American Journal of

Plant Nutrition and Fertilization Technology

ISSN 1793-9445

Academic
Journals Inc.

www.academicjournals.com

American Journal of Plant Nutrition and Fertilization Technology 2 (1): 10-18, 2012
ISSN 1793-9445 / DOI: 10.3923/ajpnft.2012.10.18

Microbial Diversity and Abundance in Soil: Related to Plant and Soil Type

[1]A. Meliani, [2]A. Bensoltane and [1]K. Mederbel

[1]Laboratory of Research of Biological Systems and Geomatic, Department of Biology, Faculty of Science, University Mascara, 29000, Mascara, Algeria

[2]Laboratory of Food and Industrial Microbiology, Department of Biology, Faculty of Science, University Oran (Es-Senia), 31000 Oran, Algeria

Corresponding Author: A. Meliani, Laboratory of Research of Biological Systems and Geomatic, Department of Biology, Faculty of Science, University Mascara, 29000, Mascara, Algeria

ABSTRACT

An increasing interest has emerged with respect to the importance of microbial diversity in soil habitats. The extent of the diversity of microorganisms in soil is seen to be critical to the maintenance of soil health and quality, as a wide range of microorganisms is involved in important soil functions. Since, the first estimate of prokaryotic abundance in soil was published, researchers have attempted to assess the abundance and distribution of species and relate this information on community structure to ecosystem function. Present study has investigated the linkage of specific organisms to ecosystem function and an increasing interest has emerged with respect to the importance of microbial diversity in soil habitats. The two main drivers of soil microbial community structure, i.e., plant type and soil type, are thought to exert their function in a complex manner. This review focuses on recent data relating how plant type, soil type, affects the microbial diversity and abundance of soil. Statistical analyses of the microbial counts indicated a significant correlation for bacteria ($p<0.01$) and no significant correlation, for fungi and actinomycetes, however, microbial enumeration indicated that bacteria were most numerous followed by actinomycetes and fungi, respectively.

Key words: Microbial, diversity, abundance, soil, distribution, plant, type, affect

INTRODUCTION

Knowledge of microbial diversity and function in soils is limited because of the taxonomic and methodological limitations associated with studying these organisms (Kirk *et al*., 2004). Soil microorganisms are vital for the continuing cycling of nutrient and for driving above ground ecosystems. It is important to study microbial diversity not only for basic scientific research, but also to understand the link between diversity and community structure and function. Soil bacteria and fungi play pivotal roles in various biogeochemical cycles (BGC) (Molin and Molin, 1997; Trevors, 1998; Wall and Virginia, 1999). Soil microorganisms also influence above-ground ecosystems by contributing to plant nutrition (George *et al*., 1995; Timonen *et al*., 1996), plant health (Srivastava *et al*., 1996), soil structure (Dodd *et al*., 2000) and soil fertility (O'Donnell *et al*., 2001). However, activity and species composition of microbes are generally influenced by many factors including physic-chemical properties of the soil, temperature and vegetation. The dynamics of soil microorganisms have important implications for the response of subsurface soil ecosystems to

perturbations. Despite all attempts to measure fluxes and gross microbial pools, the soil and its microbiota still remain a black box. Most soil microorganisms are still unknown (Crecchio *et al.*, 2004). The comparison between direct microscopic counts and plate counts indicates that as less than 0.1% of agricultural soil microorganisms are cultivable (Atlas and Bartha, 1998). Understanding the diversity and dynamic of indigenous microbial populations represents one challenge of modern soil ecology. In this context, we undertook a study to evaluate bacterial community structures and diversities located in different ecosystems and tilts correlation with the soil and plant type.

MATERIALS AND METHODS

Study site and species studied: The study was conducted in three field sites (Table 1) located on the same geographic area of Mascara (Northern-Algerian West, 2°,11' W, 35°,26' N) . These fields have not the same soil type and topographical features and have received different soil management practices and cropping systems. For each site a farming profile per species was realized.

