Effects of Soil Organic Matter, Total Nitrogen and Texture on Nitrogen Mineralization Process

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Abstract

The objectives of this study were to 1. Determine soil texture, microbial com0munities, chemical and physical properties of soils collected from nine different localities of Sulaimani governorate; 2. Measuring the rates of nitrogen mineralization of plant residues and it's correlation with tested parameters. After analysis, soils were classified into six textures (sandy loam, loamy sand, silty loam, silty clay loam, loam and clay loam). Statistical analysis of variance indicated there were no significant differences among soil textures in fungal counts (ranging from 4.09–4.49 log of CFU per 1 g dry soil) whereas total bacteria showed significantly higher in clay loam and silty clay loam in compare to other soil textures (ranging from 6.07–8.77 log of CFU per 1 g dry soil), soil chemical analysis showed that the soil organic matters and total nitrogen contents are strongly correlated with each other (r^2=0.96, $p \leq 0.001$), and both parameters indicated positive correlation with the major microbial groups (r^2=0.798, r^2=0.772, $p \leq 0.001$) respectively, whereas they are negatively correlated with mineralization rate (r^2=-0.379, r^2=-0.338, $p \leq 0.001$) respectively; finally the effects of soil texture on N-mineralization showed that this process tends to be greater in coarse-textured soils than fine textured soils.

Keywords: Mineralization, Soil microorganisms, Nitrogen, Soil texture, Soil chemistry.

Introduction

Nitrogen in soil is largely depends on soil organic matter and microbial activity [1], which founds in both organic and inorganic forms [2]. Organic nitrogen (N) present in various forms, including plant and microbial proteins, amino acids and nucleic acid in the soil and enters to the soil in the form of crop residue and amendments (e.g., manures, composts, and specialty products) [3, 4, 5], and Inorganic N, mostly ammonium (NH_{+4}) and nitrate (NO_{-3}), crops can only assimilate these two inorganic forms of nitrogen [2]. Therefore before organic N can be taken up, it must first be converted to inorganic forms [6].This process, which is completed by the activities of soil microorganisms as a by-product of organic matter decomposition, is called *mineralization* [5]. In this process *organic* N contained in soil organic matter is converted into plant-useable *inorganic* forms (ammonium NH_{+4} and nitrate NO_{-3}) [5,7], in soil immobilization process will also occurs when nitrogen is needed for microbial growth and microbial biomass [2]. Thus N availability of a soil will change depending on the amount of N mineralized or immobilized during the decomposition of crop residues and microbial growth [8, 9].

Soil nitrogen is greatly influenced by various populations of microorganism, soil organic matter, soil pH, the climate of the soil and textural classes of soil [9]. Soil texture is an important factor that influences distribution of minerals, organic matter retention, nitrogen (N) mineralization, microbial biomass and other soil properties [10]. However, little is known about the role of soil texture and chemistry (soil carbon and nitrogen contents) on N-mineralization process.

The objectives of this study were to: 1-evaluates some chemical properties and texture classes of soils collected from different locations 2-counting of most distributed soil microbial communities in selected localities 3-rates of N-mineralizaion /immobilization among tested localities and their correlation with tested parameters.

Materials and Methods

This work was carried out in July 2008 at the Biology department, University of Sulaimani. Nine locations of Sulaimani were selected for soil sampling [Arbat, Grgasha, Mawat, Penjwen, Qashan, Qaradagh, Sharazwr, Sulaimani (city center) and Taben] for this purpose from each location about 25 random samples were collected in each plot to 15 cm depth using a 2.5 cm diameter soil auger. Soils were mixed, homogenized, and considered as a composite and representative sample of the study site. After removing recognizable stones, plant and animal debris, these composite samples were air-dried and sieved through a 2 mm mesh sieve before analysis and kept in sealed containers at 4℃ before analysis and incubation experiment [9, 11, 12].

Soil particles distribution (spd) was determined according to the international pipette method, other chemical composition and pH was measured in soil-to-water suspension with a pH meter. Organic C (OC), total N (TN) and other parameters by standard methods [12, 13].

