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Effect of Different Organic Crop Rotations on Soil Chemical and Biochemical Properties

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Abstract: A long-term study on the effects of different crop rotations on microbial biomass, Dehydrogenase Activity (DHA) and chemical soil properties is reported. The experiment was established in 2000 at the Technical Center of Organic Agriculture Station located in Sousse, Tunisia. The 10 cropping systems (8 organic plots and 2 conventional plots as control) were compared. Differences in microbial biomass Carbon (C) and Nitrogen (N), dehydrogenase activity, available phosphorus, soil bases, Electrical Conductivity (EC) and pH appeared to be related in parts to inputs but perhaps also to differing efficiency of crop rotations at soil fertility maintenance. Overall, the finding indicates that soils in the organic systems had higher microbial biomass, DHA, soil bases, EC and available phosphorus than soils in conventional systems. Organic green house plot, characterized by the most diversified crops (19 crops in 10 years), had the highest levels of microbial biomass C and N, dehydrogenase activity, available phosphorus, exchangeable K and Na and EC. pH was the highest in an organic open field plot which included a combination of crops (perennial, vegetable and field crops) with different deep rooting.

Key words: Crop rotations, microbial biomass, dehydrogenase activity, chemical soil properties, phosphorus

INTRODUCTION

Organic farming is a form of agriculture that avoids or largely excludes the use of synthetic fertilizers and pesticides, plant growth regulators and livestock feed additives. An understanding of microbial processes is important for the management of farming systems, particularly those that rely on organic nutrient input (Melero *et al*., 2006). Microbial processes make a large contribution to the release and availability of nutrients required for crop growth. In organic management systems, Nitrogen (N) is supplied in organic form via cover crops and manures and large amounts of Carbon (C) are included in the mass of organic material required to achieve adequate amounts of N (Gunapala and Scow, 1998). Carbon additions of virtually any form to arable soils often increase the amount of microbial biomass (Bohme and Bohme, 2006) and its activity (Shannon *et al*., 2002; Marinari *et al*., 2006). Microbial biomass, rather than total organic C has been suggested as a useful and more sensitive measure of change in organic matter status (Melero *et al*., 2006). Studying microbial biomass C (Cmic) can result in a greater understanding of the biological and chemical changes that occur with different agricultural practices (Anderson and Domsch, 1990). Enzymes may respond to changes in soil management more quickly than other soil variables and therefore, enzymes might be useful as early indicators of biological change (Bandick and Dick, 1999). Organic manures, such as animal manure, green manure and crop residues, significantly increased the activity of a wide range of soil enzymes, as compared to unamended soil (Martens *et al*., 1992). A number of studies have shown that organic farming leads to higher soil quality and soil biological activity than conventional farming (Carpenter-Boggs *et al*., 2000; Fliessbach *et al*., 2000; Shannon *et al*., 2002).

The objective of the present study is to evaluate the impact of different organic cropping systems on soil microbial biomass, enzyme activity (dehydrogenase) and chemical properties compared to conventional cropping systems under Mediterranean conditions in Center East of Tunisia.

MATERIALS AND METHODS

The experiment was carried out at the experimental station of the Technical Center of Organic Agriculture located in Sousse region in the Center East of Tunisia, 35 m above the sea level latitude 35°51'32 North and longitude 10°35’38’’ East Greenwich. The region is

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Table 1: Crop rotations in CTAB station