Total microbial count: Soil microorganisms were extracted by shaking 10 g of soil in 100 mL of one-quarter strength Ringer solution (Oxoid). Data from triplicate readings were expressed as Colony Forming Units (CFU) g^{-1} dry soil. The total number of bacteria was determined on meat-peptone agar with beef extract and glucose (MPA), actinomycetes-on glycerine-glycine medium, microscopic filamentous fungi-on Martin's medium with Bengal rose and streptomycin sulfate.

Soil physical and chemical analysis: Soil samples were taken from different depths (5-10, 10-15 and 15-20 cm) and collected randomly from 27 different sites. The samples were analyzed for pH, soil chemistry and texture.

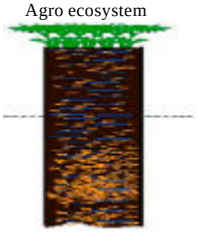
Statistical analysis: All samples (n = 27) were analysed in triplicate. Pearson's correlation coefficients using a traditional Euclidean distance (Legendre and Legendre, 1998) were conducted on the soil physical and chemical variables, as well as on the vegetation cover and microbial properties analysed to determine how these variables were interrelated. All data processing the Pearson's correlation coefficients were performed by STATISTICA 7.

RESULTS AND DISCUSSION

Microbiological results: Marked effects were found to have taken place on the bacterial populations under different ecosystems. This is clearly demonstrated by the total number of bacteria CFU recorded from the plates. Our results showed that microbial population was different in soils under different plant covers, soil types and depths (Fig. 1). The total number of isolated bacteria varied in different samples of studied soils, a maximum of 1,8. The 10^{11} CFU g^{-1} was signalled in the *Lens* sp., rhizosphere (0-5 cm) and a minimum of 2,7 10^{9} CFU g^{-1} in *Vicia* sp., rhizosphere (5-10 and 10-20 cm). Ecological characterization of studied soil is shown in Table 1.

Soil types had influence on soil microbial organisms' activities. The highest density of fungi was observed in *Triticum* sp., rhizosphere (0-5 cm) (1, 35. 10^{9} CFU g^{-1}) and the lowest one in *Vicia* sp., rhizosphere (1, 8.10^{9} CFU g^{-1}) (10-20 cm). The actinomycetes showed a maximum of 1, 98. 10^{10} CFU g^{-1} in the *Triticum* sp., rhizosphere (5-10 cm) and a minimum of 1,8. 10^{9} CFU g^{-1} in *Vicia* sp., rhizosphere (10-20 cm). In the forest ecosystem, bacteria were abundant in all the

Table 1: Ecological characterization of studied soil

Site	Altitude (m)	Average of annual precipitation (mm)	Average of annual temperature (°C)	Vegetation	Ecosystem type
Experimental farm	494 m for all stations	45.89	16.48	*Vicia* spp. (C1-C2-C3) *Triticum* spp. (C4-C5-C6) *Lens* spp. (C7-C8-C9)	Agro ecosystem 
El-Zakour forest	P.1. 708 m P.2. 693 m P.3. 666 m	19.04	16.04	*Pinus* spp. (C10-C11-C12) *Asphodelus* spp. (C13-C14-C15) *Tamarix* spp. (C16-C17-C18)	Forest ecosystem 
El-Kouayer station	P.1. 708 m P.2. 693 m P.3. 666 m	25.53	18.00	*Triticum* spp. (C19-C20-C21) *Cirsium* spp. (C22-C23-C24) *Hordium* spp. (C25-C26-C27)	Humid ecosystem 

rhizosphere of *Pinus* sp., *Asphodelus* sp. and *Tamarix* sp. with values of $2{,}7.10^9$ CFU g^{-1}. The highest density of fungi (1, 35. 10^9 CFU g^{-1}) was signalled in all of the horizons analysed of *Pinus* sp. The actinomycetes were present with a maximum of 3,5. 10^9 CFU g^{-1} in the rhizosphere of *Tamarix* sp., (0-5 cm) but totally absent in *Asphodelus* sp. Among the soils prospected, microbial enumeration indicated a higher abundance of bacteria in the humid ecosystem than in agricultural and forest ecosystem, with the predominance of the *Pseudomonas* and *Bacillus* species. They are the most diverse and ecologically significant group of bacteria on the rhizosphere (Dommergues and Mangenot, 1970).

