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Soil nutrient content and olive tree nutritional status after composted olive husk application in an olive orchard of Northern Tunisia

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Abstract - The present study aims at assessing the soil nutrient content and olive tree nutritional status in an olive orchard in Northern Tunisia after five years of organic farming practices. The soil of three plots (P1, P2, and P3) planted with *Picholine*, *Manzanilla* and *Meski* olive cultivars, was sampled and analyzed for Soil Organic Matter (SOM), Phosphorous (P) and Potassium (K) contents. The foliar diagnosis technique was used to assess the olive nutritional status during three months monitoring period. The results showed that soil P contents ranged between a minimum of 9 ppm in P3 and a maximum of 13 ppm measured in P1. The soil K contents at soil surface varied between 280 ppm in P1 and 380 ppm in P2. Compared to reference levels these values depict satisfying soil P and K fertility in the study site. As for olive nutritional status, the foliar diagnosis showed that in all studied plots olive trees did not show any deficiency in N, P and K contents during the investigation period. These results suggest that organic fertilization using the olive husk compost as practiced in the studied area successfully maintained the soil nutrient content stock as well as the olive tree needs.

Keywords: soil fertility, nutrients, olive tree, organic farming, olive husk compost

1. Introduction

The organic farming as a healthy, economic and sustainable system of agricultural production has developed rapidly all over the world (Lodolini *et al*., 2013). This relatively new concept of agricultural production is becoming an integral part of development plans in many countries where the public opinion is becoming more and more aware of the importance of organic products.

In Tunisia, organic farming is practiced in several agricultural sectors in particular the olive farming which registers an important increasing trend during the last few years. As a matter of fact, olive orchards organically managed increased from 173 ha in 1997 to 100500 ha in 2014 (CTAB, 2014). One of the basic components of this new concept of agricultural production is organic fertilization used to maintain and to develop the soil fertility by stimulating its organic and humic fractions. Indeed, enhanced soil fertility is one of the main pillars on which an effective organic farming system depends (Mäder *et al*., 2002).

This important component of organic farming remains nowadays one of the main concerns of Tunisian olive tree growers. Many researchers studied the effectiveness of such fertilization in olive tree orchards and reported contradicting results. For instance, Hassan et *al.*, (2010) studied the response of *Klamata* olive young trees to mineral and organic fertilization and found that mineral treatments showed higher leaf N and P contents than organic treatments (cattle manure). For leaf K content the organic fertilization gave the highest significant value. Their investigation showed also that leaves N, P and K contents of organically fertilized olive groves were always higher than standard thresholds. Fernandez-Hernandez *et al.* (2014) reported that organic fertilization with composted olive-mill waste in a *Picual* olive orchard in Spain was superior to mineral fertilization in terms of soil fertility and olive oil quality. In contrast, Monge et *al.*, (2000) reported that organic wastes fertilization did not lead to significant increases in olive mineral leaf contents during a first year trial. In a *Picual* olive tree orchard in Egypt, Hegazi *et al*., (2007) found that the highest values of the studied growth parameters were obtained after pure organic fertilizer application in comparison with combination with bio and chemical fertilizers. Aranda *et al.* (2015) reported that olive grove soils after 17 years of organic management with application of olive-mill pomace co-compost were of higher quality than those with conventional management where no co-compost had been applied. In Tunisia, scarce information exists about the impacts of organic fertilization on soil and olive tree in Tunisian olive orchards. In one of the rare studies, Gargouri *et al*., (2013) assessed the effects of olive mill wastewater spreading and olive husk compost use on soil quality and olive yield. After three years of investigation they concluded that these organic fertilizers proved to have beneficial effects on soil and plants and with very limited impacts on the environment.

