Iran Agricultural Research, Vol. 25, No. 2 and Vol. 26, No. 1-2
Printed in the Islamic Republic of Iran, 2007
Shiraz University

Long – Term Tillage and Manure Effect on Soil Physical and Chemical Properties and Carbon and Nitrogen Mineralization Potentials

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ABSTRACT-The objective of this work was to study the effects of tillage and liquid manure applications on some physical and chemical properties as well as on the carbon and nitrogen mineralization potential of a meadow soil. Our results indicated that tillage and manure applications had no effect on the concentration of Cu, Mn, total N and organic C in 0-15 cm layer of soil after 15 years of treatment. However soil P, Ca, Mg and Zn contents significantly increased with manure applications. Soil organic matter and total N significantly decreased in a 15-30 cm depth. No significant change was detected in soil structural stability in any of the layers. Moreover, tillage affected soil soluble C and the C/N ratio significantly. Application of 100 t ha^{-1} manure significantly increased soil soluble C. The results of this study suggest that tillage increased the soil N mineralization rate significantly. The potentially mineralizable nitrogen (N_0) was higher in tilled than in no-tilled soil and was at its maximum in the 0-15 cm layer. Furthermore, a significant positive interaction was observed between tillage and manure application on mineralized N after 1.4 wk (N_e). No significant change was detected in C mineralization rate (C_m) and potentially mineralizable C (C_0). The total amounts of mineralizable carbon (C_m) and nitrogen (N_m) significantly decreased in 15-30 cm depth and were very closely correlated with the total amounts of C or N and mineralization rate constants (K).

Keywords: Carbon And Nitrogen Mineralization Potentials, K Constants, Physical and Chemical Properties

INTRODUCTION

Soil biological properties play an important role in the transformation and cycling of plant nutrients, especially carbon and nitrogen. In general, soil organic matter is the main source of N by means of microbial mineralization. Tracy et al. (41) found for winter wheat that no-tilled soils accumulated greater NO_3-N, NH_4-N, PO_4-P at the 0-2.5cm soil depth, than did recently plowed soil. Below the 5cm depth, tillage did not influence net N, P and S mineralization. There were higher carbon mineralization rates early of the incubation in soil from no-till, compared to those measured after plowing treatments, but at the end of the incubation period all treatments were releasing similar amounts of CO_2-

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C (18 and 41) determined nitrogen mineralization potential (N_0) in a soil from a long-term crop rotation tillage experiment and found that the average N_0 was unaffected by tillage or crop rotation in the 0-15 cm depth when sampling was performed in the fall. In the spring sampling, average N_0 for either chisel plowing or no-till was significantly higher than for moldboard plowing. Moldboard tillage also resulted in a significantly lower organic C and a narrower C/N ratio in the top 15cm relative to the no-tilled treatment (18 and 4) also found that N_0 in the surface 15cm layer was higher for the no-tilled than for conventially tilled corn (*Zea mays*) plots. Carter and Rennie (1982) reported that potential net mineralizable C and N were significantly greater in surface soil under zero tillage in comparison to conventional tillage.

Animal manure supplies additional mineralizable C and N that directly stimulates microbial activity and growth (28).Manure improved soil fertility by increasing the labile organic N constituent such as the amino compounds. This was reflected by a higher N-supplying power in manured soils (7). The rate of net mineralization of N depends on manure composition and on soil physical, chemical and biological properties. If animal manure is applied regularly in large quantities over a long period of time, it increases the soil organic matter content, soil porosity, mineralizable N, Na-HCO_3-extractable-P, microbial activity, and reduces bulk density (37, 39 and 36) .

N_0 values can be calculated based on the hypothesis that the rate of N mineralization is proportional to the quantity of N comprising the mineralizable substrate (38). However, N_0 is affected by many factors such as moisture, aeration, temperature, nature and quantity of organic matter, nature and quantity of the previous crop residues as well as by, other soil physical, chemical, and biotic properties (35 and17).

Tillage and manure application influence soil moisture, soil temperature, pH, soil organic matter (OM) distribution, and soil physical, chemical and biological properties and thus their rates (K_n, K_c) and potentials of C and N mineralization (19, 13 and 30)

The objective of this study was to determine the influence of tillage and liquid manure application on some soil physical and chemical properties and on C and N mineralization potential in a meadow soil.

