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Research article

# Assessment of radial variation of soil properties in an olive tree – barley/common vetch agroforestry system under low-input conditions in a Tunisian semi-arid climate after three cropping seasons

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## Abstract
Tree-based intercropping system is a great example of agroecology that a growing body of research has suggested as a solution to several environmental problems, among others, losing soil fertility. We aimed to assess the effect of intercrops and the distance from the tree canopy on active carbon, soil organic carbon, total nitrogen, C/N ratio and available phosphorus in samples collected at 0-30 cm layer in an olive tree – barley/common vetch agroforestry system. In this experiment, the measured soil parameters varied significantly and linearly with distance from tree canopy except for C/N ratio. The highest means were recorded near by the tree olive canopy (0m). In the middle (4m) of the interrows, the studied soil parameters recorded the lowest contents. With vetch and barley-vetch intercrops soil carbon and soil measured nutrients recorded the highest means compared to barley and fallow.
We conclude that the tree component in agro-ecosystems, sowing nearby tree rows did not alter soil nutrient availability mainly with legume and mixture of legume and grass species.
In a short scale time intercrops showed no significant changes in soil quality mainly with barley. Thus the choice of intercrops and the continuity of TBI system practice remain impotent to show significant change in a long-term scale.

***Key words:*** Barley, Intercropping, Olive trees, Vetch, Soil organic matter.


## 1. Introduction
Tree-based intercropping (TBI) is an agroforestry system integrating crops with *tree* production (Batish et al., 2007). It is a tradition practice widespread in Mediterranean regions (Daoui et al., 2014). It became more and more appreciated as an alternative to intensive production systems. It has several socioeconomic and environmental benefits (Garrity, 2006; Swallow et al., 2009; Dugué et al., 2014). From a socioeconomic angle, it provides high productivity and additional income with lower costs and environmental externalities, increasing job opportunities and improving the livelihoods of rural farmers. From an environmental angle, it contributes to the control of water balance and greenhouse gas emissions, as well as biodiversity and soil degradation. Intercrops used in TBI contribute to improving soil quality which enables to reduce fertilizer use, the main cause of soil degradation. The use of non-legume as well as legume intercrops increases Soil Organic Matter(Lal et al., 1995, Poeplau et al., 2015), enhance Total Nitrogen (TN) content (Sainju et al., 2003, Ordóñez-Fernández

et al., 2018, Chehab et al., 2019), and available Phosphorus (Muchane et al., 2020).Soil Organic Carbon (SOC) is the main indicator of Soil Organic Matter in response to farming practices(Lal et al., 1995, Purakayastha et al., 2008). Change in total SOC content depends on agricultural management practices and is not always detectable in the short term (Xavier et al., 2013). Denef et al., (2007), Gregorich and Ellert (1993), Haynes (2005) suggested labile SOC fractions (Permanganate oxidizable C; POXC) have been suggested as an early indicator of the effects of soil management and cropping systems on SOM quality.

Despite the benefits of TBI, other studies showed a competition between trees and intercrops for light, water and soil minerals, especially in the areas surrounding trees canopy (Williams et al., 1992). These negative interactions could be avoided when the associated crops and planting distance from tree canopy are well chosen (Razouk et al., 2016).

In Tunisia, the most widespread TBI is olive tree with annual crops. This could be explained by the large area of olive groves in Tunisia; 34% of Tunisian arable land with approximately 70 million trees covering 1 752 000 ha of land (ONH, 2017). TBI with olive tree and barley is very ancient, because of the tolerance of this species to drought. Several studies had showed the positive effect of TBI with olive tree on soil organic matter (Bouhafa et al., 2015 in Morocco, Martinez-Garcia et al., 2018 in Spain, Paris et al., 2019 in Italy).Unfortunately, few scientific studies dedicated to this agroforestry systemin Tunisia were carried out(Chehab et al., 2019).

The present study aims to evaluating the influence of the intercrops, as well as the closeness to olive tree canopy drip line on SOC, POXC, TN and P.

## 2. Material and methods

### *2.1. Field experiment*

We carried out this work on a 4 hectares plot at the experimental station of the National Institute of Agronomic Research of Tunisia (INRAT) in the agricultural region of Mornag (36 ° 37 '58' 'N, 10 ° 16' 47 " E, altitude = 52 m), located 25 km south-east of the capital Tunis, Tunisia.