Years	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8
2000\01	Fennel, potato	Potato	Potato	Fallow, potato	Potato	Potato	Pea	Fennel, cabbage
2001\02	Garlic	Onion	Faba bean	Potato	Potato	Potato	Potato	Artichoke
2002\03	Potato	Potato	Pea, cauliflower, fennel	Tomato	Tomato, potato	Potato	Tomato, potato	Artichoke
2003\04	Fallow	Vegetables	Potato	Clover	Clover	Barley	Clover	Artichoke
2004\05	Onion, garlic	Potato	Fallow	Aromatic and medicinal plants	Fennel	Cauliflower, cabbage	Artichoke	Wheat
2005\06	Potato	Faba bean	Green bean zucchini cucumber (greenhouse)	Aromatic and medicinal plants	Cauliflower, cabbage	Potato	Artichoke	Potato
2006\07	Faba bean	Fennel, leek	Melon, tomato (greenhouse)	Aromatic and medicinal plants	Potato	Pea	Artichoke	Cauliflower
2007\08	Fennel	Artichoke	Tomato, pepper and eggplant (greenhouse)	Aromatic and medicinal plants	Leek, garlic	Faba bean	Cauliflower, cabbage, potato	Faba bean, maize
2008\09	Bean	Artichoke	Green bean, zucchini (greenhouse)	Aromatic and medicinal plants	Faba bean	Fennel, maize	Faba bean	Pea, potato
2009\10	Potato	Artichoke	Tomato, green been, zucchini (greenhouse)	Aromatic and medicinal plants	Fennel	Potato	Onion	Cauliflower

Table 2: Crop rotation of 2 conventional plots

Years	Plot 9	Plot 10
2000\01	Maize (OF)	Artichoke(OF)
2001\02	Potato (OF)	Fallow (OF)
2002\03	Fallow (OF)	Potato (OF)
2003\04	Potato (OF)	Potato (OF)
2004\05	Pepper (OF)	Oat (OF)
2005\06	Maize (OF)	Fallow (OF)
2006\07	Chickpea (OF)	Melon (GH)
2007\08	Fallow (OF)	Pepper (GH)
2008\09	Potato (OF)	Tomato (GH)
2009\10	Potato (OF)	Tomato (GH)

OF = Open Field; GH = Greenhouse

characterized by a Mediterranean climate with humid mild Winter and hot dry Summer. The yearly precipitations vary from 350-400 mm and are mainly concentrated between October and April. The annual average temperature ranges from 16-19°C with a maximum recorded in July and a minimum one recorded in January.

The soil samples were collected from ten plots (Table 1 and 2). At each sampling plot, 4 representative sub-samples were taken at random from a depth of 5-20 cm. The 0-5 cm soil layer was discarded to reduce spatial variability and also possible point contamination. The 4 sub-samples were taken with a soil auger, mixed, pooled, giving 40 independent composite samples and transferred in sealed plastic bags to the laboratory. The composite samples were sieved (<2 mm), homogenized and stored at 4°C until the analysis.

Chemical analyses were done according to the Methods of Soil Analysis on air-dried and sieved (<2 mm) soil samples:

- PH was measured in 1:2.5 soil/water suspension using a glass electrode pH-meter
- Total soluble salts were estimated in the soil saturation extract and were measured by using the electrical conductivity meter (value expressed in ds/m). The soil salinity was evaluated according to the conversion: 1 m sec cm^{-3} = 0.7 g L^{-1}
- Exchangeable bases (Na^+, K^+ and Ca)$^{++}$were determined after acid digestion with HF/HNO_3 (Liu *et al*., 2002) by a Beckman single beam flame emission spectrophotometer
- Available phosphorus was determined, according to Olsen method modified and based on the extraction of Phosphor by Sodium Bicarbonate. The dosage was made by spectrophotometer with 660 nm (Pauwels *et al*., 1992)

Measurement of biomass C and N: Biomass C was measured by the fumigation incubation method (Jenkinson and Powlson, 1976) from the relationship Bc = Fc/kc where Fc = ((C in fumigated soil)-(C in unfumigated soil)) and kc = 0.45 (Jenkinson and Ladd, 1981).

Organic C rendered extractable to 0.5 M K_2SO_4 by fumigation was measured as described by Jenkinson and Powlson (1976). Briefly, moist soil was exposed to $CHCl_3$ for 24 h, the fumigant removed and the soil then extracted with 0.5 M K_2SO_4, a non-fumigated control was extracted under the same conditions at the time fumigation started. Organic C in the extracts was determined by dichromate digestion. Total N rendered extractable by fumigation was measured on the same 0.5 M K_2SO_4 soil extracts used for measurements of extractable C (Brookes *et al*., 1985).

The extracts were kept frozen (-18°C) until analysis. Extracts were analyzed for carbon and nitrogen on a TOC-TNb analyzer (Dimatec, Essen, Germany). Fumigated and unfumigated samples were analyzed close together in order to minimize effects due to time shifts. Standards were measured with the samples as quality controls.