Physicochemical results: Soil physicochemical properties are presented in Fig. 2. Soils were fine textured (Sand: 22.42; Silt: 65.57; Clay: 38.44) with neutral pH: 7.9, $CaCO_3$: 19.72, electrical conductivity (177.97) and water holding capacity (15.08) and organic matter (8.01).

Statistical results: A negative and significant ($p<0.005$) relationship between bacterial count, pH and clay was observed ($r = -0.59$, $r = -0.50$), respectively but a positive relationship for the other soils properties however, no significant ($p>0.005$) relationship between fungi, actinomycetes and all the soils properties (Fig. 3).

The results of soil physicochemical properties varied depending on the ecosystem type. The dominating textural class is that of clay and silty clay (44%). On the basis of our results it appeared that the presences of bacteria was important in the silty clay soils of the humid station.

Soil texture affects the microbial activities (Hassink, 1994; Sorensen and Jensen, 1995). Based on the results, it appears that microbial biomass is influenced by soil texture. These data are in

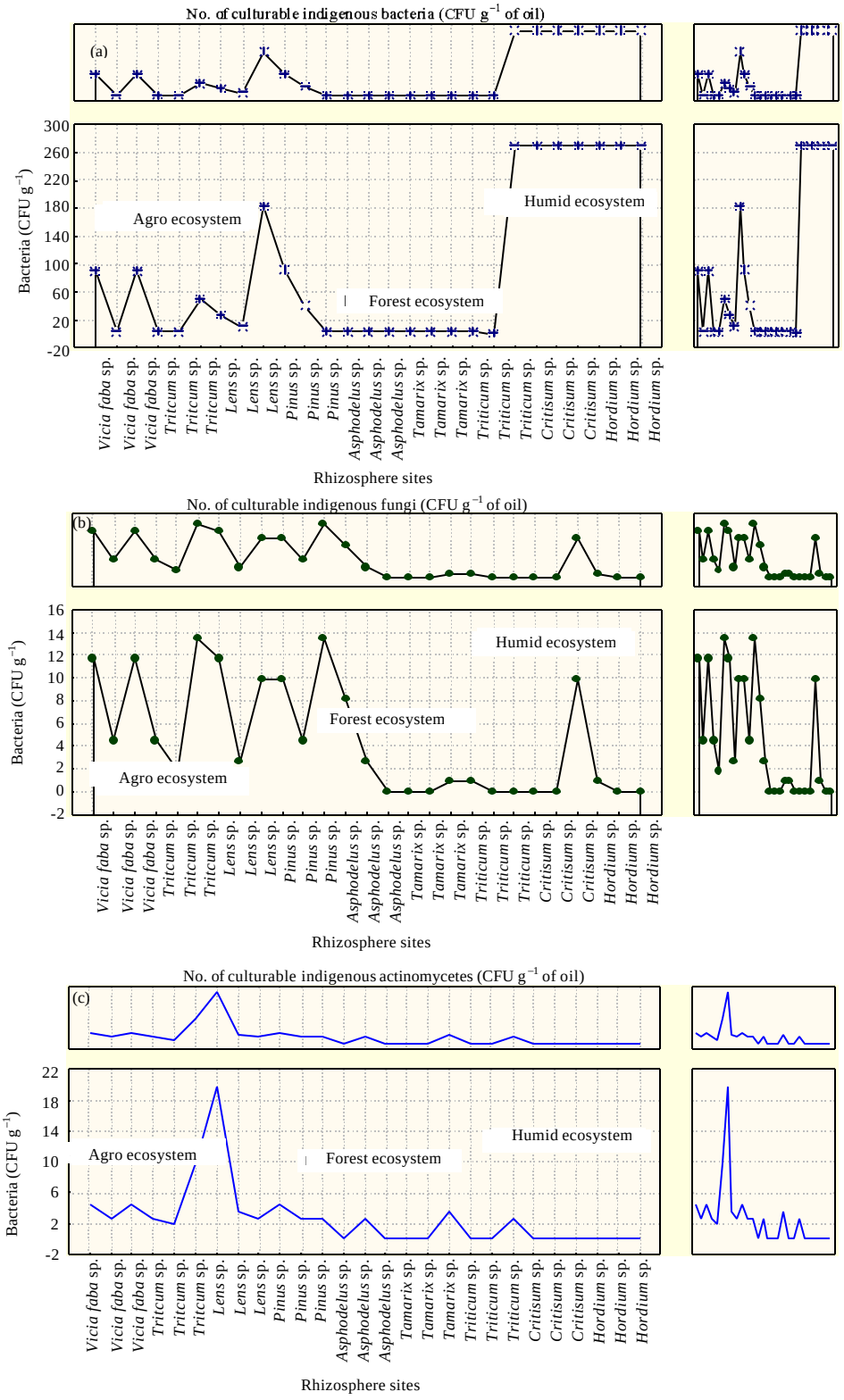


Fig. 1(a-c): Numbers of cultivable bacteria, fungi and actinomycetes as measured by plate spreading

