and Black, 1934), and organic matter was calculated using the following formula: OM in % = TOC % ×1.72. Volumetry with a Bernard calcimeter was used to determine $CaCO_3$ equivalent.

2.1. Statistical analysis

The values of the olive mil pomace and the soil properties were carried out in triplicate and the results were expressed as means ± SD. Normality of the treatment was tested. A one-way ANOVA was used to assess the effect of olive mill pomace on soil properties (pH, EC, OM, OC, $CaCO_3$) using (XLSTAT 2014.5.03). SAS 9.1 was used to evaluate the homogenous groups that used the Least Significant Difference (LSD) of students at a 5% significance level. Pearson's correlation test was used to identify significant correlations between soil properties ($p < 0.05$). The Principal component analysis (PCA) was performed for testing Multivariate difference between treatments and soil properties (pH, EC, OM, OC, $CaCO_3$) using ADE-4 Software.

3. Results

The characteristics of olive mill pomace are reported in Table 1. According to the results obtained the pH value of olive mill pomace was (4.53), indicating that the sample of olive mill pomace has an acidic pH. OMP has high electrical conductivity (12.08 mS cm^{-1}). The olive mill pomace has a very high content of organic matter content (84%) and organic carbon content (59.13%).

The one-way analysis of variance (Table 2) showed that there was a highly significant difference between all treatments for the soil parameters pH, EC, and, OM, OC, and $CaCO_3$ with

Table 1
Characteristics of olive mill pomace. Results are reported as mean ± SD of 3 different measurements

Parameter	Value
pH	4.5 ± 0.1
Electrical conductivity (EC) mS cm^{-1}	12.08 ± 0.26
Organic matter content (OM) %	84 ± 2.00
Organic carbon content (OC)%	59.13 ± 0.09

($p < 0.001$) for all measured parameters. According to the results obtained and summarized in Figure 1a, the pH of the control has been near neutrality (7.51± 0.09), While, the application of olive mill pomace caused a significant decrease in soil pH including the recommended doses, especially with high doses such as 75% and 100% OMP, the decrease in soil pH ranged between (7.02± 0.11 to 5.05± 0.08), indeed a comparison of the average pH indicated the presence of 3 groups. The application of OMP on the soil induces also a significant increase in soil electrical conductivity compared to the EC of the control (0.24 ± 0.05 mS cm^{-1}) Figure 1b, results indicated increases in soil EC reached (1.74 ± 0.13 mS cm^{-1}) with 100% OMP, the comparison of the average EC showed the presence of 5 groups. Furthermore, the analysis of the soil organic matter content revealed that the control had

Table 2
The values of one-way ANOVA of the effect of olive mill pomace on soil analysis

Source	DF	pH	EC	OM	OC	$CaCO_3$
Treatment	2	1 .70200***	1.362000***	176.7000***	156.34***	134.08***
Error	24	0.01611	0.001367	0.006111	0.00543	0.00032