It is an old rainfed olive orchard. The plantation density was 12 by 12 square meters (69 trees per hectare).

During the 2018-2019 growing season the total amount of rainfall was 530.4 mm with a maximum amount of 137.6 mm recorded during October and lack of rain from June to August. The monthly mean temperatures ranged from a minimum of 7.7°C measured in January to a maximum of 35.4°C in August (Figure 1).

Plot characterization In September 2016, before starting the experiment, we characterized the initial soil status. We randomly collected, throughout the plot, 24 soil samples. We determined Particle-size distribution according to the pipette Robinson method (Robinson, 1922). The Electrical conductivity EC Soil pH and EC were determined respectively in (1:2.5) and (1:5) slurry, and bulk density.

During three cropping seasons (from 2016 – 2017 to 2018 –2019), between olive trees, four Intercrops: (1) Barley (*Hordeum vulgare*), (2)Vetch (*Vicia sativa*), (3)Barley-Vetch mixture (60% of barley with 40% of vetch), and(4) uncultivated strip (Fallow)were cultivated. Each Crop was replicated three times. Each replication represents an area of 24 m x 24 m with an olive tree in the center.

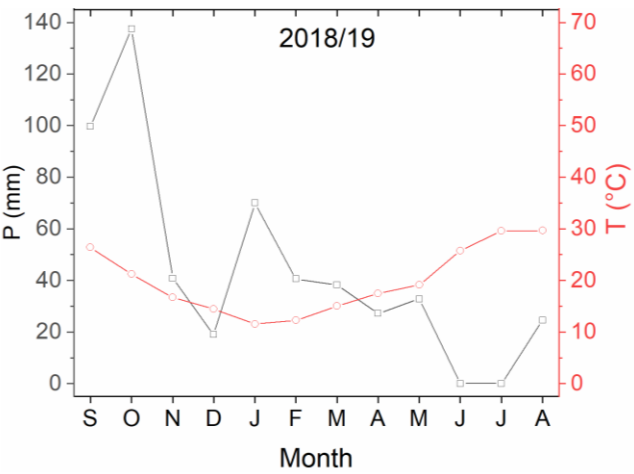


**Fig. 1.** Ombrothermic diagram of the study season 2018-2019, with monthly mean air temperature (°C) and rainfall (mm)

### *2.2. Soil Sampling*

Soil samples were taken, after harvesting annual crops in Mai 2018, from the 0-30 cm upper layer with respect to 3 distances of the olive tree rows (0, 2 and 4meters). Thus, with 3 repetitions following the same pattern for each of the 3 intercropping, as well as for the fallow part, an amount of 36soil samples were collected (4 x 3distances of intercropping x 3 replications).Samples were sieved, dried and stored for laboratory analysis. Soil organic carbon was calculated according to the modified Walkley-Black method (Walkley et Black 1934). Total nitrogen concentrations of soil samples were determined using Khjeldal method (Weil et al.

2003).Available phosphorus (P) was extracted using the Olsen method (Olsen et al., 1954)

*2.3. Statistical analysis*

The design is a Complete Blocks Design (CBD), with repeated measures, and two factors: *Crop* and *Distance*. Each of the four levels of the *Crop* factor was randomly assigned to each plot (subject) of the three Blocks. The response variables were measured repeatedly over space (*Distance* to tree canopy drip line) in the subject.

*Crop* is called the *between-subjects* factor because levels of crop change only between subjects (plots). *Distance* is called a *within-subjects* factor because different measurements on the same subject are taken at equal spaces from canopy drip line: 0 m, 2 m and 4 m. Let $Y_{ijk}$ represent the measurement at *Ditance* $_k$ on the $j^{th}$ subject (=plot) assigned to $Crop_i$. A conventional model for repeated data where the two factors are considered as qualitative is:

$$Y_{ijk} = Crop_i + Ditance_k + (Crop \times Distance)_{ik} + \varepsilon_{ijk} = \mu_{ik} + \varepsilon_{ijk} \qquad (1)$$

Where: $\mu_{ik}$ is the mean for $Crop_i$ at *Distance k* containing effects for *Crop, Distance*, and *Crop* × *Distance* interaction; and $\varepsilon_{ijk}$ is the random error associated with the measurement at *Distance k* on the $j^{th}$ subject that is assigned to $Crop_i$, assumed *iii* $N(0,\sum)$. $\sum$ is the covariance matrix between subjects as well as within subjects; it has to be specified (Unstructured, UR; Compound Symmetry, CS; or First-order autoregressive AR (1)) based on AICc criteria.

