INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
09–086/CAJ/2009/11–5–515–520
http://www.fspublishers.org

Full Length Article

Variations in Nitrogen Mineralization from Different Manures in Semi-arid Tropics of Sudan with Reference to Salt-affected Soils

A.M. YOUSIF AND A.R. MUBARAK[1]†
Department of Soil and Water Sciences, Faculty of Natural Resources and Environmental Studies, University of Kordofan, Elobeid, Sudan
†Desertification and Desert Cultivation Studies Institute, University of Khartoum, Shambat, Sudan
[1]Corresponding author's e-mail: mubarakaba@yahoo.com

ABSTRACT

Twelve weeks laboratory incubation experiment was carried out to: (1) determine variations in N mineralization of various manures (chicken manure, farm yard, pigeon, guano & sewage sludge) and to (2) examine the relationship between N mineralization and initial chemical composition. Manures were aerobically incubated in two types of soils (saline & non-saline) at a rate of 200 mg N kg^{-1} soil and mineral N was monitored after 0, 2, 4, 6, 8, 10 and 12 weeks. With the exception of sewage sludge and pigeon manure, NO_3-N was the dominant form of mineral N. Net N released from the manure in the saline and non-saline soils was negatively correlated with initial N content, C/N ratio and lignin (r^2 = -0.837/-0.385, -0.719/-0.095, -0.448/-0.903), respectively. Cellulose and hemicellulose in saline soils were positively correlated with net N released (r^2=0.558 & 0.613), however in non-saline soils net N released was positively correlated with cellulose (r^2 = 0.899) and negatively with hemicellulose (r^2 = -0.118). It could be concluded that monitoring mineral N release during decomposition of manures is a useful tool for fertilization programs that include incorporation of organic sources of N.

Key Words*:* Decomposition; Initial chemical composition; Organic sources; Problematic soils; Relationship

INTRODUCTION

Soil salinization is one of the major factors that contribute to land degradation and decrease in crop yield (Al Yassin, 2005; Anjum *et al*., 2005). It exists in areas with precipitation to evaporation ratios of about 0.75 or less (Brady & Weil, 2000). In Sudan, it was found that about 250 thousand hectares in the Northern Sudan were affected, to some degree, by sodicity and/or salinity (Ali & Fadil, 1977). The Soil Survey Department stated that the total area affected by salinity and/or sodicity was estimated at 2.5 million hectares. The largest areas are mostly found to the north of Khartoum along both banks of the River Nile. Amelioration of salt-affected soils necessitates the replacement of Na^+ by Ca^{2+} cations, which can be done chemically or by using organic wastes, which was found to be a good strategy, especially in arid regions (Garcia, 2000). A number of organic N-containing materials, such as animal manure or sewage sludge, are being used as soil amendments and a source of N and for improving the soil quality. Mineralization of nutrients from an organic amendment depends on biotic (Rowell *et al.,* 2001) and abiotic factors (Nakhone & Tabatabai, 2008).

The interaction between plant residue quality and salinity affecting nitrogen mineralization/immobilization is not well understood (Nourbakhsh & Hossein, 2006). In Sudan, studies on N mineralization from manures under salt-affected soils are greatly lacking. Measurement of N mineralization and immobilization rates will enable mathematical models of nutrient release and leaching to be developed, which in turn can be used to provide management guidelines for waste application on land (Zaman *et al.,* 1998). Therefore, the objectives of this study were to: (1) monitor NH_4-N and NO_3-N release from various locally available manures and to (2) Examine the relationship between N released and their initial contents of N, C/N, lignin, cellulose and hemicellulose.

MATERIALS AND METHODS

Soil and manure. Two soil types (saline & non-saline) were collected from the top 30 cm depth from two sites Sunduse Scheme, south of Khartoum and the university of Khartoum experimental research farm, respectively. The saline and non-saline soils were classified as fine, montmorillonitic, isoh-yperthermic, vertic natrargid and fine, montmorillonitic, iso-hyperthermic, typic chromustert (Soil Survey Staff, 1996). Roots and other plant materials were removed, crushed and sieved (2 mm). Manures were oven-dried (65 -70°C) for 48 h, sieved through a 2-mm

To cite this paper: Yousif, A.M. and M.A. Abdalla, 2009. Variations in nitrogen mineralization from different manures in semi-arid tropics of Sudan with reference to salt-affected soils. *Int. J. Agric. Biol*., 11: 515–520

sieve, thoroughly mixed and stored for subsequent analysis (pH $_{(1\text{ g: }10\text{ mL D. water})}$, OC using the modified Walkley-Black methods (Walkley & Black, 1934), TN (Bremner & Mulvaney, 1982), lignin and cellulose were determined by the acid-detergent-fibre (ADF) method and soluble polyphenols were extracted using 70% acetone and determined gravimetrically by the ytterbium precipitation method (Reed *et al.,* 1985). Chemical properties of the manures are presented in Table. I.