MATERIALS AND METHODS

Soil Sampling

This study was conducted on a silt-loam at the MAPAQ experimental farm in St. Lambert, Quebec, Canada. Treatments were in a split-plot design consisting of no-till and tillage as main plots and three liquid manure rates (0, 50, 100 t ha^{-1}) as sub plots. Since 1978, some plots have never been plowed down (no-tilled treatments) whereas in the tilled treatment, soil was plowed in the fall every 5 years. Liquid manure was applied in the spring of each year. Soil sampling for this study was performed in June 1994 and in July 1995. Soil samples were taken from 0-15 cm and 15-30 cm depths. The moist soil samples were sieved (>6mm) to remove roots and stubble in the field and were kept at 4°C until performing both physical and microbial activity analyses. For chemical analysis, sub-samples were air-dried and screened at 2mm and 250 µm.

Physical Analysis

Distribution of aggregate size was carried out on samples sieved at 6 mm. Structural stability measurements were determined by wet sieving (> 2mm; > 1mm; > 0.5 and 0.25 mm) on moist soil as described by Angers and Mehuys (1993).

Chemical Analysis

Soil pH was measured in a soil:water ratio of 1:2. The organic C content was determined by wet oxidation procedure (42). The total N was estimated by Kjeldahl digestion (32). Macro-and micronutrients were extracted using the Mehlich solution (29). Soil water-soluble C was assessed as described by Dormaar et al. (1984).

Nitrogen and Carbon mineralization measurements (Incubation Studies)

Field-moist samples (400g), were incubated for 270 days in 4-L cylinders to insure optimum aeration and microbial activity (38). Carbon dioxide evolution was trapped in 1N NaOH (5 mL) solution and the excess NaOH was titrated with HCL 1M (5 mL) (1). For N mineralization analysis, the soil samples were leached as described by Stanford and Smith (1972) , with 100 mL of 0.01 *M* $CaCl_2$ followed by 25 mL of N-free nutrient solution (0.002 *M* $CaSO_4.2H_2O$; 0.002*M* $MgSO_4$; 0.005*M* $Ca(H_2PO_4)_2.H_2O$; and 0.0025M K_2SO_4). Nitrogen-N was determined colorimetrically on a Technicon Autoanalyzer.

Data Analysis

Analysis of variance was performed for the effect of tillage and manure on biological, physiological and chemical characteristics by SAS general linear model procedure (34). The multiple comparison test was carried out with protected Fisher's least significant difference (LSD). Linear correlations were calculated for physical and chemical characteristics, and for C and N mineralization parameters. The soil carbon and nitrogen mineralization potentials (C_0 and N_0) were determined by the cumulative model of (16), $I_{ct}=M_0\ (1-e^{-kt})$ where I_{ct} is the cumulative amount of C and N mineralized (mg kg^{-1}) after time t (in wk) and M_0 is the potentially mineralizable C or N and k is the first order rate constant ($week^{-1}$).

RESULTS

Soil Physical Properties

Tillage and manure application did not have any significant effect on soil aggregates distribution. The observed soil structural stability determined by mean weight diameter (MWD) was generally low for this type of soil and was not influenced by tillage or manure application.

Soil Chemical Properties

Chemical properties of soil samples from different tillage and liquid manure treatments are presented in Table 1. Liquid manure application significantly increased soil P, Ca, Mg and Zn levels. In the absence of manure application tillage significantly reduced surface soil (0-15) P content. However surface manured plowed soils had a P levels much higher than those observed in no-tilled soils. At the 15-30cm depth, tillage did not affect soil P content. In both tilled and no-tilled soils the addition of 50 t ha^{-1} liquid manure slightly increased soil pH.

Table 1: Mean squares for the effect of tillage, manure, depth and their interactions on some chemical properties of a meadow soil.