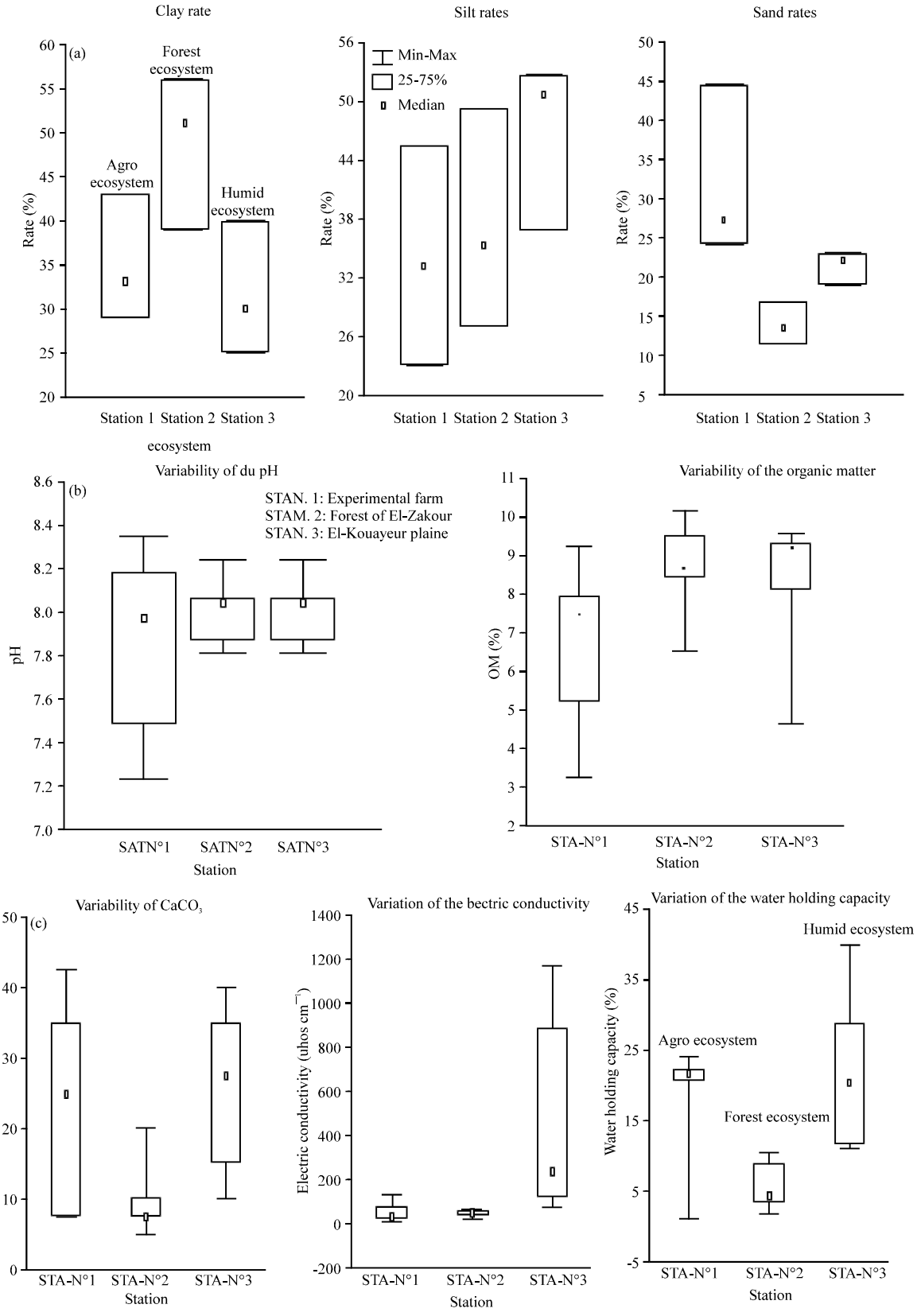


Fig. 2(a-c): Box plot of Soil (a) Physical and (b,c) Chemical properties

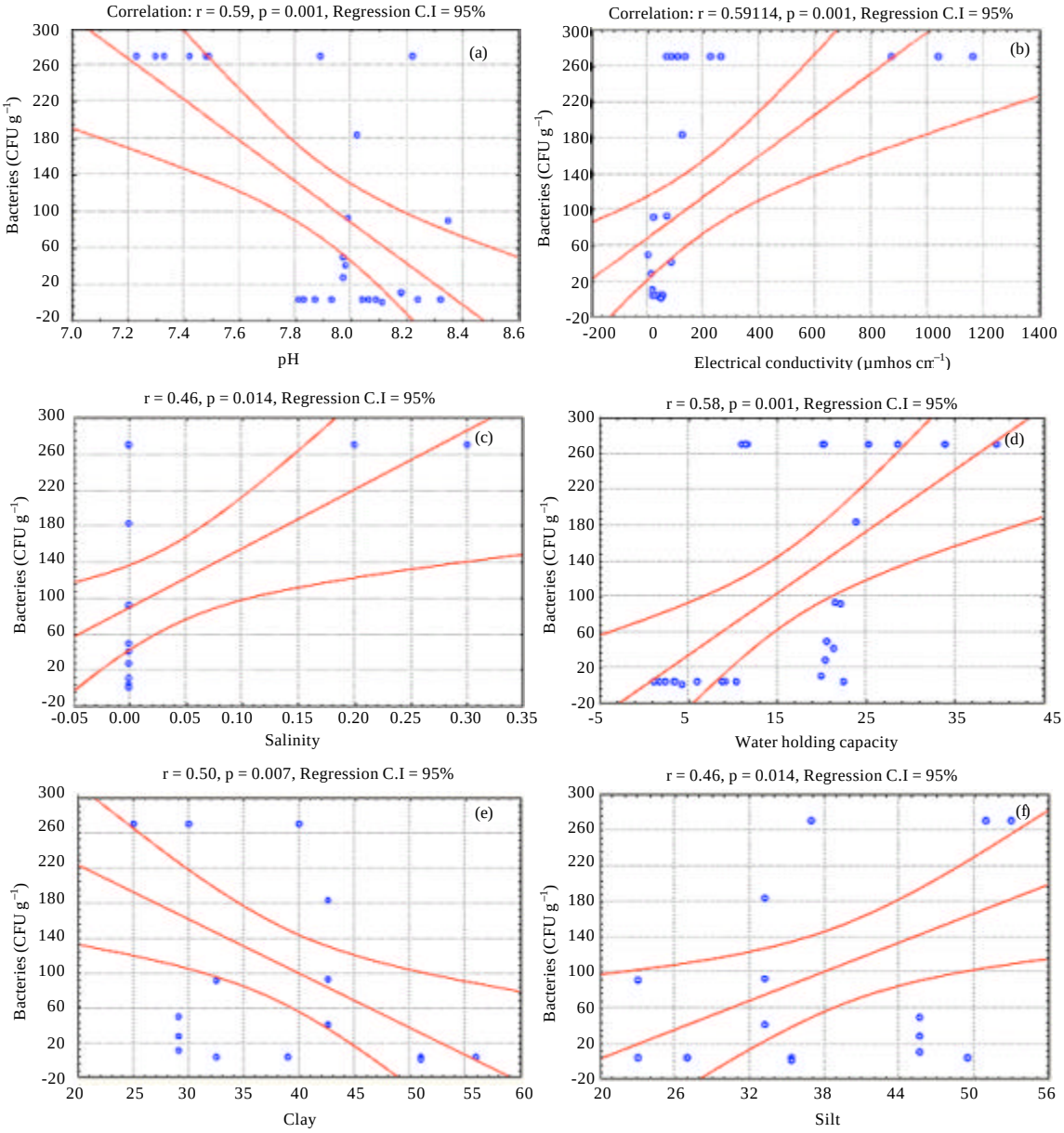


Fig. 3(a-f): Significant correlation between of bacteria abundance and soil properties

agreement with previous results. Fine-textured soils typically contain greater quantities of organic matter and microbial biomass than coarse-textured soils. Bonneau and Souchier (1994), demonstrated that this fine texture promoted the bacterial growth (i.e., clay humic complex). Clay-sized particles are thought to protect organic matter through adsorption and aggregation, shelter soil microorganisms from predation (Elhott *et al.*, 1980). According to Alvarez *et al.* (2002), the fine-textured soil (<50 microns) have a protective effect on total microbial biomass, due to the higher proportion of micropores compared to sandy soil which limited meso fauna development. Fine-textured soils typically contain greater quantities of organic matter and microbial biomass than