In order to assess olive tree nutritional status, the foliar diagnosis has been shown to be an effective tool (Fernández-Escobar *et al*., 2009). The mineral composition of leaves reflects the nutritional status of the olive tree (Lavee, 1997). It is used as well to check for nutrient deficiencies and especially to guide the fertilization process in order to apply only the needed fertilizers at specific rates. The results of foliar diagnosis are interpreted by comparison to standards established by numerous researchers in various conditions. For the phosphorous, Gargouri and Mhiri (2002) proposed a critical threshold of 0.07 % in the case of rain fed olive orchards. In Spain, Llamas (1984) gave an optimal leaf P content of 0.15 %. As for the optimal critical leaf potassium content, Gargouri and Mhiri (2002) proposed a threshold of leaf K content of 0.5 % DM. Comparing measured leaf nutrient contents to these reference values allows the diagnosis of nutrient deficiency, sufficiency or excess (Fernández-Escobar *et al*., 2009). This information combined with soil analyses can be used for optimum olive tree nutrition.

In this respect, the present study aims at assessing the impact of five years organic fertilization by composted olive husk biomass on soil fertility and olive tree nutritional status in a Tunisian olive orchard. It is a contribution to check whether Tunisian olive growers can rely on organic fertilization to satisfy their plants demand.

2. Material and Methods

2.1. Study site

The study site is located in the irrigated area of Testour in the Northwest of Tunisia (36°31 ' 19.20 " N / 9°25 ' 50.00 " E). The climate is semi-arid with annual average precipitation of 375 mm, an annual mean temperature of 17°C and annual potential evapotranspiration of 1436 mm. In this site three plots P1, P2 and P3 of 5 ha each were selected for soil and olive tree (*Olea europaea* L.) nutrient assessment. The plots are planted with different olive tree cultivars namely *Picholine* in P1, *Manzanilla* in P2 and *Meski* in P3. All trees have an age of 6 years. All plots are organically managed since five years ago. For fertilization the farmer applied locally produced compost. This organic fertilizer is made up of 50 % olive husk biomass (a byproduct of olive oil mill industry containing crushed pulp and stones), 30 % cattle manure and 20 % poultry manure. The process of composting begins by putting all these constituents in superposed layers. After approximately two months these layers are sliced, mixed and allowed to decompose in piles over a period of 4 to 5 months. During this period, the compost piles are weekly mixed and watered. They are also covered to protect them from the sun and the temperature variations.

2.2. Soil, compost and plant sampling and analyses

In each plot a composite soil sample obtained by thoroughly mixing several samples taken randomly at 0-20 cm depth was collected. Soil samples were then taken to the laboratory for analyses. The Soil Organic Carbon (SOC) content was determined by the Walkley and Black method (Pauwels *et al*., 1992). The Organic Matter (OM) content was derived from SOC by the relation OM = 1.724 SOC. The pH was measured in a 1:1 soil/water suspension. The available phosphorous (P) was determined by the Olsen procedure and exchangeable potassium (K) by a flame photometer (Pauwels *et al*., 1992).

In each of the studied plots a row of 10 olive trees was chosen to collect a sample of 100 leaves per tree. The one year old leaves located in the central half of the twig were collected. The sampling was made three times during the months of March, April and May. The leaves K and P contents were determined in extracts by flame photometer and spectrophotometer, respectively. The N content was determined by the Kjeldhal procedure (Cotenie, 1980).

Compost samples were analyzed for N, P and K contents using the same methods described previously for olive leaves. The organic matter was determined by loss on ignition. The water content was determined after drying the compost samples at 105°C for 24 hours (Cotenie, 1980)..

2.3. Statistical analysis

The foliar diagnosis data were subject to analysis of variance (ANOVA) to compare the various varieties and to characterize the seasonal variation of leaf N, P and K contents. Two factors were considered: variety (V1 *Meski*, V2 *Manzanilla*, and V3 *Picholine*) and date of sampling (D1 in March, D2 in April and D3 in May). Samples taken in each plot were considered as repetitions.