***: highly significant at 5%   *: significant   ns: not significant

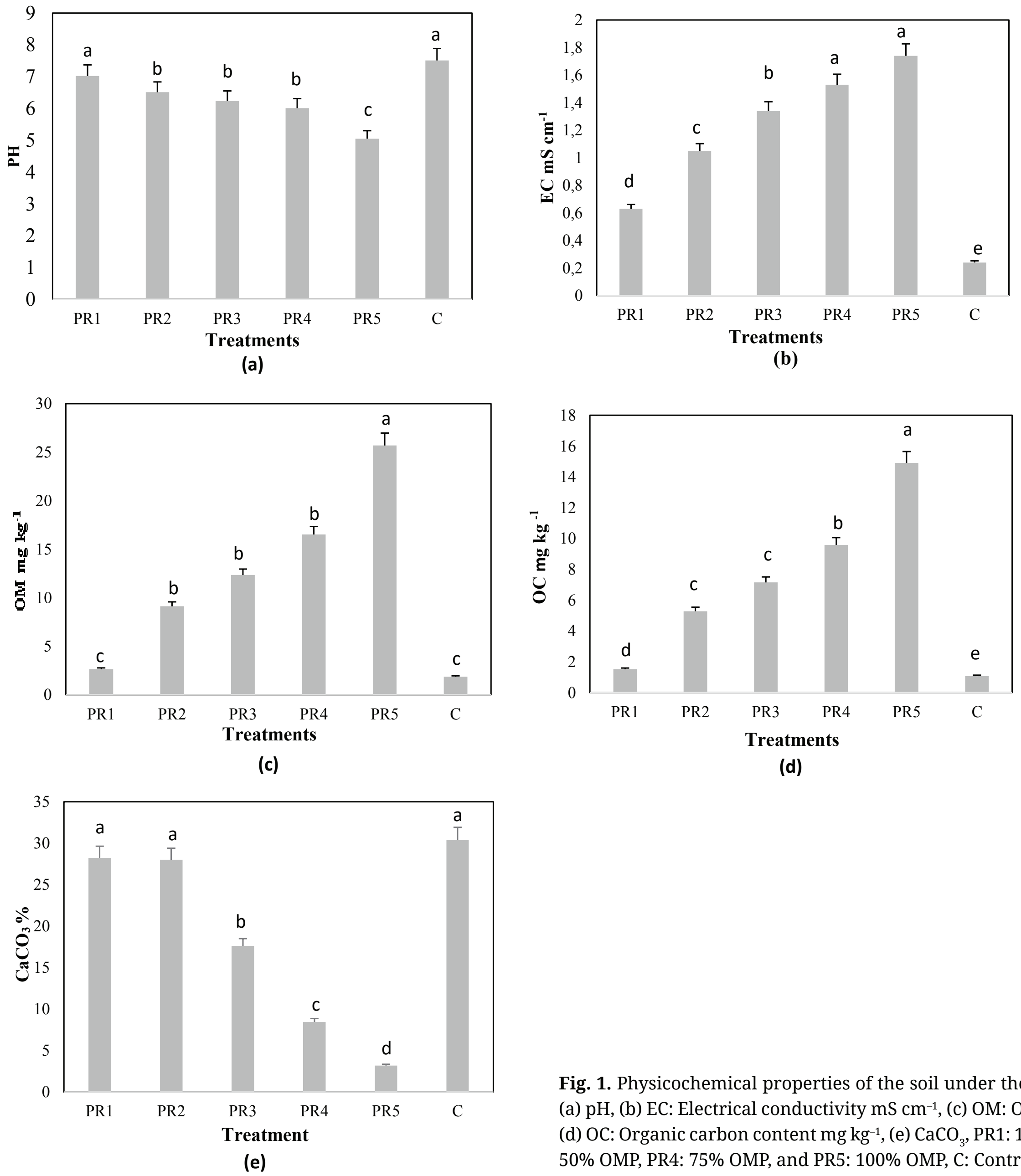

Fig. 1. Physicochemical properties of the soil under the treatment with OMP, such as (a) pH, (b) EC: Electrical conductivity mS cm^{-1}, (c) OM: Organic matter content mg kg^{-1}, (d) OC: Organic carbon content mg kg^{-1}, (e) $CaCO_3$, PR1: 12.5% OMP PR2: 25% OMP, PR3: 50% OMP, PR4: 75% OMP, and PR5: 100% OMP, C: Control

a low organic matter content initially Figure 1c, and the comparison of the average showed OM the presence of 3 groups. Treatment with OMP has increased the soil content of OM (from 2.64 ± 0.21 to 25.69 ± 0.16 mg kg^{-1}) as well as the soil content of OC Figure 1d (from 1.08 ± 0.18 to 14.90 ± 0.33 mg kg^{-1}) and the homogeneous groups of OC revealed the presence of 5 groups. Whereas the carbonate content of soil ($CaCO_3$) decreased after the treatment by OMP Figure 1e, (from 28.23 ± 0.22 to 3.19 ± 0.07 %), and the comparison of the average $CaCO_3$ indicated the presence of 4 groups.