First, a two-factor repeated measures ANOVA using the conventional model was carried out. The equality of simple effects of *Crop* factor for a given level of the *Distance* factor was also tested (slice test), and a Tukey-Kramer post hoc test was used to compare means the Main effects and Interaction.

Second, a regression analysis over distance from canopy drip line *(d)*, considered as quantitative factor, by *Crop* was carried out with a repeated measures Analysis of Covariance (ANCOVA). The regression model is:

$$\mu_{ik} = \alpha_i + \beta_i d_k \qquad (2)$$

Where: $\alpha_i$ is the intercept for the $i^{th}$ *Crop*; $\beta_i$ the slope for the $i^{th}$ *Crop*.

Slopes of Model (2) could be reparametrized into $\beta_i = \beta_4 + (\beta_4 - \beta_i)$, where $\beta_4$ is the slope of a reference *Crop* (=Fallow), and the model becomes:

$$\mu_{ik} = \alpha_i + \beta_4 d_k + (\beta_4 - \beta_i) d_k \qquad (3)$$

A common slope ($\beta$) model is:

$$\mu_{ik} = \alpha_i + \beta d_k \quad (4)$$

To establish the definitive model, several steps detailed in Littell et al. (2006) were followed: (1) Test the Slopes-Equal-to-Zero Hypothesis; (2) Determine If a Common Slope Model Is Adequate to Describe the Data; (3) Fit Equal (or Unequal) Slope Model, and (4) Test for Lack of Fit of the Simple Linear Regression Model. Type 3F-Test of $d$ × *Crop* interaction of the model (2), with no intercept neither covariate $d$ , helps to examine the Slopes-Equal-to-Zero Hypothesis. Type 3F-Test of the $d$ × *Crop* interaction of Model (3) examines the hypothesis of equal slopes. The Test for Lack of Fit of the Simple Linear Regression Model is accomplished by using the *Distance* effect as both a qualitative and a quantitative variable in the same model.

Fitted models were compared based on corrected Akaike Information Criterion, AICc, as well as Root Mean Square Error, RMSE, and R square ($R^2$). The analyses were implemented using Proc Mixed procedure of SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

## 3. Results

The initial status of the studied soil is summarized in Table 1. According to the USDA classification, the soil of the experimental site has a sandy clay loam texture in the different soil depth (0 – 20 and 20 – 40 cm). The soil of both soil layers is alkaline, non-saline with high level of carbonate and relatively low amounts of organic matter (< 2 %) in all plots. The measured available P contents are very low about 1 ppm. The soil bulk densities were very similar in both of plots at both of soil depth and were about 0.6 g/cm$^3$.

**Table 1** Physico-chemical measured soil property before installing experimental design: mean±SE

| | 0-20 cm | 20-40 cm |
|---|---|---|
| **AC (pmm)** | 284.78± 59.32 | 182.335± 45.769 |
| **COT (%)** | 0.61± 0.087 | 0.482± 0.139 |
| **NT (ppm)** | 507.5± 75.74 | 375.833± 76.815 |
| **C/N** | 12.21± 2.06 | 13.42± 5.24 |
| **SOM (%)** | 1.01± 0.15 | 0.832± 0.239 |
| **P (ppm)** | 1.05± 0.58 | 1.004± 0.57 |
| **CaCO3 (%)** | 25.01± 8.27 | 27.21± 2.07 |
| **pH (H2O)** | 8.28± 0.26 | 8.31±0.19 |
| **CE (µS/cm)** | 204.19± 86.07 | 161.23± 28.97 |
| **BD (g/cm$^3$)** | 0.58± 0.07 | 0.59± 0.08 |
| **Clay (%)** | 26.30± 4.58 | 27.36± 4.72 |
| **Sand (%)** | 59.94± 8.97 | 57.21± 6.35 |
| **Slit (%)** | 12.17±4.09 | 12.39± 3.26 |
| **Textural class** | sandy clay loam | |