Treatment	pH (H_2O)	P	K	Ca	Mg	Cu	Mn	Zn
Tillage (T)	0.62	4.45**	9.7**	2.64	2.98	4.75	3.65	39.2**
Manure (M)	6.65**	27.3**	0.75	5.66*	5.61*	1.64	1.25	31.6**
Depth (D)	0.08	6.46*	1.59	24.4**	1.08	9.43	0.11	87.9**
T X M	0.41	4.18*	0.98	2.5	1.62	1.96	1.64	23.1**
T X D	0.06	6.13*	0.09	0.0	0.06	4.33	0.13	21.7**
D X M	0.32	5.81**	1.89	1.72	1	1.81	0.95	26.3**
T X M X D	0.58	5.42*	0.14	0.39	1.01	0.68	0.95	16.4*

**, *: Significant at $p \leq 0.01$ and $p \leq 0.05$ respectively

Soil C and N Levels and C and N Mineralization

Results on the influence of both tillage and liquid manure upon soil C and N levels and mineralizable C and N and the statistical analyses of these parameters are presented in Table 2.

Table 2: Mean squares for the effect of tillage, manure, depth and their interactions on carbon and nitrogen mineralization and some chemical characteristics of a meadow soil.

Treatment	C	N	C_s	C/N	OM/C_s	N_m	C_m	C_e	N_e
Tillage (T)	3.39	1.02	14.68**	13.4 **	0.00	13.9 **	0.93	2.8	0.11
Manure (M)	2.84	0.19	34.99**	1.36	3.54	1.47	1.64	3.18	1.8
Depth (D)	44.23**	86**	0.65	47.7**	6.43*	28.2**	8.35**	7.38*	18.92**
T X M	0.92	0.38	17.16**	3.5	3.82*	0.99	1.27	1.71	5.56*
T X D	0.01	0.37	5.69*	0.00	0.62	2.68	0.44	2.09	0.09
M X D	3.77*	2.22	0.61	1.56	0.06	1.59	0.66	0.24	0.98
T X M X D	0.26	1.13	6.68**	3.29	0,18	0.75	0.58	1.13	0.97

**, *; Significant at $p < 0.01$, and $p < 0.05$, respectively.
N_m, total amount of N mineralized and N_e, N mineralized over 10 days.
C_m, total amount of C mineralized and C_{0e}, C mineralized over 10 days.
OM, organic matter
C_s, soluble carbon

Contents of organic carbon are maximum in the upper layer (0-15cm) of the no-tilled treatment that did not received manure and the upper layer of the tillage treatment with 100 t ha^{-1} manure application. The soil N contents significantly decreased in the 15-30cm depth. Tillage and manure application did not have significant effect on soil C and N contents. Without manure application, tillage slightly increased soil soluble carbon (C_s). However, soils receiving 100 t ha^{-1} liquid manure had the highest content of C_s which was significantly decreased by tillage. The mineralized C (C_e) significantly decreased in 15-30cm depth over 10 days. Tillage significantly increased the net mineralized nitrogen (N_m) and the mineralized N (N_e) significantly decreased in 15-30cm depth over a 1.4 wk period. Cumulative net mineralized N and C showed a curvilinear relationship over time. A significant interaction between tillage and manure was observed on initial mineralized N. Figures 1 and 2 illustrate the effect of tillage and liquid manure application on the cumulative C and N mineralized in 270 days incubation**.**

Soil C and N mineralization potentials

Results of the effect of both tillage and liquid manure on the mineralizable C and N are shown in Table 2. Tillage and manure treatments did not have any significant effect on C_0 and N_0 or on their mineralization rate constants K_c and K_n.

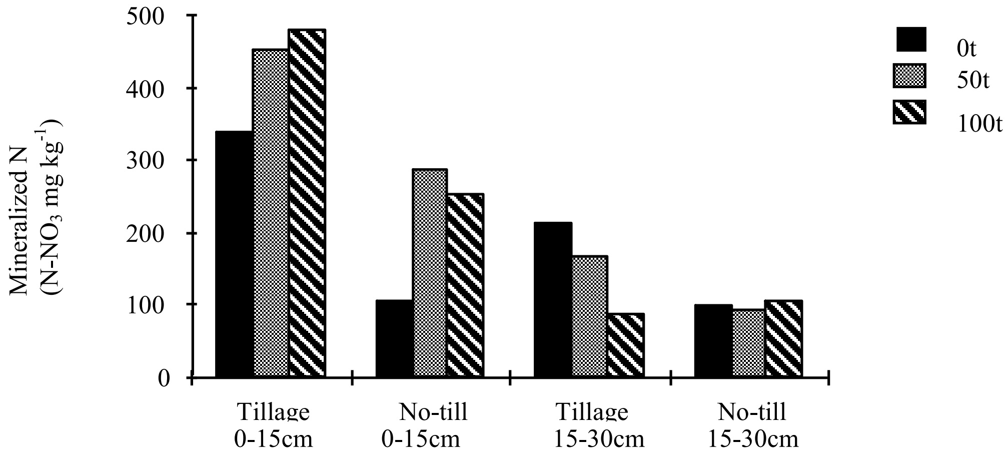

Fig 1: Effect of tillage and liquid manure on cumulative N mineralized over 270 d incubation