4. Discussion

The physicochemical properties of OMP are influenced by the techniques used in olive oil extraction, as well as by other agronomic factors such as the extraction process, growing conditions, olive variety, stage of ripeness, olive origin, and storage conditions (Mekersi et al., 2021). Our data regarding the pH value of OMP were showed an acidic pH due to the presence of organic acids (phenolic acids, fatty acids, ...) While previous studies were showing pH values between 5.4 and 6.6 (Aviani et al., 2010; Medjahdi et al., 2014; Michele et al., 2017). The high electrical conductivity could be due to the high salt content used to preserve the olives before extraction, as well as the mineral components present in the olive mill wastes (Bouknana et al., 2014). The electrical conductivity of olive pomace is an indicator of total mineralization and is related to the concentration and nature of dissolved chemicals (Mekersi et al., 2021). Our results were higher than those found by Ragni et al. (2017); Michele et al. (2017); Ameziane et al. (2019), The findings regarding the organic matter content and organic carbon content are similar to those of Ameziane et al (2019).

The Treatment of soil with olive mill pomace has a significant effect on soil pH, EC, OM, OC, and $CaCO_3$. The soil pH was decreased under the treatment with OMP, this decrease was depending on the olive mill pomace rate added to the soil. The treatments PR1 and PR2 showed a slight decrease in soil pH. The slight change in soil pH is mainly due to the high buffer capacity of the soil. In fact, the acidity of olive mill pomace is due to the presence of organic acids (phenolic acids, fatty acids. (de la Fuente et al., 2011; Aviani et al., 2010). Our results are confirmed by Aranda et al. (2015). Found that the soil becomes more acidic after the application of olive mill by-products and only slightly modifies the soil pH due to the buffering capacity of the soil itself. In addition, García-Ruiz et al. (2012). Found a remarkable lower in soil pH after the application of olive mill pomace and the decrease was dependent on the number of years of application. The initial value of soil electrical conductivity classifies soil as non-saline, this value reflects the salinity content in this soil (Meftah et al., 2019). After the application of the olive mill pomace, a significant increase in the soil's electrical conductivity was observed compared to the control. This increase is related to the high content of salts added to conserve the olive, particularly potassium salt (Obaid et al., 2014). Our findings were in accordance with those of Ameziane et al. (2019). Found that the EC of the soil varies depending on the amount of olive mill pomace added. The increase in the soil OM content as a function of the olive mill pomace rates applied was related to the richness of the olive mill pomace in organic matter (Regni et al., 2017). The high organic matter in the soil improves soil water retention and increases total soil stability, rendering soils less sensitive to erosion (Lozano-García et al., 2011). Our results are in agreement with Aranda et al. (2015) found that the soil organic matter was improved by the amendment with olive mill pomace. Moreover, García-Ruiz et al . (2012) confirmed that the application of olive mill pomace on the soil increased soil organic matter content. The soil organic carbon content was also observed to be raised as a result of the contribution of olive mill pomace treatment to the soil organic matter. The value of organic carbon in the different soil samples complemented the value of soil organic matter precisely. The percentage of carbonate content in the soil decreases significantly with the increase of the percentage of olive mill pomace in the soil also their decrease depended on the decrease of soil pH and the increase of soil organic matter content. Overall, the soil treatment with olive mill pomace especially at high doses renders the soil non-calcareous.

4.1. Correlation analysis and PCA

Pearson's correlation analysis showed that the correlations between soil pH and $CaCO_3$ and the measured variables were significantly negative with EC, OM, OC. While the EC, OM, and OC are positively correlated. Table 3.