coarse-textured soils (Schimel, 1986). Clay-sized particles are thought to protect organic matter through adsorption and aggregation and increase substrate-use efficiency (Martin *et al.*, 1976).

This is consistent with the correlation tests between bacterial abundance and these fractions where correlation was significant ($p<0.005$) and no significant for fungi and actinomycetes ($p>0.05$). For fungi and actinomycetes this fine texture had not affects on their abundance. Insam *et al.* (1989) found a significant but weak, correlation ($R^2 = 0.02$) between soil texture (e.g., clay content) and microbial biomass in temperate agricultural soils. They used two measures of soil texture (silt+clay and clay content), but found no relationship between those variables and microbial C. Although, several studies have demonstrated that soil texture has a significant influence on soil microbial biomass (Van-Veen *et al.*, 1985), this relationship may only be of importance within a particular climatic regime.

Bacterial abundance displayed a positive linear relationship ($p = 0.005$) with soil pH, Bardgett and Leemans (1995) recognized that a reduction in the pH from 5.4-4.7 occurred following the interruption of any fertilization led to a decrease of 18% of the microbial biomass. The highest values were signaled in agroecosystem and the humid ecosystem soils. However, no correlation ($p>0.05$) with $CaCO_3$, certain authors recognized that this one had a propriety to replace the hydrogen ions and to exhibit atypical high acidity.

The electrical conductivity occur either naturally or as a result of inappropriate soil use and management and the humid ecosystem station tended to be more saline (1163 $\mu sec\ cm^{-1}$) and the correlation was significant only for bacteria.