*3.1. Soil organic carbon (SOC)*

SOC means ranged from 2303 to 15875 mg/kg soil with a mean (±standard deviation) of 8938.11±3548.71 mg/kg soil. According to ANOVA analysis, SOC was significantly influenced by *Distance*, with a significant interaction *Crop* x *Distance* (Table 2). Overall, SOC average is significantly higher at 0 m *Distance* from canopy drip line and tend to linearly decrease as the distance increases (Figure 2). *Crop* effect test for a given level of *Distance*, showed that *Crop* seemed to have a significant effect on SOC only for the 0 m *Distance* level (pr > F =0.0161). At that level, *V* level of *Crop* had the highest SOC average value, whereas *B* level has the lowest one, but did not differ significantly from the one of the other levels.

Concerning ANCOVA analysis, the *p*-value <0.0001 of $d$ × *Crop* interaction of the model (2) indicates that the slopes are most likely not all equal to zero (Table 3). Whereas the *p*-value of 0.2390 of $d$ × *Crop* interaction of the model (3) indicates that the hypothesis of unequal slopes should be rejected. A common slope model should be adequate to describe the relationship between average SOC and *d* across the four crops (Table 4). The examination of the separate intercepts of this common slope model, clearly showed that V Crop had the highest SOC LS-mean value at 0 m distance *d*, significantly different from the one of B Crop, whereas the other Crop levels had intermediate mean values. Overall, SOC mean value decreases with the same common rate with increasing distance from canopy drip line. The common slope model fits SOC better that the simple one with both common intercept and slope (Table 5). Moreover, the Test for Lack of Fit of the common slope Linear Regression Model (p= 0.7756) indicates that there is insufficient information to conclude that this model does not fit the data for each of the Crops.

*3.2. Active carbon (POXC)*

POXC varied from 170.64 to 687.14 mg/kg soil with an average of 413.85±127.44 mg/kg. This parameter varied significantly only according to *Distance*. The highest POXC average value was observed at 0 m Distance, whereas the highest one was at 4 m Distance.

As for SOC, the *p*-value of model (2) *d* × *Crop* interaction for POXC showed that the slopes are most likely not all equal to zero, and the one of the model (3) *d* × *Crop* interaction showed that the hypothesis of unequal slopes has to be reject. A common slope model was then fitted to describe the relationship between average POXC and *d* across crops. Even though the common slope on *d* was highly significant (p<0.0001), the *Crop* effect, representing both an overall intercept and deviations between the Crop intercepts and the overall intercept, was not significant (p=0.5157). Therefore, a simple model with both common intercept and slope had a lower AICc and seems to better describe the relationship between POXC average and *d*. For all Crops, POXC mean value tends to linearly decreases with the same rate with increasing distance from canopy drip line.

As for SOC, there is no evidence for lack of fit *in the fitted linear model* for POXC (p=0.9421).

*3.3. Total Nitrogen (TN)*

TN values varied from 190 to1020.00 mg/kg soil with a mean of 664.90 ± 223.74 mg/kg soil. This parameter was significantly influenced by both *Crop* and *Distance*, with a significant interaction *Crop* × *Distance* only at 0.10 significance level. *Crop* seems to have a significant effect on TN for all *Distance* levels. TN had the highest average value at 0 m *Distance* and tend to decrease with increasing *Distance* levels, to reach the lowest one at 4 m *Distance*. Regardless of the *Distance*, both BV and V *Crops* had the highest TN mean values, whereas B and F had the lowest ones.

The *p*-values of $d$ × *Crop* interaction for both model (2) and model (3)were significant, indicating that the slopes are most likely not all equal to zero and the hypothesis of unequal slopes must be accepted. Unequal Slopes Model should be suitable for the fit TN in function of *d* across *Crops*. For the three distances, 0 m, 2 m and 4 m, TN mean value was the highest for BV crop, followed by V, but the difference was not significant, and the lowest one was either for B or F crops. By examining the separate slopes of the *TN = fct(d)* model across *Crops*, it appears that TN linearly decreases with increasing distance from canopy drip line and that the decrease rate was more important for both V and B Crops, compared to both F and BV ones. It must be mentioned that there is not enough evidence to conclude that there is a lack of fit *in the unequal-slopes linear regression model* (p= 0.7756).