4.2. Multivariate analysis (PCA)

A principal component analysis was utilized to assess the development of the various parameters under investigation. The PCA Figure 2a showed that the first principal component

Table 3
Pearson correlation coefficients of the physicochemical properties of the soil under OMP treatment (P < 0.05).

	pH	EC	OM	OC	$CaCO_3$
pH	–0.912				
EC	–0.843	0.854			
OM	–0.754	0.864	0.721		
OC	–0.631	0.753	0.654	0.532	
$CaCO_3$	–0.643	0.646	0.512	0.542	–0.821

pH, Electrical conductivity (EC), Organic matter content (OM), Organic carbon content (OC), $CaCO_3$

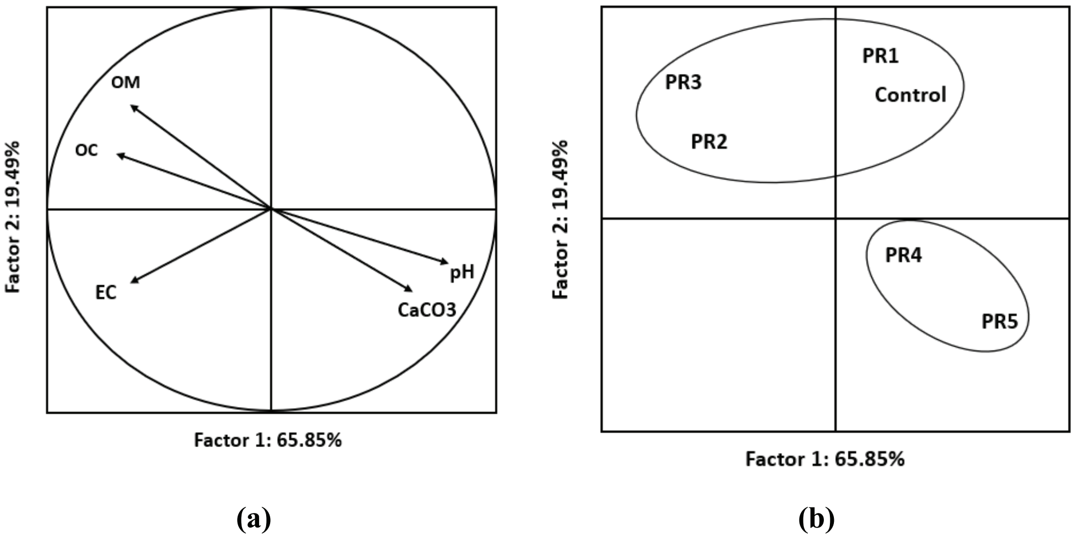

Fig. 2. Principal component analysis PCA of soil properties, (a) correlation circle of soil properties pH, EC: Electrical conductivity mS cm^{-1}, OM: Organic matter content mg kg^{-1}, OC: Organic carbon content mg kg^{-1}, $CaCO_3$. (b) Projection of experimental points of the treatments applied PR1: 12.5% OMP PR2: 25% OMP, PR3: 50% OMP, PR4: 75% OMP, and PR5: 100% OMP, Control

was positively determined by pH and $CaCO_3$, and negatively determined by EC, OM, OC, its relative inertia was 65.85%. While OM content and OC were positively determined by the second principal component, whereas EC, pH, and $CaCO_3$ were negatively determined, and its relative inertia was 19.49%. The results of the projection points Figure 2b of the treatments applied on axis 1 and axis 2, indicated that treatment of soil with olive mill pomace have a significant effect on soil properties compared to the control.

5. Conclusions

In this study, the amendment of soil by the olive-mill pomace at increasing doses were effective in improving the soil organic matter content soil organic carbon content. Moreover, the application of olive mill pomace causes an increase significantly in the acidification of the soils according to the doses used, also the treatment with olive mill pomace significantly increased the electrical conductivity and salinity of the soil compared to the control, this increase is proportional with the high salt content present in olive mill pomace and increased the carbonate content in the soil. Further, the addition of olive mill pomace to the soil can constitute a significant and very important organic amendment. As a result, we can consider the olive mill pomace as a source of soil organic matter, also we recommend a reduce of their acidic pH and salt content prior to use as a soil amendment.

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