Soil organic matter (OM) was higher in the forest ecosystem soils but lowest in the agroecosystem soils. These values can be explained by the fact that any OM fraction incorporated was quickly assimilated by microorganisms present especially by the most pathogens (i.e., presence of competition). It may be pointed out that only amount to a smaller percentage of organic soil C, contributes substantially to plant available nutrient content (Diaz-Ravina *et al.*, 1995). According to diverse authors the ratio of microbial C and extractable C to total organic C are related to substrate quality. As previously observed no significant correlation ($p>0.05$) between OM and microbial abundance (bacteria: $r = -0.08$; fungi: $r = -0.27$; actinomycetes: $r = -0.09$).

The reduction of OM content observed in the soils could also be a cause of reduced soil enzyme activity (i.e., class of OM not hydrolysable). It has been demonstrated by Namour (1999), that the density of heterotrophic community is slightly correlated with the quantity of the substrate available. These results are in agreement with previous report of Namour (1999), focused on the OM kinetic. As described by Servais (1989), the OM is divided into four classes of decreasing lability: a class directly comparable to effectively control microbial growth, two classes slowly hydrolysable and finally a class not used by microorganisms (not assimilated). Our data indicate that this organic matter in these ecosystems was relatively recalcitrant.

In summary, our results suggest that plant type influences microbial abundance and diversity. Plant type displayed a positive linear relationship ($p<0.001$) with bacterial abundance ($r = 072$) but a inverse relationship between fungi and actinomycetes ($r = -0, 19$, $r = -0, 55$), respectively, this correlation was significant for fungi ($p = 0.001$) and not for actinomycetes ($p = 0,32$). Present study suggests that plant production holds promise in predicting patterns of labile organic matter pools and microbial biomass at much larger spatial scales.

CONCLUSION

The diversity and abundance of soilborne microbes may be strongly influenced by some abiotic and biotic factors; however, few studies have described the diversity and dynamics of soilborne bacteria, fungi and actinomycetes in the region of Mascara (Northern-Algerian West).

To obtain an accurate representation of the function and structure of soils, it is necessary to study the inter-relationship between physical, chemical, biochemical and biological properties. Measurement of only one or some of these properties will give only a partial evaluation of the state of the soil ecosystem. The results showed that field data interpretation of soils properties is difficult, particularly when several factors exerting an influence on microbial communities are involved. Further studies are necessary in order to confirm these preliminary field data.

REFERENCES

Alvarez, G., R. Chaussod, D. Cluzeau, B. Godden and C. Lemarie *et al.*, 2002. Biological Activities and Soil Fertility, Interest and Limitations of Analytical Methods Available. 1st Edn., ITAB., UK., pp: 5.

Atlas, R.M. and R. Bartha, 1998. Microbial Ecology: Fundamentals and Applications. 4th Edn., Benjamin Cummings, America, Pages: 640.

Bardgett, R.D. and D.K. Leemans, 1995. The short-term effects of cessation of fertiliser applications, liming and grazing on microbial biomass and activity in a reseeded upland grassland soil. Biol. Fert. Soils, 19: 148-154.

Bonneau, M. and B. Souchier, 1994. Pedology: Constituents and Soil Properties. 2nd Edn., Masson Publisher, Paris.

Crecchio, C., A. Gelsomino, R. Ambrosoli, J.L. Minati and P. Ruggiero, 2004. Functional and molecular responses of soil microbial communities under differing soil management practices. Soil Biol. Biochem., 36: 1873-1883.

Diaz-Ravina, M., M.J. Acea and T. Carballas, 1995. Seasonal changes in microbial biomass and nutrient flush in forest soils. Biol. Fert. Soils, 19: 220-226.

Dodd, J.C., C.L. Boddington, A. Rodriguez, C. Gonzalez-Chavez and I. Mansur, 2000. Mycelium of Arbuscular Mycorrhizal Fungi (AMF) from different genera: Form, function and detection. Plant Soil, 226: 131-151.