### 3.4. C/N ratio

The CN ratio had an overall average of 14.18±6.19 and varied between 3.30 and 34.79. It was not significantly influenced neither by *Crop* nor *Distance*, with a significant interaction *Crop* x *Distance* at 0.05 significance level. The test of effect Slices showed that *Crop* had a slight effect on CN ratio, only at 0 m Distance (*p=0.0760*). At that distance F Crop had the highest CN ratio average value (20.6±1.89), whereas BV Crop the lowest one (11.59±1.98), but the difference was significant only at 0.10 significance level.

The *p*-value of the $d$ × *Crop* interaction in model (2) for CN ratio showed that the slopes are most likely all equal to zero.

### 3.5. Available Phosphorus, P

P ranged from 2.24 to6.02 mg/kg soil with an overall mean of 4.08 ± 1.05 mg/kg soil. It was significantly influenced only by *Crop* and *Distance*. P average is the highest at 0 m *Distance* from canopy drip line, and decreased with increasing *Distance*, to reach the lowest value at 4 m *Distance*. Concerning *Crop* effect, V crop had the highest P average value (4.72±0.23 mg/kg), that did not differ significantly from the one of BV crop (4.45±0.23 mg/kg), whereas F had the lowest P average value (3.30±0.23 mg/kg), not significantly different from the one of B crop (3.83±0.23 mg/kg).

The *p*-values of $d$ × *Crop* interaction of model (2) was significant, whereas the one of model (3)was not significant, indicating that the slopes are most likely not all equal to zero and the hypothesis of unequal slopes must be rejected. A common slope model was then used to relate average P to *d* over crops. There is not enough evidence to conclude that there is a lack of fit *in the unequal-slopes linear regression model* (p=0.1151).

According to the fitted model, P value decreases with the same rate with increasing distance from canopy drip line. The separate intercepts of the common slope model showed that V *Crop* had the highest LS-mean P value at 0 m distance *d*, whereas F had the lowest one.

## 4. Discussion

The sampling method was designed to examine the intercrops and the spatial variation in the inter-rowsof3-year-aged olive TBI of some parameters characterizing soil quality: SOC, POXC, TN, C:N ratio and P. In the tree rows, the soil remained undisturbed over the study period. Soil samples were collected in the interrow between two tree canopies of each plot (Levillain et al., 2011; Bouhafa et al., 2015, Cardinael et al., 2015).

The sampling distance from the olive tree canopy significantly influenced all the measured parameters. Except for CN Ratio parameter, the highest amounts of SOC, POXC, TN and P were recorded close to the tree canopy. In addition, as the distance from tree canopy increase, the soil measured parameters seems to decrease significantly and linearly. Cardinael et al., 2017 found that the closeness to tree row had a positive effect on SOC storage in the topsoil layer (0 – 10 cm) as well as on the increase in soil nutrient stocks, mainly P, N and K. Nearby the tree canopy, olive trees contribute to organic matter inputs via litter and root exudates (Cardinael et al. 2017). Based on soil nutrient availability, the intercrop sawing distance could be as close as possible to tree canopy. However, light competition should be considered, by evaluating intercrop yields.

The SOC was significantly influenced by intercop. The highest SOC mean was recorded with V crop at 0m which was significantly higher than B crop. Thus, barley could not be a suitable intercrop with olive trees under low input. Ibrahimi et al., (2015) found that SOC vary insignificantly after a five-year application of composted olive husk in an olive orchard of Northern Tunisia. Similar results were reported by Chehab et al., (2019) after two years of legume intercrops with olive orchard. However other studies showed that long-term scale TBI System adoption had enhanced significantly SOC amounts. Bouhafa et al., (2015) reported that in a traditional rainfed olive orchard, regularly associated with legume (faba been) and grass species (wheat), the distance from olive tree rows of SOC was not significant, while the presence of intercrops increased the SOC amounts mainly in the middle of the interrow.