3. Results and discussion

3.1. The soil organic matter and nutrient contents

The results of soil physical and chemical analyses are summarized in table 1. According to the USDA classification, the soil of the study site has a clay loam texture in the plot P1 and silty clay loam one in the plots P2 and P3. The soil organic matter content is relatively low (< 2 %) in all plots except for P3 where the SOM level is above 2 % despite the somewhat high content of organic matter of the used compost (Table 2). The SOM contents outlined in table 1 may be considered as the initial rates of change due to compost application in the studied plots for a period of five years. Changing SOC levels in agricultural fields is a long term objective (Blair *et al.*, 2006) especially under Mediterranean climate conditions (Gucci et al., 2012). Similar findings were reported by Altieri and Esposito (2010) who found no significant effects of olive-mill waste on soil humic content after a short-term study (6 months). Similarly, Nasini *et al.* (2013) studied an amended soil with olive-mill waste for four years and found no significant changes in SOC levels compared to soil without amendment. These levels depend mainly on soil type, land use and climatic conditions. For a longer period (17 years), however, Aranda *et al.* (2015) found that the SOC increased by 6 to 9 folds in soils where olive-mill pomace co-compost was applied compared to conventionally managed soils. In more detailed investigation, Serramia *et al.* (2013) reported changes in soil humic pools after soil application of composted olive-mill waste.

Table 1: Soil physical and chemical selected properties in the studied plots P1, P2 and P3.

Property	Unit	Value		
		P1	P2	P3
Clay	%	36	34	36
Silt	%	36	54	48
Sand	%	28	12	16
$CaCO_3$	%	26	26	26
pH	-	8.80	8.80	8.80
SOC	%	0.82	0.82	1.31
SOM	%	1.41	1.41	2.27
P	ppm	13	12	9
K	ppm	280	380	300

SOC: Soil Organic Carbon, SOM: Soil Organic Matter, N: nitrogen, P: available phosphorous, K: exchangeable potassium

Table 2: Selected chemical properties of the olive husk biomass compost applied in the study site

Property	Unit	Value
Carbon	%	31
Organic Matter	%	75.80
Nitrogen	ppm	1.40
Phosphorous	ppm	0.34
Potassium	ppm	2.20
C/N ratio	-	22.14
Water content (%)	%	28.77

The soil of the study site presents a rate of exchangeable K ranging between a minimum of 280 ppm in the plot P1 and a maximum of 380 ppm in the plot P2 (Figure 1). According to the standards of potassium fertility appreciation in Tunisian soils (Zaier, 1988), this soil presents overall a sufficient level of exchangeable K. Moreover, the measured rate of potassium in all plots is greater than the critical thresholds of this element defined by several authors in soils with olive trees (e.g. Recalde, 1975: 40-250 ppm; Gargouri and Mhiri, 2002: 150 ppm for soil clay content > 15%). Similarly, Nasini et al. (2013) have reported greater exchangeable K contents in soils amended with olive mill waste compared to the control ones and stated that the used amendment may be a source of this element. Fernandez-Hernandez et al. (2014) reported a significant increase in olive-mill waste compost treated soils independently of the compost composition. Similar observations were reported by Proietti et al. (2015) who found that the soil amended with olive-mill waste had the greatest increase in exchangeable K.