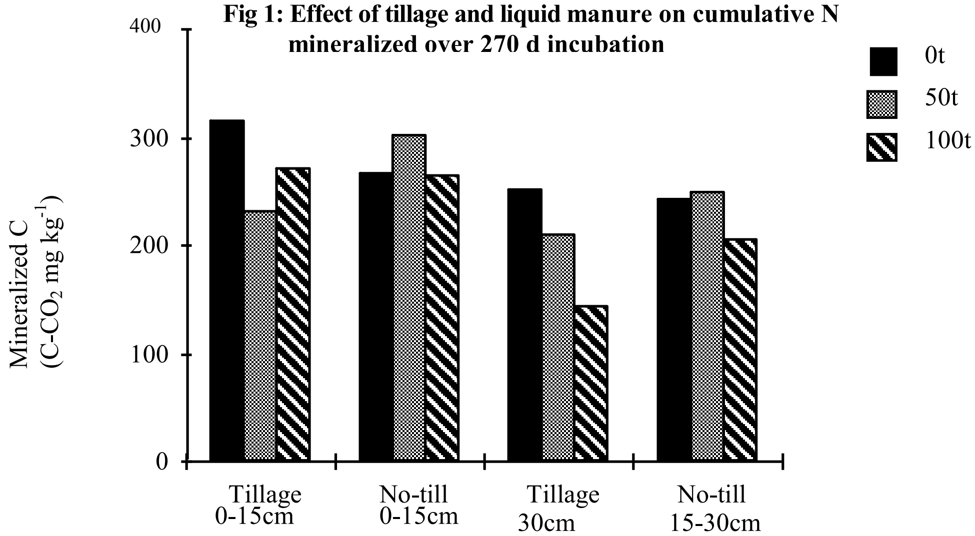

Fig 2: Effect of tillage and liquid manure on cumulative C mineralized over 270 d incubation.

Relationships between calculated and measured C and N mineralization parameters

The linear correlation between calculated mineralization parameters are given in Table 3. The total amount of mineralized N (N_m) was correlated with rate constant Kn ($P \leq 0.05$), and with the N_e fraction ($P \leq 0.01$). The total amount of C mineralized (C_m) was correlated with C_0 ($P \leq 0.05$), and with the initial mineralizable C (C_e) ($P \leq 0.05$). The C_m was inversely related to the rate constant K_c of the Ellert equation ($P \leq 0.01$). The potential C mineralization (C_0) was also inversely related to K_c ($P \leq 0.05$). The initial mineralizable C (C_e) was closely correlated to K_c of the Ellert equation ($P \leq 0.01$).

DISCUSSION

Effect of tillage practice and manure application on soil physical and chemical properties

Physical properties

In this study no difference was observed between soil physical properties measured for meadow soil following different tilth and manure treatments. Sommerfeldt and Chang (36) observed that increasing rates of manure on irrigated land tended to decrease the amount of soil aggregates < 1mm, and to increase those > 1mm of soil. They reported that tillage treatments affected the aggregate size distribution at a depth of 0-15cm. Despite the absence of any statistically significant value for the mean weight diameter (MWD), it was 24% and 15% higher in the no-till soil than in the tilled soil at 0-15cm and 15-30cm depths respectively. Our results corroborate the results of Karlen et al (25) who obtained average stability values (MWD) of 46 and 96% for long-term no-till and plow treatments respectively.

Table 3: Linear correlation coefficient carbon and nitrogen mineralization parameters of meadow soil over 270 days incubation.