Dommergues, Y. and F. Mangenot, 1970. Microbial Ecology of Soil. Masson and Cie, Paris. pp: 33-45.

Elhott, E.T., R.V. Anderson, D.C. Coleman and C.V. Cole, 1980. Habitable pore space and microbial trophic interactions. Oikos, 35: 327-335.

George, E., H. Marschner and I. Jakobsen, 1995. Role of arbuscular mycorrhizal fungi in uptake of phosphorus and nitrogen from the soil. Crit. Rev. Biotechnol., 15: 257-270.

Hassink, J., 1994. Active organic matter fractions and microbial biomass as predictors of N mineralization. Eur. J. Agron., 3: 257-265.

Insam, H., D. Parkinson and K.H. Domsch, 1989. Influence of macroclimate on soil microbial biomass. Soil Biol. Biochem., 21: 211-221.

Kirk, J.L., L.A. Beaudette, M. Hart, P. Moutoglis, J.N. Klironomous, H. Lee and J.T. Trevors, 2004. Methods of studying soil microbial diversity. J. Microbiol. Methods, 58: 169-188.

Legendre, P. and L. Legendre, 1998. Introduction a l'analyse Multidimensionnelle. Numerical Ecology. 2nd Edn., Elsevier, USA Pages: 4.

Martin, J.P., Z. Filip and K. Haider, 1976. Effects of montmorillonite and humate on growth and metabolic activity of some actinomycetes. Soil Biol. Biochem., 8: 409-413.

Molin, J. and S. Molin, 1997. CASE: Complex adaptive systemsecology. In: Advances in Microbial Ecology, Jones, J.G. (Ed.). Vol. 15, Plenum, New York, pp: 27-79.

Namour, P.H., 1999. Auto purification of waste organic nature of the organic matter and waste domestic effect in rivers. Ph.D. Thesis, University Claude Bernard Lyon, France.

O'Donnell, A.G., M. Seasman, A. Macrae, I. Waite and J.T. Davies, 2001. Plants and fertilisers as drivers of change in microbial community structure and function in soils. Plant Soil, 232: 135-145.

Schimel, D.S., 1986. Carbon and nitrogen turnover in adjacent grassland and cropland ecosystems. Biogeochemistry, 2: 345-357.

Servais, P., 1989. Modeling of biomass and bacterial activity in the Meuse. Rev. Water Sci., 2: 543-563.

Sorensen, P. and E.S. Jensen, 1995. Mineralization of carbon and nitrogen from fresh and anaerobically stored sheep manure in soils of different texture. Biol. Fertil. Soils, 19: 29-35.

Srivastava, D., R. Kapoor, S.K. Srivastava and K.G. Mukerji, 1996. Vesicular Arbuscular Mycorrhiza: An Overview. In: Concepts in Mycorrhizal Research, Mukerji, K.G. (Ed.). Kluwer Academic Publishers, Netherlands, pp: 1-39.

Timonen, S., R.D. Finlay, S. Olsson and B. Soderstrom, 1996. Dynamics of phosphorous translocation in intact ectomycorrhizal systems: Non-destructive monitoring using a B-scanner. FEMS Microbiol. Ecol., 19: 171-180.

Trevors, J.T., 1998. Bacterial biodiversity in soil with an emphasis on chemically-contaminated soils. Water Air Soil Pollut., 101: 45-67.

Van-Veen, J.A., J.N. Ladd and M. Amato, 1985. Turnover of carbon and nitrogen through the microbial biomass in a sandy loam and clay soil incubated with [^{14}C(U)] glucose and [^{15}N]$(NH_4)_2SO_4$ under different moisture regimes. Soil Biol. Biochem., 17: 747-756.

Wall, D.H. and R.A. Virginia, 1999. Controls on soil biodiversity: Insights from extreme environments. Applied Soil Ecol., 13: 137-150.