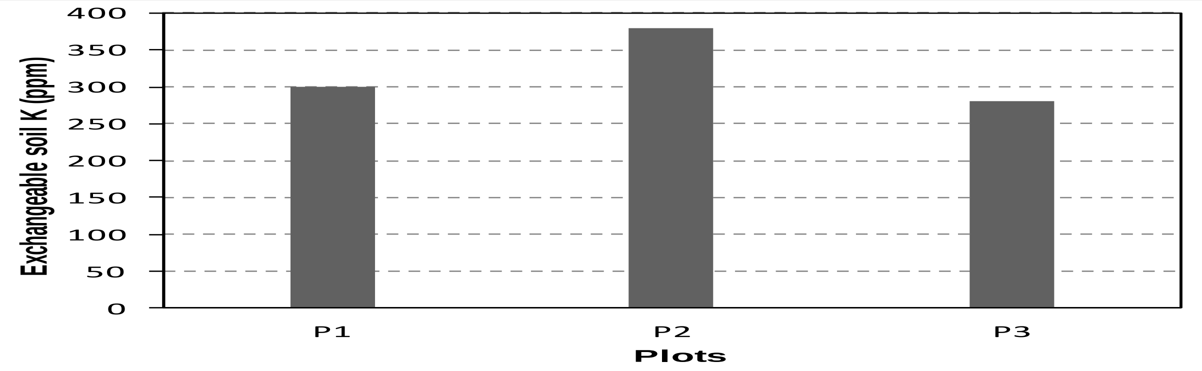

Figure 1: Soil exchangeable potassium content in the studied plots P1, P2 and P3 after 5 years of olive husk compost application.

Figure 2 presents the measured available P contents in the studied plots. The maximum P level of 13 ppm was measured in the plot P1 at the soil surface (0-20 cm) and the minimum of 9 ppm in the plot P3. These levels are above the critical threshold of 8 ppm (Olsen method) proposed by Gargouri and Mhiri (2002) for soils of olive orchards under Tunisian conditions. However, the measured P contents in the study site are under the threshold of 20 ppm (method of analysis not cited) proposed by Llamas (1984) and Recalde (1975). Results from recent literature have shown an increase of available P in soils amended with composted and raw olive husk biomass (Nasini *et al.*, 2013; Fernandez-Hernandez *et al.*, 2014; Aranda *et al.*, 2015; Proietti et al., 2015). These authors stated that this increase was probably due to the fertilizing effect of the used amendment. While the P level in the studied soil is relatively satisfactory its availability and mobility need to be considered. The soil is reach in calcium (26%) and clay (36%) on which P availability is highly dependent (Soltner, 1990; Wardrusaka, 2006). Moreover, the irrigation applied in the studied plots may enhance P mobility throughout the soil profile as was demonstrated by a number of authors (Lessa and Anderson, 1996; Ojekami et al., 2011).

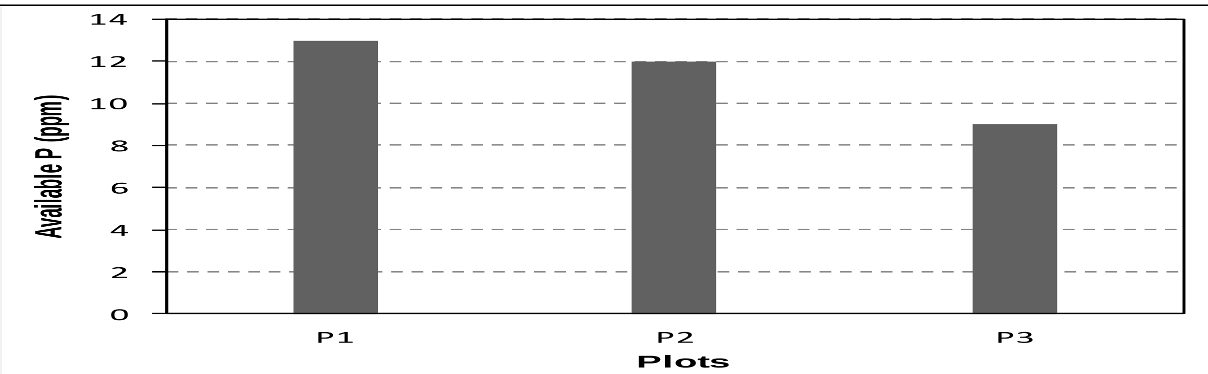

Figure 2: Soil available phosphorous content in the studied plots P1, P2 and P3 after 5 years of olive husk compost application.

3.2. The olive tree nutritional status

The foliar diagnosis showed a net decrease of the leaf N concentration during the monitoring period. Hence, for the *Picholine* variety for instance the leaf N content decreased from 2.04 % DM in March to 1.57 % DM in May (Figure 3). The statistical analysis showed that the differences between mean values of leaf N concentration among sample dates were significant at $p<0.05$ for all studied olive varieties. Fernandez-Escobar *et al.* (1999) found the same variation for the *Picual* olive cultivar in Spain and reported that the leaves N concentration decrease continued until July-August to reach a minimum concentration. The comparison between mean values of N leaf content for the same sampling date (D1, D2, D3) showed a significant ($p<005$) difference between olive cultivars.