	Soil Characteristics							
	N_m	N_0	K_n	N_e	C_m	C_0	C_e	K_c
N_m	-	0.058	-0.399*	0.494**	0.360	-0.250	-0.25	-0.294
N_0		-	-0.337	-0.180	-0.332	-0.204	-0.284	-0.063
K_n			-	0.321	-0.245	-0.205	0.459**	0.712**
N_e				-	0.382	0.006	0.409*	0.156
C_m					-	0.398*	0.417*	-0.473*
C_0						-	-0.233	-0.57**
C_0							-	0.716**
K_c								-

N_0, N mineralization potential; K_n, rate of N mineralization; N_m, total amount of N mineralized and N_e, N mineralized over 10 days.
C_0, C mineralization potential; K_c, rate of C mineralization; C_m, total amount of C mineralized and C_e, C mineralized over 10 days.
***,**: Significant at $p \leq 0.05$, and $p \leq 0.01$, respectively.**

Chemical properties

Phosphorus is relatively immobile in soil and so tends to remain near the site of application unless mixed or incorporated with the soil. Under zero-tillage (ZT) and conventional tillage (CT) available P was concentrated in the surface layer (0-15cm) of soil Grant and Bailey (22). In the meadow soil conventional tillage significantly ($P<0.05$) reduced the level of available P in the surface (0-15cm) layer of the soil that did not receive manure. However Campbell et al (7) reported that the available P level increased significantly following manure application.

Manure treatments did not show any effect on soil K (Tabe 1). However, it was higher in tilled as compared to no-tilled soil. Grant and Bailey. (22) found that the concentration of K was generally higher in the surface soil under zero-tillage, presumably because of the lack of normal mixing attributed to plowing.

Tillage did not have any effect on soil Ca and Mg levels. However as previously observed by N'dayegamiye (31) the addition of manure significantly increased soil Ca and Mg contents.

Tillage practices did not influence the soil pH as observed by Doran (14). Our results indicated, however, that there was a significant effect of manure application on soil pH. The application of 50 t ha^{-1} of manure increased the soil pH values as observed by Antoun et al. (3).

Soil organic C was not affected by the addition of manure and was generally present at higher concentration in the surface soil (0-15cm). In the absence of manure treatment the surface soil under no-tillage contained significantly more carbon than under tillage (Table 2). This is in agreement with the results of Blevins et al (5) who found that in the 0-5cm surface layer organic C and N were approximately twice as high with no-tillage as with conventional tillage. Grant and Lafond (23) also observed that total carbon content was higher in the surface soil of the zero tillage treatment as compared with the conventional tillage system. These results indicated of that tillage influences the organic C pools. In no-tilled soil, C accumulation can be attributed to a decrease in the rate of organic matter oxidation resulting from higher soil moisture and lower temperature Tracy et al. (41). On the other hand, C loss rate from soil is greatly accelerated by conventional tillage as indicated by Doran (12). Richter et al. (33), observed that annual tillage changed dominant plant species from grasses to annual herbs and consequently altered the distribution of carbon in root biomass. In annually tilled plots, herb-dominated root biomass averaged about 232g C/m^2 compared with about 753 g C/m^2 in no-tilled plots. As previously observed by N'dayegamiye and Coté (30), manure application did not affect soil's total N content.

Effect of tillage practice and manure application on C and N mineralization

Cumulative N mineralization (N_m) was higher in plowed treatments than in no-tilled treatments. (Fig.1) Our data are in agreement with the findings of (9 and 18) who found that cumulative N mineralization was higher under conventional than zero tillage system.

We observed that the initial N mineralization (N_e) was higher in the 15-30 cm plowed soil (51%) as compared with no-tilled soil. The observed rates of N_e were in the same range as those obtained from comparable meadow soils from Québec Simard and N'dayegamiye, (35).

The cumulative model of Ellert and Bettany (16) was used to describe the effect of tillage on a meadow soil. Nitrogen mineralization potential (N_0) and N mineralization rate coefficients (K_n) were calculated. The rate constant (K_n) values calculated with this model ranged from 0.0045 to 0.0458 day^{-1}. Nitrogen mineralization potential (N_0) was affected by many factors such as soil moisture, aeration, temperature, the nature and quantity of organic matter, and the nature and quantity of the previous crop residues. Other soil physical and biotic properties can influence K_n (11, 27 and 35). Higher K_n values and lower N_0 values in the no-till treatments compared with those calculated for the plowed soils suggest that the mineralizable substrate concentration was lower but decomposed more rapidly under no-till condition.