**Table 2.** Two-factor repeated measures ANOVA to determine the effect of the qualitative fixed variables(Crop: between-subjects factor and Distance: within-subjects factor) on dependent variables (Soil organic carbon, SOC; Active carbon, POXC; Total nitrogen, TN; C:N ratio;Available phosphorus, P; and hydrogen potential pH): pr > F (type 3).

| Effect | SOC | POXC | TN | C/N ratio | P | pH |
|---|---|---|---|---|---|---|
| ***Crop*** | 0.2203 | 0.5379 | 0.0359 | 0.3465 | 0.0194 | 0.6248 |
| ***Distance*** | <.0001 | 0.0004 | <.0001 | 0.1653 | 0.0022 | 0.8278 |
| ***Crop×Distance*** | 0.0284 | 0.5578 | 0.0688 | 0.0576 | 0.2726 | 0.2728 |

**Table 3.** Two-factor repeated measures ANCOVA to (i) test the slopes-equal-to-zero hypothesis using model (2), and to (ii)determine if a common slope model is adequate to describe the dependent variables (Soil organic carbon, SOC; Active carbon, POXC; Total Nitrogen, TN; C:N ratio; Available Phosphorus, P; and hydrogen potential pH)using model (3): pr > F (type 3).

| Effect | SOC | POXC | TN | C:N ratio | P |
|---|---|---|---|---|---|
| **Model (2):** | | | | | |
| ***Distance*** | <0.0001 | <0.0001 | <.0001 | <.0001 | <.0001 |
| ***Crop×Distance*** | <0.0001 | 0.0001 | <.0001 | 0.0939 | <.0001 |
| **Model (3):** | | | | | |
| ***Crop*** | <0.0001 | <0.0001 | 0.0312 | – | 0.2116 |
| ***Distance*** | <0.0001 | <0.0001 | <.0001 | – | <.0001 |
| ***Crop×Distance*** | 0.2390 | 0.2799 | 0.0070 | – | 0.1011 |

**Table 4.** Parameters of the Linear mixed-effects models (LMM) selected to fit SOC, POXC, TN, CNratio and P, in function of covariate distance(d) andCrop (Vicia sativa L., V; Hordeum vulgare L., B; mixture of 40% Hordeum vulgare and 60 % Vicia sativa, BV; Fallow, F) factors with or without their interactions, as well as Type 3 Tests of Fixed Effects, and parameters of goodness-of-fit.

| | | SOC | POXC | TN | P |
|---|---|---|---|---|---|
| ***Parameter ±SE:*** | | | | | |
| **Crop** | **B** | 11495±618.89b | 475.02 ±48.39a | 745.28 ±68.66b | 4.61±0.27bc |
| | **BV** | 12761±618.89ab | 555.81 ±48.39a | 1012.61±68.66a | 5.24±0.27ab |
| | **V** | 13588±715.57a | 545.73 ±57.88a | 932.50±84.09ab | 5.50±0.31a |
| | **F** | 12892±618.89ab | 481.18 ±48.39a | 673.61±68.66b | 4.09±0.27c |
| **Distance** | | -1897.69±176.77 | -50.10±9.02 | - | -0.39±0.06 |
| **Crop*Distance** | **B** | - | - | -96.92±7.13 | - |
| | **BV** | - | - | -76.08±7.13 | - |
| | **V** | - | - | -104.00±8.73 | - |
| | **F** | - | - | -65.25±7.13 | - |
| ***pr > F (type 3):*** | | | | | |
| **Crop** | | 0.1025 | 0.5157 | 0.0312 | 0.0194 |
| **D** | | <.0001 | <.0001 | - | <.0001 |
| **Crop*Distance** | | - | - | <.0001 | - |
| | | - | - | | - |
| ***Goodness-of-fit:*** | **R2** | 0.81896 | 0.51356 | 0.80382 | 0.67458 |
| | **AdjR2** | 0.77718 | 0.40130 | 0.72705 | 0.59949 |
| | **RMSE** | 1687.07 | 97.5564 | 115.373 | 0.65392 |
| | **AICc** | 508.5 | 430.352 | 298.4 | 70.7 |

**Table 5**. Parameters of the Simple Linear model selected to fit SOC, POXC, TN, CNratio and P, in function of Distance.