Cultivation on agar plates was used for counting of soil microorganisms using different culture media. In this study standard plate count was used through ten fold dilution method, Two sets of four plates were labeled each as follows: fungi (10^{-2}, 10^{-3}, 10^{-4}, and 10^{-5}) and bacteria (10^{-4}, 10^{-5}, 10^{-6}, and 10^{-7}), one ml of each soil dilution distributed on the respective plates as indicated. Petri plates of incubated for 2 to 7 days at room temperature for bacteria and fungi respectively and monitored daily for the appearance of colonies, then plates were counted and calculated as follows [14]:

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

To determine the net N mineralization/ immobilization rates, soil samples were divided into two sets unamended soil (control) and amended soil were mixed thoroughly with plant residue at the rate of 3g residue/100g soil. Moisture was adjusted at 50% water holding capacity and incubated at 25°C for 8 weeks. The experiment was conducted with two replicates [15, 16].

Accumulation of inorganic nitrogen is measured by extracting each soil sample with 80 ml of 2M KCl. After adding KCl and shaking each container by hand to suspend the soil, sample containers were placed on a rotary shaker at speed (100 rpm/min.) for 1 h, and then shaken again by hand to re-suspend the soil. Samples were filtered (Whatman No. 42 filter paper). All soil extracts were frozen at (-20°C) to prevent secondary formation of nitrite ions by microbial or chemical redox reactions from ammonium ions or nitrate ions. Based on these backgrounds NH_{+4} and NO_{-3} measurements, gross N mineralization and nitrification rates were measured on whole soil samples [7, 15, 16].

Extracted NH_{+4} from soil samples was determined by titration method [17] by treating (20 ml) of extracted soil with five drops of methyl red reagent and titration was done with (0.05 N) of H_2SO_4 until the end point of the reaction (yellow to red), then samples were boiled off and cooled to room temperature and the same step of titration was repeated to the same color, and distilled water corresponding of the blank test serves as the control sample.

Equations used for determination of NH_{+4} in soil water extract:

$$G = (a - b) \times F \times 902 / V$$

(1 ml of 0.05N H_2SO_4 corresponds to 0.902 mg of NH_4)

G: content of ammonium ions in the water sample, in (mg/L).

a: consumption of 0.05N H_2SO_4 in ml for the extracted water sample.

b: consumption of 0.05N H_2SO_4 in ml for the distillated water (blank).

F: factor of the 0.05N H_2SO_4.

V: undiluted volume of sample used in (ml).

Finally all (NH_{+4}) values were expressed in (ppm).

Determination of nitrate using nitrate reductase method:

Nitrate is usually determined as nitrite after the reduction of nitrate by copperized-cadmium reduction column. Nitrite is spectrometrically determined after addition of (0.2ml) of each sulphanilic acid and 1-naphthylamine and leaved out to stand for 2 hours in a darkness place. Samples were measured at absorbance (530nm), with respect to a sample containing both nitrite and nitrate. The amount of nitrite was obtained by subtracting the amount of nitrite from the total amount of nitrite after reduction of nitrate. Thus, this is an indirect method for determination of nitrate [17, 18]. This method is suitable for the determination of nitrite ions in water between concentrations (0.0005-0.05 mg/L) [10].

$$NO_3^- + H^+ + NAD(P)H \xrightarrow{\text{(Nitrate Reductase)}} NO_2^- + NAD(P)^+ + H_2O$$

Standard nitrite curve was prepared ranging between (0.01-0.09 mg / liter of water) for determination of nitrite in soil extracts (Fig.(1)).

Finally this equation is used to calculate the net rates of N mineralization/ immobilization.

$$N\ m/i = (NH_4^+ + NO_3^-)f - (NH_4^+ + NO_3^-)i$$

Nm/i: is the net rate of N mineralization or immobilization. Positive and negative values of Nm/i considered as net N mineralization and net N immobilization, respectively. $(NH_4^+ + NO_3^-)f$ and $(NH_4^+ + NO_3^-)i$ are the final (after 8 weeks of incubation) and initial (before incubation) [15]. For statistical analysis F-test with two replicates and the P-value at 0.01, 0.001 was accepted as significant and linear regression and correlation were used to determine relationships among soil properties and net N-mineralization [19].

Results and Discussion

This study was carried out using nine soil samples to represent the range of N-mineralization/immobilization potential in the most different soils in textures, composition of microbial communities and availability of soil organic matter (SOM) and total nitrogen content (TNC).