Under no-till, the ratios of organic matter/soluble C (OM/Cs) are generally higher than in plowed soils. This indicated that N_0 and K_n were quite different in the two tillage systems. An inverse relationship between N_0, N_m and K_n values was evident, suggesting that a major part of the microbial biomass is easily mineralizable Torben and Rosswal (40).

We did not observe any effect of manure application on the initial N mineralization (N mineralization over 10 days, N_e) or on the total amount of N mineralized (after 270 days incubation, N_m).

Our results with liquid manure are not comparable to those of Campbell et al (7) who observed that mineralizable N increased significantly by the addition of barnyard manure. As observed by Lindemann and Cardenas (26), the addition of 50 and 100 t ha^{-1} liquid manure increased the total amount of N mineralized by 34% and 41% in the 0-15cm soil, respectively. We observed that the total amount of N mineralization decreased with increasing manure application in 15 to-30cm depth in plowed treatments.

In this study, K_n values decreased with increasing rates of manure application. Our results are different from the observations of Boyle and Paul (6), who found that N and C mineralization rates (K_n,K_c) increased with sludge application rate. The average k_n value was slitghly greater for subsoil than surface soil in plowed treatments, as previously calculated by Campbell et al. (8).

As compared to the value for untreated soil, N_0 values were higher with 50 t ha^{-1} (32.45%) and 100 t ha^{-1} (42.78%) manure application in the surface plowed soil. Also N_0 values increased with 50 and 100 t ha^{-1} manure application in no-till soil at all depths. Our results agree with those of Nídayegamiye and Coté (30) who also observed that high liquid manure application rates increased N_0.

C mineralization

Tillage also influenced strongly the amount of soluble C. The soluble C (C_s) has been suggested as an index of organic matter decomposition and humidification, Hu, et al (24). In this study, C_s was higher in plowed treatments than in no-till treatments.

Cumulative net mineralized C showed a curvilinear relationship with time. These results suggested that CO_2-C production decreased during incubation in all samples.

It is interesting to note that in the absence of manure application, the C_s values obtained from plowed soils are negatively correlated with the C_m values (r = -1; for C_s, 10.22 and 14.7 mg kg^{-1} and C_m , 314.54 and 249.62 mg kg^{-1}). Under no-till condition C_s values were positively correlated with the C_m values (r =1 for C_s, 8.73 and 7.64 mg $kg^{-1}$and

C_m. 265.55 and 241.91 mg kg^{-1}). This indicated that the index developed by (Hu, et al., 1972) would apply mainly to forest soils and soils maintained under no-till conditions. In manured soils, calculated r values are not statistically significant but in tilled soils C_s values seem to be positively correlated to the C_m values while the contrary is observed under no-till conditions. More work is required to establish the exact relationship between C_s and C_m values in soils submitted to different tillage and manure applications.

The cumulative model of Ellert and Bettany (16) was used to describe the effect of tillage on the level of the potential mineralizable C (C_0), and to calculate the first order rate constant for mineralizable C (k_c). Tillage showed no significant effect on C mineralization potential (C_0). The K_c values were higher in no-till soil than plowed soil in 0-15 cm depth but were higher in plowed soil than in no-till soil in 15-30cm depth. Higher K_c values were obtained by Franzluebbers et al (20) in wheat and soybean crops under conventional tillage (0.33 day^{-1}) and no-tillage (0.34 day^{-1}).

Results suggested that tillage had no effect on total mineralized C (C_m), however, depth significantly affected C_m values. In fact, under both tillage and zero-tillage systems, greater C_m was observed in surface (0-15cm) soils compared to deeper soil (15-30cm). Carter and Rennie (10) also observed that potential net mineralizable C and N were significantly greater in surface soil under zero-tillage in comparison to conventional tillage. But the reverse situation was observed at the lower depth.

Easily mineralizable C (mineralizable C after 10 days of incubation, C_e) was 51.61% higher in no-till soil than in plowed treatments in 0-15 cm. However, C_e was 70.61% higher in plowed treatments than in no-till soil in 15-30 cm depth. These results reflected the different availability of easily decomposable substrates between no-till and plowed soils. These results were similar to those of Franzluebbers et al (20 and 21) who observed that carbon mineralization was higher in conventional tillage for the 0-20cm depth those in no-till soil.