Measurement of Dehydrogenase (DHA): DHA was measured following the procedure described by Alef and Nannipieri (1995). Briefly, DHA was determined using 2, 3, 5-Triphenyl-Tetrazoliumchlorid (TTC), as the artificial electron acceptor which is reduced to the red colored 1, 3, 5-Triphenyl-Tetrazoliumformazon (TTF) (Benefield *et al.*, 1977). Then, the formazan was extracted with acetone and measured spectro-photometrically at 546 nm (DHA activity is expressed as μg TPF g^{-1} soil h^{-1}).

Statistical analysis: Data on all parameters/response variables were subjected to analysis of variance (ANOVA) using SAS. Separation of means was done using multiple range duncan test at $p = 0.05$.

RESULTS AND DISCUSSION

Figure 1 and 2 show the results of soil pH and Electrical Conductivity (EC). According to these results, the rotation program significantly influenced soil pH and EC ($p<0.05$). Cultivation is likely to increase soil acidity due to increased oxidation of organic matter. The soils experienced are generally alkaline, the pH ranged from 8.08-8.84. The addition of cations via manure application has resulted in higher pH levels in the organic systems. Soil pH in the plot 8 is higher than the other treatments, this plot included perennial plants (artichoke for 3 years), vegetable crops (cabbage, cauliflower, potato and faba bean) and field crops (wheat, maize), this combination of crops with different deep rooting decreased oxidation of organic matter in surface (5-20 cm) and as result decreased soil acidity. pH is lower than the other treatments in plot 9 (conventional greenhouse), this result can be explained by addition of chemicals fertilizers which are responsible for soil acidity. The pH of the experimental treatments is higher than the optimal value, this may be due to the high pH of the Tunisian soils.

Electrical conductivity is a measure of total cations and anions in solutions and is usually determined largely by Ca and Mg ions. Electrical conductivity levels have been found to be tightly linked to NO_3 concentrations in the soil. Nitrification (oxidation of NH_4-NO_3) acidifies soil, bringing cations into solution. Thus, Ca and Mg concentration in solution and EC levels are highly dependent on N fertility practices. The highest soil EC in this study was obtained in plot 3 which included legumes more than other treatments.

There were significant differences between the levels of soil bases (Ca^{2+}, K^+, Na^+) measured under different cropping systems (Fig. 3). The general low levels of exchangeable bases is the consequence of crops nutrients uptake in soil and the absence of refund.

Plots 4 and 5 with highest levels of pH had lowest levels of available Phosphorus (P). The maximum P availability is when soil pH ranges between 6 and 7.

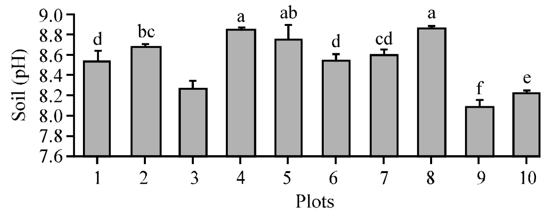

Fig. 1: Effect of cropping system on soil pH

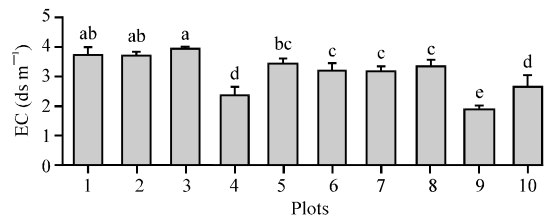

Fig. 2: Effect of cropping system on soil Eelectrical Cconductivity (EC)

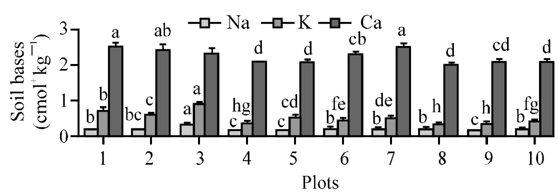

Fig. 3: Effect of cropping system on soil bases (Na^+, K^+, Ca^{++})

Generally, soils with pH of 7.5 and higher have a high calcium concentration that binds P as calcium phosphate creating an insoluble compounds that is not available to plants. Soil available P content in the plot grown after fennel and maize at the last year (plot 5) is lower than the other treatments. Similar results were found by Bahouaoui (2008).

