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Research article

ASSESSING CHANGES IN SOIL MICROBIAL POPULATION WITH SOME SOIL PHYSICAL AND CHEMICAL PROPERTIES

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ABSTRACT: Soil is a dynamic system in which continues interaction takes place between soil minerals, organic matter and living organisms that influences the soil physico-chemical and biological properties. In present investigation soil microbial community (bacteria and fungi) and soil chemical properties and their relation with soil texture has been addressed. Soil samples with a range of texture were collected from nine sites. Soil chemical characteristics (e.g., pH, organic matter (OM), total soil nitrogen (TN) that might influence microbial population were quantified for each site. The finding demonstrate that bacterial population was significantly affected by particle size, yielding higher bacterial population in finer soil texture, furthermore bacterial population strongly correlated with clay concentration (r = 0.90), pH(r = -0.85), OM (r=0.80), SOC (r = 0.79), TN (r= 0.81) and C:N ratio (r=-0.92). Fungal propagules did not show any significant differences in any soil texture with respect to sites. Soil texture significantly ($p<0.05$) affected pH, organic matter, organic carbon, water contents, total nitrogen and C:N ratio; and they were strongly correlated with clay concentration. Increasing bacterial population in finer soil likely due to protective microhabitat, the increased rate of organic matter and total nitrogen in finer texture, suggesting that the vicinity between microbes, organic matter, and clay is required for the survival and activity of microbes, in which organic matter and clay particles provide microhabitat, substrates and nutrients.

Key words: Soil texture, Microbial communities, Organic matter, Soil characteristics

INTRODUCTION

Soil microorganisms are crucial for continuing nutrient cycling and for driving above ground ecosystems [1–5] and it is the biggest and most diverse biotic community in soil; according to [6] a gram of typical agricultural soil contains about 1 million to 1 billion bacteria. Microbial biomass contributes the dynamics of soil organic matter and availability of many nutrients. Furthermore, roots interact with diverse populations of soil microorganisms which affects significantly on plant growth and nutrition [7,8]. However, the activity and species composition of microbes are generally influenced by many environmental factors including edaphic properties of soil, Some of these factors are called modulators, in contrast to resources that the microbial community needs for growth and survival. The variation between modulators and resources is that organisms actively compete for resources (e.g. Carbon, nitrogen), while they cannot compete for modulators. Examples of modulators are temperature, pH, water potential and salinity [9].

The concentration and structural organization of soil particle fractions (silt, sand and clay) provided a spatially heterogeneous habitat for microbial community characterized by different substrate, nutrient, and oxygen concentration and water contents as well as variable pH value [10].Other studies suggesting that soil texture play the important role in contributing soil microbial population [11, 12].

Although these researches gave initial insight for the structure of microbial community in soil microhabitats, it is not well understood whether particle size fractions and/or soil chemical characteristics influence the microbial population. The overall goals of present study were to test the influence of soil physical and chemical properties on soil microbial community.

MATERIALS AND METHODS

Sampling protocol

Nine locations of Sulaimaniyah governorate-Kurdistan region–Iraq were selected for soil sampling (Kani-Panka, Arbat, Grgashi, Mawat, Penjwen, Qashan, Bakrajo, Sulaimaniyah (city center) and Taben). From each location 25 random soil samples were collected at a depth of 15 Cm using a 2.5cm diameter soil auger. Soil samples were mixed and homogenized to form composite sample. Three replicates of each composite soil samples were used for future analysis. After removing recognizable stones, plant and animal debris, soil samples were air - dried and sieved through a 2 mm mesh sieve before analysis and kept in sealed containers at 4°C before analysis and incubation experiment [13,14].

Soil physical and chemical characterization

Soilparticle size distribution (psd) were determined according tothe international pipette method [15], percentage soil moisture content (PW) was estimated on the basis of gravimetric measurements in soil samples. Moreover, saturation (%vol), Field capacity (FC % vol) and welting point (WP % vol) estimated using the Soil Water Characteristics software 6.02.74 implemented by the USDA Agricultural Research Service for generating the soil information (16). Soil pH was measured in water (1:1 volumetric ratio of water-to-soil) using pH meter, Electrical conductivity EC ($ds.m^{-1}$) at 25ºC was determined in soil extract by using EC- meter [17]. Soil organic carbon (SOC), soil organic matter (OM) were estimated using Walkely and Black; and total nitrogen (TN) using Micro-kjeldahl methods as mentioned in [18].

Biological characteristics

Microbial communities in soils were typically assessed using viable plate count method for counting colony form bacteria and fungi propagules. One gram of air dried soil was placed in 99 ml sterile physiological saline and shaken for 30 min. After settling, soil suspension was diluted ten folds. From each diluted sample, three petri plates for bacteria and three for fungi were inoculated with 1 ml of the suspension. I t was determined that dilutions of 10^{-4}, 10^{-5}, 10^{-6} and 10^{-7} were the most appropriate for bacterial counts, and 10^{-2} and 10^{-3} were used for fungi.