CONCLUSIONS

The results of this study showed a significant effect of tillage on soil P, K, Zn, soil C/N, soluble C and cumulative mineralized N. Also cumulative N mineralization was significantly affected by tillage and very closely related to levels of soil chemical properties. There were large differences in N mineralization potentials (N_0) in plowed treatments and no-till treatments. Differences in rate constant (K_n) increased in no-till soil as compared to plowed soil. Results obtained in our study indicated that mineralized C (C_m) and C mineralization potential (C_0) were not affected by tillage. The data showed that soil structural stability was not affected by tillage and manure application.

Generally, liquid manure had a significant effect on soil pH, P, Ca, Mg, Zn and soluble C. The data showed that cumulative N mineralization (N_m) and N mineralization potentials (N_0) were greater at 0-15 cm depth in soils receiving manure. However, cumulative N mineralized decreased with increasing manure rates within 15-30 cm depth. The K_n and K_c values decreased with manure application. Potentially mineralizable C and N (C_0, N_0) were higher in the surface (0-15cm) than in the deeper (15-30cm) layers.

These results indicated that tillage and liquid manure application have significantly influenced N and C mineralization parameters and some other soil chemical properties. The results indicated the presence of close relationships between N and C mineralization parameters and some soil chemical properties and suggested that tillage and manure application influence the soil characteristics to some extent. Furthermore, both tillage and manure influenced soil organic matter dynamics and quality.

ACKNOWLEDGMENTS

This work was supported by grants of the Ministere de l'Education du Québec and Service des sols, Ministére de l'Agriculture, des Pecheries et de l'Alimentation du Québec. The authors wish to thank M.R. Laverdiére and A. N'dayegamiye for reviewing the early drafts of the manuscript.

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مطالعه اثرات دراز مدت شخم و کود مایع بر روی خواص فیزیکو- شیمیایی و پتانسیل معدنی شدن نیتروژن و کربن خاک

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چکیده- این تحقیق با هدف انجام پژوهش اثرات شخم و کود مایع بر روی تعدادی از فرایند های فیزیکو- شیمیایی و پتانسیل معدنی شدن نیتروژن و کربن خاک مراتع صورت پذیرفته است. نتایج نشان داد که شخم و کاربرد کود مایع بر روی مقدار مس، منگنز، و نیتروژن کل و کربن آلی در عمق ۰-۱۵ سانتی متری خاک بعد از ۱۵ سال بی اثر بوده است. مقدار فسفر ، کلسیم ، منیزیم و روی در اثر افزایش کاربردی کود مایع و مقدار مواد آلی(OM) و نیتروژن کل خاک در عمق ۱۵-۳۰ سانتی متری کاهش می یابد. همچنین تغییراتی در پایداری خاکدانه ها در دو لایه خاک مشاهده نگردید. نتایج نشان داد که اختلاف معنی داری در مقدار کربن محلول و نسبت C/N خاک در تیمار های شخم و بدون شخم وجود دارد. بررسی ها نشان داد که در اثر افزایش ۱۰۰ تن کود مایع در هکتار، مقدار کربن محلول خاک به طور معنی داری افزایش یافت. با در نظر گرفتن نتایج بدست آمده چنین استنباط می گردد که شخم به طور معنی داری مقدار معدنی شدن نیتروژن (N_m) را افزایش می دهد. میزان پتانسیل معدنی شدن نیتروژن (N_0) در خاک شخم خورده بیشتر از تیمار های بدون شخم بوده و در عمق ۰-۱۵ سانتی متری حد اکثر است. بعلاوه یک اثر متقابل بین شخم و کود مایع بر روی معدنی شدن نیتروژن بعد از ۱/۴هفته وجود دارد. نتایج تجزیه واریانس نشان داد که شخم و کود مایع بر روی معدنی شدن کربن (C_m) و پتانسیل معدنی شدن کربن(C_0) به طور معنی دار موثر نمی باشد. همچنین معدنی شدن کربن و نیتروژن در عمق ۱۵-۳۰ سانتی متری عمق خاک کاهش یافته و ارتباط مستقیم با مجموع کربن و نیتروژن و ثابت معدنی شدن (K) دارد.

واژه های کلیدی: پتانسیل معدنی شدن کربن و نیتروژن ، ثابت معدنی شدن، خواص فیزیکو- شیمیایی.

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*به ترتیب استاد یار و استاد
** مکاتبه کننده