Microbial biomass C varied from 594-150 μg g^{-1}; Microbial biomass N varied from 51-20 μg g^{-1}; dehydrogenase activity varied from 10.95-2.04 μg TTF g^{-1} sol h^{-1}. Significant differences ($p<0.05$) were observed between cropping systems. Results of the study showed highest microbial biomass carbon and nitrogen and dehydrogenase activity in the plot number 3. Similar results were obtained by Daniel when tomato crop grown after green bean had a highest microbial biomass carbon and nitrogen in comparison with other cropping systems, this may be due to the high fresh biomass incorporated in the green bean plot before the plantation of main crop. Generally, soil enzyme activities were correlated with microbial biomass, this indicates that enzyme activities were associated with active microorganisms in soil which are the major source of soil

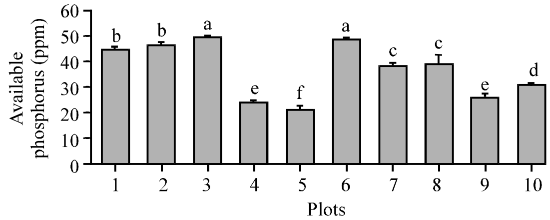

Fig. 4: Effect of cropping system on available phosphorus

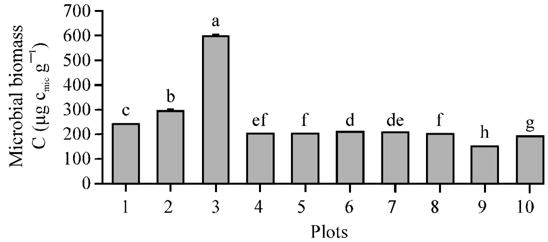

Fig. 5: Effect of cropping system on microbiol biomass C

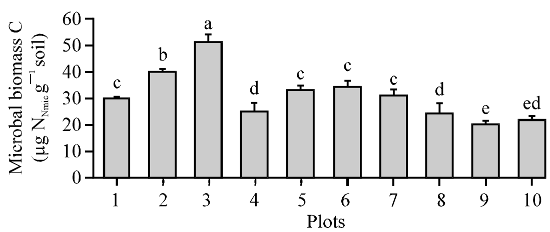

Fig. 6: Effect of cropping system on microbiol biomass N

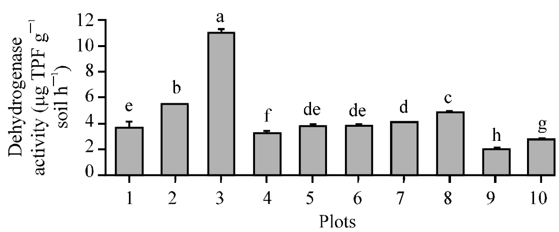

Fig. 7: Effect of cropping system on dehydrogenase activity

enzymes. In the field trial, the highest values of dehydrogenase activity and microbial biomass C and N contents were most often obtained in the organic soils and the lowest ones occurred in the conventional soils. Enhanced microbial activity in organic farming systems can be attributed mainly to the application of organic manures and higher amounts of diversified crop residues remaining on the fields than in soil under conventional systems (Martyniuk *et al.*, 2001; Mader *et al.*, 1995). The results were the previous of an extra energy source of microbial growth. Moreover, it has been documented that high doses of mineral fertilizers and pesticides, used in conventional farming systems to protect crops against pests and pathogens, might adversely affect the development and activity of the soil biota (Blevins *et al.*, 1983; Myskow *et al.*, 1996) (Fig. 4-7).

CONCLUSION

The use of organic farming practices over a 10 years period resulted in higher soil microbial biomass, dehydrogenase activity, available phosphorus and soil bases than the other treatments conducted in conventional farming. This study indicates that the use of animal manure, compost, cover crops, proper crop rotation include a legume and diversified crops and the elimination of synthetic fertilizer results in increased soil fertility.

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