The numbers of bacterial and fungal propagules colony forming units (CFU) per gram soil were estimated. The selective medium of nutrient agar was used for detection of bacteria and sabouraud dextrose agar for fungi. Petri plates were incubated at 30°C for up to 10 days, the colony forming units (CFU) were counted, which monitored daily for the appearance of colonies. Then, the plates were counted for bacteria and fungi and calculation was made according to [19]. As follows:

Colony forming unit (CFU) / gram of soil = count /plate dilution used.

Statistical analysis

Statistical analysis was carried out with JMP (SAS Institute Inc., Cary, NC). Data of soil chemical and biological parameters were tested using one-way analysis of variance (ANOVA, n=3). Where there were significant differences ($p<0.05$), Tukey's Honestly Significant Difference (HSD) test was used for mean. Correlation between variables means was performed by Spearman rank correlation tests in order to detect the relationships between and within soil parameters and microbial communities.

RESULTS

Soil texture

From the particle size distribution, significant differences of soil texture were detected. Soils classified according to its texture as: sandy loam, loamy sand, silty loam, silty clay loam, loam, and clay loam (table-1).

Table-1. Soil locations and textural classification. Values are mean of three replicates.

Soil location Name	Sand	Silt	Clay	Texture class
Kani-panka	4.2	43.0	52.8	clay loam
Penjween	27.5	41.3	31.2	clay loam
Qashan	49	43.7	7.3	Loam
Mawat	83.1	6.3	10.6	loamy sand
Arbat	56	37.3	6.7	sandy loam
Grgashi	55.5	37.6	6.9	sandy loam
Bakrajo	8.1	59.8	32.1	silty clay loam
Sulaimani	14.1	50.3	35.6	silty clay loam
Tabeen	17.2	60	22.8	silty loam

Physico-chemical characterizations

The Physico-chemical properties of the soils according to their texture are presented in Table (2 and 3). Soil pH, total OM (%), SOC, TN and C:N ratios were significantly difference between soil textures ($_p$< 0.05 in all cases).While soil EC not vary significantly across the texture classes ($_p$< 0.05). Soil reaction was predominately slightly acidic in clay loam texture to moderately alkaline in other textures ranged from 6.60 –7.75, EC values were low, but not significantly vary among the soil samples ranged from 0. 46 dS m^{-1} in sandy loam to 0.99 dS m^{-1} in Loam texture. The soil organic matter (OM) was affected by soil textures and it was low to medium and in silty clay loam and the percentage of OM was three times more (3.34%) than sandy loam (1.03%). Similar trends were also obtained for Soil organic carbon (SOC), results also indicated that C:N ratios significantly decrease in clay loam and silty clay loam textures in comparison to other textures. Furthermore, soil water contents were significantly increased with increases of clay percentage in soil textures (table-3).

Table-2. Some chemical properties sand microbial population in different soil texture class. Values are mean of three replicates.

Texture class	pH	E.C	OM (%)	(SOC) mg of C. g^{-1} soil	(TN) mg of N. g^{-1} soil	C:N ratio
Sandy loam	7.58a	0.46	1.03d	5.99d	0.49c	12.2a
Loam	7.47a	0.99	1.45cd	8.43cd	0.76bc	11.1ab
Loamy sand	7.47a	0.55	1.16d	6.16d	0.55c	11.2ab
Silty loam	7.75a	0.69	2.04bc	11.86bc	1.12bc	10.6b
Clay loam	6.7b	0.94	2.86b	16.3b	1.56ab	10.4b
Silty clay loam	7.29a	0.85	3.34a	19.42a	2.21a	8.8c

Means within one column that are not significantly different from each other at $_P$< 0.05 are followed by the same letters.

Table-3: Soil water contents properties, values are mean of three replicates

Texture class	PW %Vol	WP %Vol	FC %Vol	Sat %Vol
Sandy loam	0.8c	6.5c	17.3bc	41.6c
Loam	1.1bc	7.1c	20.8b	45.9bc
Loamy sand	1.1bc	7.3c	12.7c	41.5c
Silty loam	1.3b	15.0b	33.2a	47.4ab
Clay loam	2.1a	25.6a	39.5a	51.8a
Silty clay loam	1.9a	20.5ab	37.4a	53.9a

Means within one column that are not significantly different from each other at P<0.05 are followed by the same letters.

Microbial population

The number of Culturable Bacterial was significantly high in clay loam and silty clay loam textures than other texture classes. However, the number of fungal propagules colony form units was not vary significantly between sites nor according to texture classes (table-4).

Table-4. Microbial population in different soil textures.