The predicted results indicated that the soil samples were classified to six different soil textures (Grgasha and Arbat) locations belong to the same group of soil texture (sandy loam), and (Qaradagh, Sharazwr and Sulaimani) locations belong to other group of soil texture (silty clay loam) whereas remaining soil samples were classified into different soil textures (Table, (1)). Some of selected physical and chemical properties

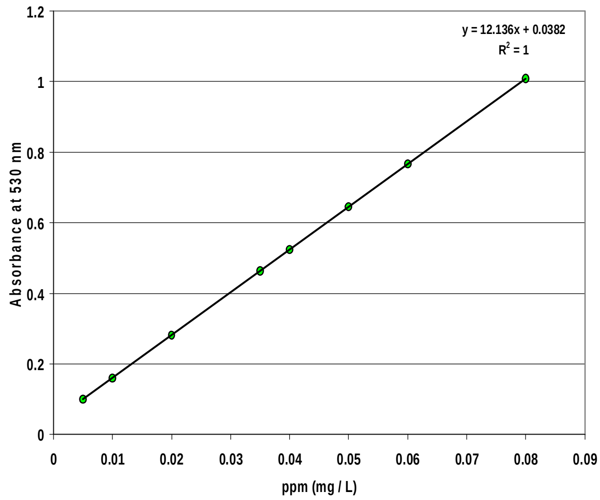

Fig.(1) Standard curve for quantification of nitrite ions in soil extracts.

were given in (Table (2)), (Table (3)). Soil pH values showed significant differences between lowest value of (pH=6.6) in clay loam and highest level of (pH=7.75) in silty loam ($p \le 0.01$), and remaining soil textures did not showed significant differences among them ranging between (pH: 7.29 – 7.58). This might be related to soil sulphate concentration which may have a direct role on pH value (Table (3)) showed no significant differences among all soil types except in clay loam which has the highest content of sulphate ($p \le 0.01$).

Table (1)
Soil locations and textural classification.

Soil series	*Name of localities*	*Textural Class*
1. (A)	Arbat	Sandy loam
2. (G)	Grgasha	Sandy loam
3. (M)	Mawat	Loamy sand
4. (T)	Taben	Silty loam
5. (Q)	Qaradagh	Silty clay loam
6. (S)	Sharazwr	Silty clay loam
7. (C)	Sulaimani	Silty clay loam
8. (Qa)	Qashan	Loam
9. (P)	Penjwen	Clay loam

Table (2)
Some physical properties of soil samples used in the study, values are mean ± S.E.

Soil texture	*Mean (E.C) $ds.m^{-1}$*	*Mean (pH)*
Sandy loam	0.36±0.05[a]	7.58±0.01[ab]
Loamy sand	0.55±0.04[a]	7.57±0.02[ab]
Silty loam	0.69±0.01[a]	7.75±0.05[b]
Silty clay loam	0.85±0.23[a]	7.29±0.09[a]
Loam	0.99±0.01[a]	7.47±0.02[ab]
Clay loam	0.36±0.03[a]	6.60±0.10[c]

Bacterial and fungal counts were determined in all selected localities in replicate soil glass jars with plant residue treatments. These microorganisms were selected on the bases of that stated by [2]. Decomposition of soil organic matter and the subsequent release of inorganic N from the organic N pool (plant residue) occur through the activity of soil microflora, principally bacteria and fungi.

The average counts of microorganisms (Table (4)) are expressed as log of CFU per 1 g dry soil, (bacteria ranging from 6.07–8.77 log of CFU per 1 g dry soil; fungi from 4.09–4.49 log of CFU per 1 g dry soil), not significant differences were founded among soil textures in number of bacteria and fungi. The lowest level of bacteria was reported in sandy loam soil (6.07 log of CFU per 1 g dry soil), with no significant differences among all soil types except clay loam ($p \leq 0.01$) which was reported the highest level of bacteria (8.77 log of CFU per 1 g dry soil). These average counts of microorganisms correspond with usual counts of microbes in arable soils [20], and same results in evaluating both groups of microorganisms in different soil types were obtained previously by other researchers [21, 22]. Distribution of microorganisms in various soil textures might be related to soil moisture and nutrient contents as explained by [4] who stated sandy soils with relatively small surface area cannot retain water very well and drain very quickly this may lead to the formation of soil dryness, in contrast clay loam preserves water and hold nutrients for long period of time. Finally results of major soil microbial groups indicated positive correlation with organic matter $r^2=0.798$, $p \leq 0.001$; total nitrogen $r^2=0.772$, $p \leq 0.001$. Also strong correlation was obtained between soil organic and total nitrogen contents ($r^2=0.9681$, $p \leq 0.001$), same result was obtained by other researchers [8].