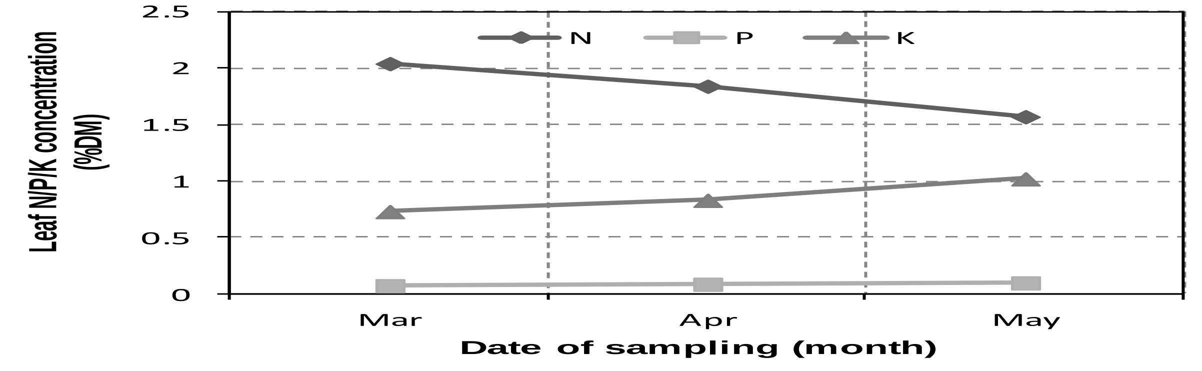

Figure 3: Leaf nitrogen (N), phosphorous (P) and potassium (K) changes during the monitoring period in the plot P1 (cv. *Picholine*).

By comparing the measured N concentrations with the common used standards, it seems that they are within normal limits and do not show any deficiencies. Nitrogen was always above the sufficiency threshold of 1.5 % in all studied plots. The observed decrease of these contents can be managed by a reasonable fertilization.
The diagnosis of changes in leaves P concentrations during the studied period showed a similar behavior among the three varieties *Picholine*, *Manzanilla* and *Meski* (Figure 3, 4 and 5). There was a slight decrease of leaf P contents from March to May. Bedbabis *et al.* (2010) who studied the olive cultivar *Chemlali* in the region of Sfax (Central-Eastern Tunisia) reported similar variations of leaves P concentrations. Besides, by comparing the found P leaves contents to the standards reported by several authors (Fernandez-Escobar *et al.*, 2009: 0.05-0.07 % DM ; Recalde, 1975 : 0.085 % DM ; Gargouri and Mhiri, 2002 : 0.07 % DM) it appears that all investigated samples had an acceptable foliar P content.