| | | SOC | POXC | TN | P |
|---|---|---|---|---|---|
| | | **Parameter ±SE** | **Parameter ±SE** | **Parameter ±SE** | **Parameter ±SE** |
| **Intercept** | | 12594±<br>493.71 | 511.60±28.94 | 832.68±53.06 | 4.80±0.24 |
| **Distance** | | -1897.69±181.55 | -50.10±8.99 | -83.8864±4.78 | -0.3916±0.06458 |
| **Goodness-of-fit:** | | | | | |
| | **R2** | 0.77530 | 0.51356 | 0.39682 | 0.39505 |
| | **Adj R2** | 0.75205 | 0.46323 | 0.33442 | 0.33247 |
| | **RMSE** | 1779.65 | 92.3727 | 180.162 | 0.84421 |
| | **AICC** | 561.7 | 377.6 | 374.2 | 81.9 |

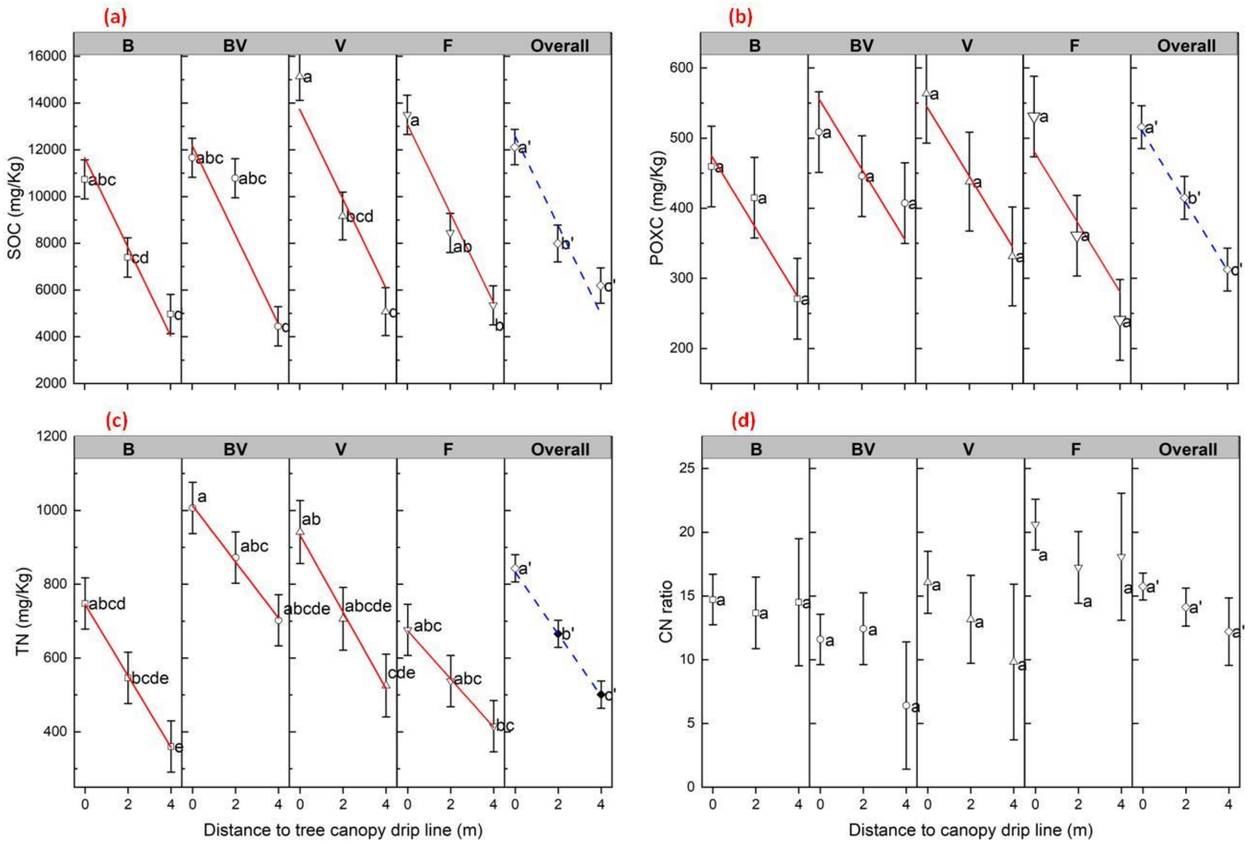


**Fig. 1.** (a) Soil organic carbon (SOC), (b) Active carbon (POXC), (c) Total Nitrogen (TN) and (d) CN ratio mean changes by the distance of the olive tree row according to intercrop (Vicia sativa L., V; Hordeum vulgare L., B; mixture of 40% Hordeum vulgare and 60 % Vicia sativa, BV; Fallow, F). Significant at 5% level