Concentrations of soil organic matter and total nitrogen contents showed relatively in association with fine soil particles; therefore soils with highest clay contents is proportionally greater in C/N contents, in contrast soils with more sand and silt composition contains low levels of both soil C/N contents (Fig. (2; 3)) and (Table (5)). These results were documented previously by other researchers [8], this might be related to that explained by [5] finely textured soils high in clay are abundant in micropores in which organic matter can find physical protection from microbial decomposition. This demonstrates the influence of particle size in mediating C/N retention in these soils.

Enhancement of N-mineralization in control soil group (unamended) and in treated soil group with plant residue (amended); plant tissue was added to the soil as a primary source and sinks for C and N [6]. Mineralization rate of nitrogen were significantly greater ($p \leq 0.01$) in loam and silty loam (98.77, 98.25 ppm/100g of soil) respectively for (amended soils), and (-30.38, -29.37 ppm/100g of soil) respectively for (un-amended soils), whereas other soil textures with lower mineralization rate of nitrogen and did not showed significant differences among them (clay loam, loamy sand, silty clay loam, sandy loam) (Fig.(4)) (Table (6)). Same results were obtained by [8] who explained the difference behavior in nitrogen mineralization/ immobilization attributed to different soil textures.

Negative values of un-amended soil group were related to decreasing of soil NH_{+4} and NO_{-3} content at the end of incubation period when compared to initial values of the same soil sample as a result of immobilization process. Immobilization process occurs when nitrogen is needed for microbial growth and microbial biomass [2].

Table (3)
Variations in the levels of soluble ions (mmole.L^{-1}) in different soil textures, values are mean ± S.E.

Soil texture	*Soluble ions (mmole.L^{-1})*				
	Calcium	*Potassium*	*Sodium*	*Chloride*	*Sulphate*
Sandy loam	1.42±0.20^{ab}	0.13±0.015^{a}	0.46±0.04^{a}	0.52±0.01^{ab}	0.63±0.18^{a}
Loamy sand	1.38±0.18^{ab}	0.13±0.005^{a}	0.37±0.03^{a}	0.72±0.01^{b}	0.42±0.08^{a}
Silty loam	1.90±0.10^{b}	0.24±0.005^{b}	0.51±0.01^{a}	0.61±0.01^{ab}	0.66±0.06^{a}
Silty clay loam	1.21±0.11^{ab}	0.11±0.014^{a}	0.51±0.18^{a}	0.51±0.09^{ab}	0.67±0.12^{a}
Loam	1.23±0.11^{ab}	0.13±0.005^{a}	0.58±0.03^{a}	0.31±0.01^{a}	0.57±0.07^{a}
Clay loam	0.95±0.04^{a}	0.16±0.005^{a}	0.44±0.01^{a}	0.41±0.01^{ab}	1.38±0.18^{b}

The net rates of N mineralization/ immobilization were negatively correlated with soil organic and total nitrogen contents (r^2=–0.379, p≤0.001; r^2=–0.338, p≤0.001) respectively. Several explanations have been proposed to explain this phenomenon in soil with low C/N content enhance N-mineralization process as indicated in our results, silty loam and loamy soil textures with low organic and total nitrogen contents (13.35 g.Kg^{-1}, 0.48 mg.g^{-1}) and (14.35 g.Kg^{-1}, 0.53 mg.g^{-1}**)** respectively (Table (5)); except in sandy loam and loamy sand texture the organic carbon and total N contents of soils would suggest in proportion with mineralization potential (Figs.(1; 2)), however mineralization rates of nitrogen in soil textures that are rich in silt and clay tend to have reciprocal relation with soil organic carbon and total N contents. Thus the amount and type of clay in a soil affects N mineralization process. Mineralization tends to be greater in coarse-textured soils with low clay contents and mineralization tends to be fewer as the soil clay contents increased.