Texture class	Bacteria (Log no. of colonies g^{-1} dry soil)	Fungal propagules (Log no. of colonies g^{-1} dry soil)
Sandy loam	6.07b	4.39
Loam	6.41b	4.09
Loamy sand	6.77b	4.49
Silty loam	6.82b	4.37
Clay loam	8.87a	4.36
Silty clay loam	8.03a	4.35

Means within one column that are not significantly different from each other at $P < 0.01$ are followed by the same letters.

DISCUSSION

We studied the potential impact of soil texture on soil chemical properties and microbial community among nine distinct sites, which may occur because of the variation of silt, sand and clay concentration, also the interaction between these particle size fractions and soil chemical properties that might influence microbial community population.

Soil texture and microbial community.

Abiotic factors, including availability of soil nutrient, soil reaction, topsoil depth, soil water content, soil aeration, soil temperature, and soil management practices, may affect the structure and activity of soil microbial communities [20, 21, 22, 23]. In present study, our results noticeably demonstrated that soil textural differences significantly affected bacterial population, and that smaller size fractions (silt and clay) host higher bacterial community than larger size particles (sand).Among six soil textures we found highest microbial population in clay loam and silty clay loam and there were strong correlations between percentages of clay contents and bacterial population (table-5). Our results agree with other researchers suggesting that soil texture is one of the most importance factors contributing soil microbial population [11, 12, 13, 24, 25, 26, 27], that observed higher levels of microbial population and diversity in the finer (silt and clay) fractions of soils, with lower values in the sand fraction.

Table-5. Correlation coefficients for the relations between and within soil physico-chemical properties and soil biological parameters (*df* =26).

Parameters	Clay (%)	PW (%Vol)	pH	E.C	OM	(SOC)	(TN)	C:N ratio	Bacterial Number
Clay (%)									
PW (%Vol)	93**								
pH	N.S.	N.S							
E.C	N.S.	N.S.	N.S.						
OM	0.93**	94**	N.S.	N.S.					
(SOC)	0.92**	94**	N.S.	N.S.	0.99***				
TN	0.92**	93**	N.S.	N.S.	0.99***	0.99***			
C:N ratio	-0.94**	85*	N.S.	N.S.	-0.85*	-0.94**	-0.95**		
Bacterial Number	0.90**	95**	-0.85*	N.S.	0.80*	0.79*	0.82*	-0.92**	
Fungal propagates	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

* P<0.05, ** P<0.01, *** P<0.001

It has suggested by some researchers that finer particle fractions were suitable for bacterial survival, also smaller size particles provide a protective habitat for microorganisms through pore size exclusion of predators [12, 28, 29] Alternatively, higher bacterial population in clay loam and silty clay loam may be due to a higher organic matter content, water contents and nutrient availability in finer soil particles[30,31], the organic matter (OM) and total nitrogen (TN) contents, water contents were high and significantly (p<0.05) correlated with bacterial population in clay loam and silty clay loam compare to other soils (Table-2 and 3). Microbial activity in soil is strongly influenced by the clays and humates which bind organic chemicals, inorganic nutrient ions, and water films to their surfaces. According to Van Gestel et al., [32] the vicinity between microbes, organic matter, and clay is required for the survival and activity of microbes, in which organic matter and clay particles provide substrates and nutrients.

In present study there were no significant differences in culturable fungal propagules number, may be because it is very difficult to relate the number of such colony form propagules to the status of the fungal community in the original environment. This is because the number of colony form propagules formed will not only relate to the natural conditions developing within the microcosm of the culture system, but also the frequency of spores present in the environment and the degree of disruption of the mycelia in the sample preparation procedure [33]. In addition, one more challenge facing microbial ecologistsm including those working on fungi, is that the vast majority of species discovered in natural environments are not easily culturable [34].

Soil texture and chemical properties of soil

In present study Among six soil textures we found that soil texture significantly (p<0.05) affected soil OM, TN and SOC contents and C:N ratio and there were strong correlations between percentages of clay contents with OM, TN and SOC contents and C:N ratio (Table-2 and 5),

According to [35], clay performs as an absorption sink for organic matter. Increase in organic matter in clay loam and silty clay loam textures as compared to sandy loam, loam and loamy sand textures with the increase in clay can be due to the fact that organic matter complexes being absorbed onto clay surface are being physically protected against decomposition[36]. Increasing soil N contents in higher clay concentration is in agreement with previous research, Grandy et al., [37] found that The TN concentration in soil increase with increasing the clay concentration. Our observations agree with other research, that smaller size particles had narrower C:N ratio range comparing to larger particles which has a wider C:N ratio range [29, 12]. Moreover, in this study we found that C:N ratio had a strong negative correlation with clay concentration (r= -0.92).

CONCLUSIONS

We addressed the potential impact of soil texture on soil chemical properties and microbial population. Soil texture significantly affected bacterial population, soil organic matter and nitrogen contents, soil reaction and C:N ratio range. So one can conclude that clay concentration play a crucial role in soil bio-chemical characteristics.

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