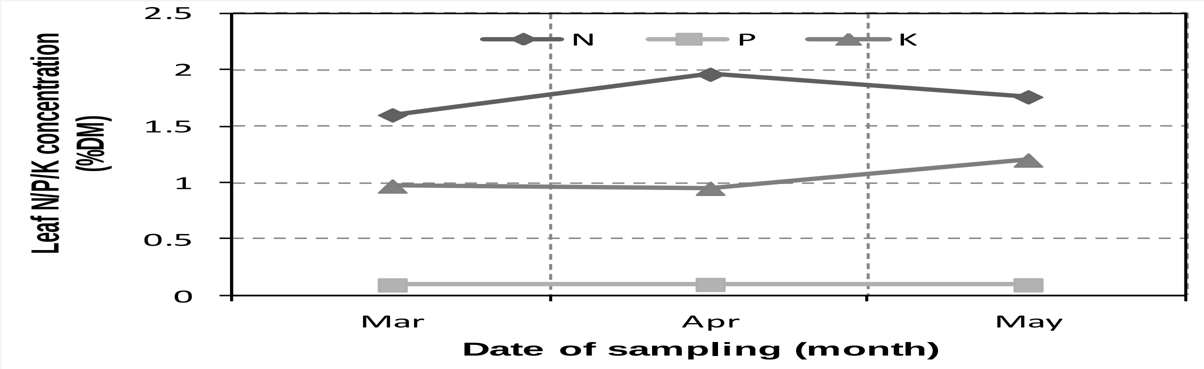

Figure 4: Leaf nitrogen (N), phosphorous (P) and potassium (K) changes during the monitoring period in the plot P2 (cv. *Manzanilla*).

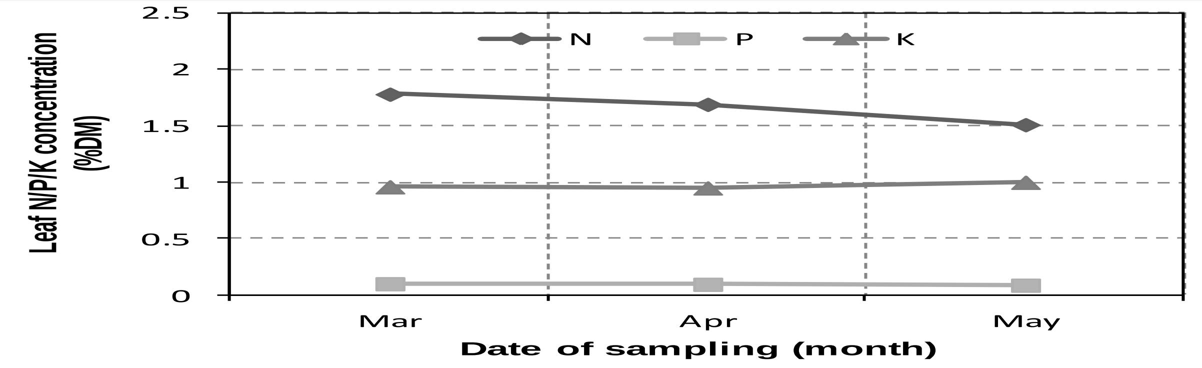

Figure 5: Leaf nitrogen (N), phosphorous (P) and potassium (K) changes during the monitoring period in the plot P3 (cv. *Meski*).

As for potassium variation, foliar diagnosis results showed a slight increase from March to April in all investigated plots (Figures 3, 4 and 5). This is in contrast to the findings of Bedbabis *et al.* (2010) who reported a decreasing trend of leaf K contents in irrigated olive orchards of central Tunisia. Moreover, the statistical analysis showed a significant difference ($p < 0.05$) between means of foliar K contents of *Picholine* cultivar at dates D1-D3 and D2-D3. The difference was no significant between the sampling dates D1 and D2. Moreover, the comparison of measured leaves K contents during the monitoring period to standards proposed by several authors (e.g. Recalde, 1975: 0.3 % DM; Gargouri and Mhiri, 2002: 0.5 % DM) shows that none of the samples is K deficient.

Overall, the olive nutritional status in the studied plots was not negatively affected after five years of olive husk compost application. This was also reported by Altieri and Esposito (2008) who compared olive behavior in soils amended with olive-mill wastes and soils amended with a standard mineral fertilizer and found similar responses in terms of leaves N, P and K levels as well as olive growth and yield.

4. Conclusion

An assessment of soil nutrient and organic matter content as well as olive tree nutritional status was carried out in an olive orchard in Northern Tunisia after five years of organic management. Overall, neither the soil nor the olive tree showed nutrient deficiencies in N, P and K suggesting the effectiveness of the used organic compost to maintain sufficient soil fertility and olive tree growth. Besides, the use of composted olive husk biomass could be a promising solution to address environmental problems related to disposal of olive oil industry by products. Nevertheless, additional work over a longer period and a wider range of soils and olive cultivars is needed.

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