Several suitable explanations are available for explaining this phenomenon; soils that are high in clay contents are abundant in micropores which offer considerable physical protection to organic matter, which can reduce microbial activity [5], or N-mineralization is low because soil.

Table (4)
Average counts of microorganisms in different soil textures, values are mean ± S.E.

Soil texture	*Log CFU bacteria / g of soil*	*Log CFU fungi / g of soil*
Sandy loam	6.07^{a}	4.29^{a}
Loamy sand	6.77^{a}	4.49^{a}
Silty loam	6.42^{a}	4.37^{a}
Silty caly loam	8.03^{b}	4.35^{a}
Loam	6.81^{a}	4.09^{a}
Clay loam	8.77^{b}	4.36^{a}

Table (5)
Variations in organic matter and total nitrogen in various soil texture; values are mean ± S.E.

Soil Texture	*Organic matter* $(g.Kg^{-1})$	*Total nitrogen* $(mg.g^{-1})$
Sandy loam	20.65 ± 0.05^{b}	0.77 ± 0.01^{bc}
Loamy sand	10.25 ± 0.15^{a}	0.34 ± 0.0^{ab}
Silty loam	13.35 ± 0.15^{ab}	0.48 ± 0.03^{ab}
Silty clay loam	27.43 ± 2.77^{c}	1.04 ± 0.10^{d}
Loam	14.35 ± 0.15^{ab}	0.53 ± 0.03^{abc}
Clay loam	24.80 ± 0.20^{c}	0.88 ± 0.03^{cd}

microorganism's activity is limited by water availability. In saturated soils rich in clay, lack of oxygen limits N-mineralization rate because only soil microorganisms that can survive under anaerobic conditions are active [2], or attributed to other soil chemical properties such high concentration of sulphate in clay loam soil decreased pH value to 6.6. On the other hand decreased activities of microorganisms and mineralization process in this type of soil (Table (6)).

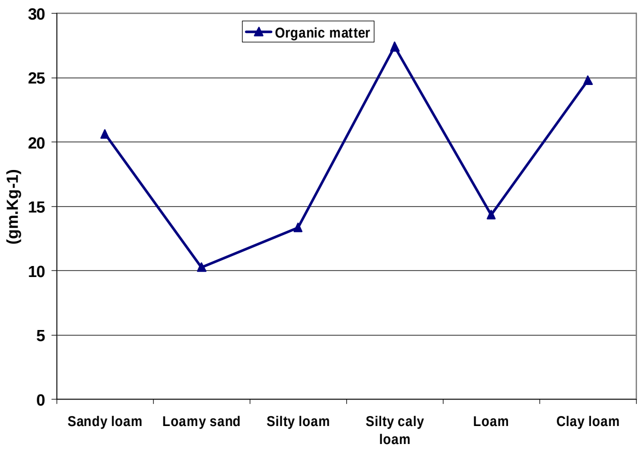

Fig.(2) Variations in the levels of soil organic matter concentration in different soil textures.

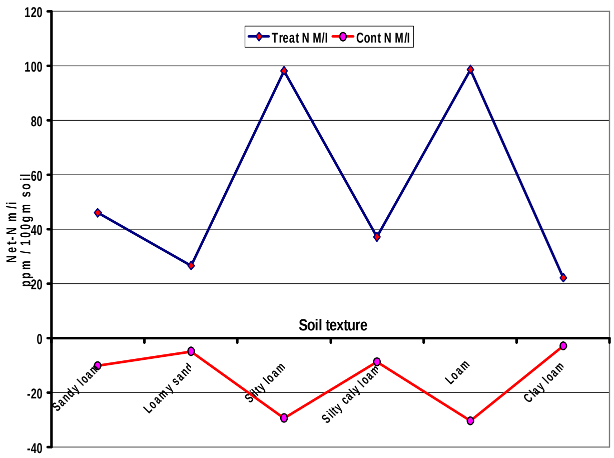

Fig.(3) Variations in the levels of total nitrogen concentration in different soil textures.