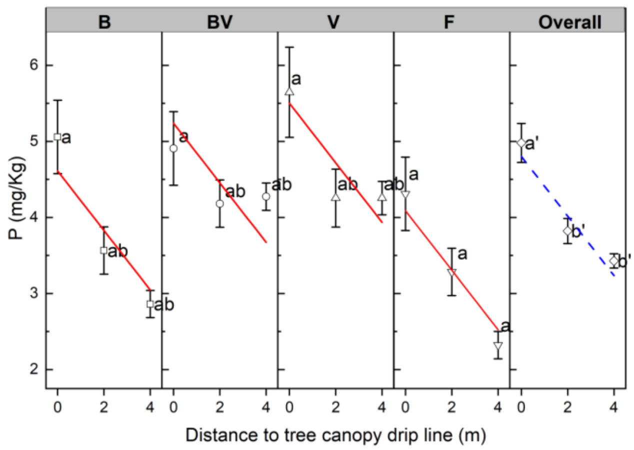


**Fig. 2.** Available Phosphorus (P) mean changes by the distance of the olive tree row according to intercrop (Vicia sativa L., V; Hordeum vulgare L., B; mixture of 40% Hordeum vulgare and 60 % Vicia sativa, BV; Fallow, F). Significant at 5% level

Cardineal et al., (2015) showed that in an 18-year-old agroforestry plot demonstrated that SOC accumulation rates between the agroforestry and the agricultural plots were 248±31 kg C ha−1 yr−1 for an equivalent soil mass. Occasionally, the low content of organic matter in tilled soils (Nieto et al., 2013) means that tillage (Fallow) is a factor that causes soil degradation and the decrease in different compounds including organic matter excessive oxidation and hence soil quality decrease.
Intercrops did not influence significantly POXC amount. In the present case, POXC could not be considered as a quit indicator of soil quality with low input in response the studied TBI system. It must be mentioned that this result represented the first response of TBI system for a short scale study of 3 years. This may be explained by the slow rate change of soil organic matter particularly in the Mediterranean regions (Blair et al., 2006; Gucci et al., 2012).

The lowest TN mean, and the highest CN mean ratio were recorded with Barley crop at 4m Distance from crown drip line, followed by those of Fallow at the same distance. These results agreed with those reported by Sainju et al. (2007), who find that non legume cover crops, such as grass species, deceases soil TN and Increases CN Ratio. It has to be mentioned that the use of legume or mixture of legume and grass, had increased N supply to succeeding crops due to higher residue N concentration, and have lower C/N ratio than nonlegume cover crops (Rodriguez et al. (2013); Ordóñez-Fernández et al., (2018).

Overall, P means were considerably lower than the critical threshold of 8 ppm (Olsen method), reported by Gargouri and Mhiri, (2003) for soils of olive orchards under Tunisian conditions. This could be explained by the availability of P in the soil which is highly dependent on its calcium and clay content and its pH value (Soltner, 1990; Wandruszka, 2006). The studied soil is alkaline (pH=8) and rich in calcium (over 28%) and clay (over 27%). These characteristics explain the low value of available phosphorus in our soil.

## 5. Conclusion

This work aimed at evaluating the influence of the intercrops, as well as the closeness to olive tree canopy on SOC, POXC, TN and P.
In this experiment, the measured soil parameters varied significantly and linearly with distance from tree canopy except for CN ratio. The highest means were recorded near by the tree olive canopy (0m) which highlighted the importance of the tree component in agro-ecosystems on the one hand and the possibility of sowing nearby tree rows without altering soil nutrient availability mainly with legume and mixture of legume and grass species in the other hand.
In the middle (4m) of the interrows SOC, POXC, TN and P recorded the lowest contents.
We conclude that, in a short scale time intercrops showed no significant changes in soil quality mainly with barley.
With V and BV intercrops SOC, POXC, TN and P recorded the highest means compared to barley and fallow. Thus the choice of intercrops and the continuity of TBI system practice remain impotent to show significant change in a long-term scale.

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