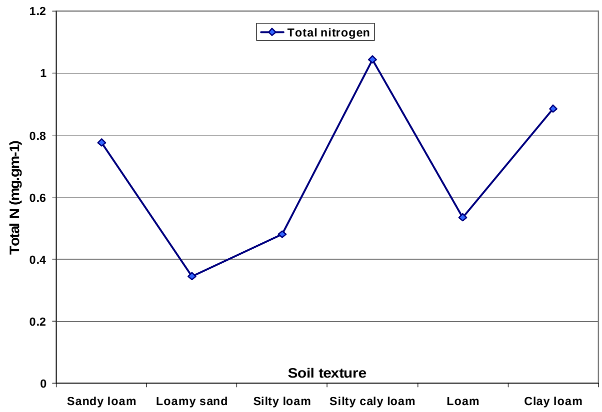

Fig.(4) Net of N-mineralization in treated and control groups of different soil textures.

Table (6)
variations in net of N-mineralization in treated and control groups of different soil textures; values are mean ± S.E.

Soil Texture	*Treated Net-N m/i ppm/100 g*	*Control Net-N m/i ppm/100 g*
Sandy loam	46.01 ± 1.14^{a}	-10.11 ± 0.38^{b}
Loamy sand	26.74 ± 1.32^{a}	-4.80 ± 0.83^{cd}
Silty loam	98.25 ± 0.75^{b}	-29.37 ± 1.13^{a}
Silty caly loam	37.18 ± 0.53^{a}	-8.64 ± 0.74^{bc}
Loam	98.77 ± 1.98^{b}	-30.38 ± 1.84^{a}
Clay loam	22.24 ± 0.71^{a}	-2.84 ± 0.31^{d}

In conclusion: Soil texture mainly influences the rate of N-mineralization especially in rich coarse-textured soil, and negative correlation was observed between this process and concentration of soil organic matter, total nitrogen contents. These final observations are useful for considering overall soil nitrogen content.

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الخلاصة

تهدف الدراسة الحالية الى أولاً: تحديد قوام التربة، المجتمعات الميكروبية في التربة، خواصها الفيزيائية والكيميائية لعينات جمعت من مناطق مختلفة من محافظة السليمانية. ثانياً: قياس نسبة النتروجين الممعدن من بقايا النبات وارتباطها بالمعايير المجربة. جمعت العينات من مناطق (عربت، كركاشة، ماوت، بنجوين، قشان، قرداغ، شهرزور، مركز مدينة السليمانية وتابين). ربطت عينات التربة غير المعالجة (سيطرة) أو المعالجة بمواد نباتية بنسبة3ملغم/ 100ملغم (بنسبة ترطيب 50% من سعة الحقلية) وحضنت بدرجة (25°م) لثمانية أسابيع تحت ظروف هوائية. قيس صافي النتروجين الممعدن في نهاية التجربة عن طريق التسحيح والمطياف الضوئي لكل من الامونيوم والنترات على التوالي. بعد التحليل صنفت الترب الى خمس قوام (رملية مزيجيه، مزيجيه رملية، مزيجيه غرينية، غرينية طينية، تربة مزيجيه وتربة طينية مزيجيه)، أشارت التحاليل الإحصائية للتباين إلى عدم وجود اختلاف بين قوام الترب المجربة في العد الفطري (تتراوح من لوغاريتم 4.09−4.49 وحدة تكوين المستعمرة) بينما العد البكتيري (فقد تتراوح من لوغاريتم 6.07−8.77 وحدة تكوين المستعمرة) فكان معنوياً في (تربة مزيجيه رملية وغرينية طينية مزيجيه). اما وتأثيرات محتوى المواد العضوية والنتروجين الكلي للتربة على صافي معدلات معدنة النتروجين فقد أظهرت سالبية الارتباط مع تركيز المواد العضوية للتربة ($p \le 0.01$, $r^2 = 0.379$)، وتركيز النتروجين الكلي ($p \le 0.01$، $r^2 = 0.338$)، بينما اثر قوام التربة في معدلات نفس العملية معنوياً مع زيادة المحتويات الطينية في التربة المزيجيه والتربة والتربة الغرينية المزيجيه (98.77 و98.25 ppm/100gm) على التوالي، بينما الترب الأخرى (مزيجية رملية، رملية مزيجية، مزيجية طينية و تربة مزيجية طينية) انخفاضاً في نسبة معدنة النتروجين.