Manure collection. 1. Chicken manure (CM) was obtained from a poultry farm in North Khartoum.

2. Pigeon manure (PM) was obtained from private rearing farmers located in Omdurman.
3. Farm yard manure (FYM) was obtained from farms near by the Farm of the Faculty of Agric., U. of K.
4. Sewage sludge (SS) was obtained from the main treatment station of Khartoum State.
5. Guano manure (GM) was obtained from the North State.

Incubation procedure. Nitrogen mineralization from the manure and the soil mixtures was determined using the non-leaching and aerobic incubation technique of Sommers *et al.* (1980). A sample (500 g air dried soil, 2 mm ∅ sieve) of each soil (saline & non-saline) was thoroughly mixed with each of the 5 types of manures (CM, PM, FYM, SS & GM) at a rate equivalent to 200 mg N kg^{-1} soil (2.2, 10.3, 5.0, 7.2 & 2.8 g dry matter of the manure), respectively. A control treatment (without manure) from each soil was included. All treatments (12) were assigned in polythene bags (25 X 10 cm) and treatments were replicated three times (total experimental units are 36), placed in the laboratory of the Desertification and Desert Cultivation Studies Institute, University of Khartoum and at room temperature (25ºC). Soil moisture was kept constant at 80% of water holding capacity using distilled water. This is achieved by regular weighing of the bags (every 3 days) and also, to keep bags aerobic.

Mineral N (NH_4-N, NO_3-N) was determined at 0, 2, 4, 6, 8, 10 and 12 weeks from incubation. At each sampling week exactly two sub-samples of 10 g each were taken from each treatment. The first sub-sample was used for the determination of soil moisture content, while the other was extracted after shaking (for one hour) with 40 mL of 2 M KCL and filtered through Whattman No. 42 filter paper. 10 mL of the extract was steam distillated with 0.2 g of MgO and Devarda alloy for the determination of NH_4-N and NO_3-N, respectively. Ammonia was received in 20 mL of 20% Boric acid mixed with methyl red and bromocresol green indicators and back titrated with 0.01 N HCL (Keeny & Nelson, 1982).

$$\frac{NH_4\text{-N/or } NO_3\ (\text{mg/kg}) = (S-B) \times N \times 14 \times 10^{3} \times D.F}{\text{Dry wt soil}}$$

Where,

S: Volume of HCL for the sample

B: Volume of HCL for the Blank

N: Normality of HCl

D.F: Dilution factor

Determination of net N mineralization/immobilization. Total mineral N (TMN) in each week was taken as the summation of NH_4^+- N and NO_3^- N in similar weeks. However, Net N mineralization/immobilization (+ve values indicate mineralization, while -ve values indicate immobilization) from amended treatments was calculated by subtracting soil mineral N of the control at the week 12 from the amended treatment of the same week. Relationship between N mineralization and initial manure chemical composition (TN, C/N, lignin, cellulose & hemicellulose was determined using values of TMN of week 12 & net N mineralization/immobilization). Bets fitting models and R^2 values were recorded.

Statistical analysis. Significant differences among treatments were determined using SAS (1987) and means were separated using Least Significant Difference (LSD).

RESULTS

Manure chemical composition. Initial composition of manures shows clear variations (Table I). Accordingly, pH ranged from 5.9 to 7.4, organic carbon ranged between 9 (PM) and 36 (FYM) and N ranged from 1.9 to 9.2 mg kg^{-1}. The lowest and the highest N concentration were observed in FYM and pigeon, respectively. The C/N ratio shows a trend of PM < CM = GM < SS < FYM. Calcium content ranged from 0.03 to 0.17%, while magnesium ranged between 0.16 and 1.03%. The contents of P ranged from 2.8 to 2.9%. All manures have high lignin content of 26.1-31.5% except the CM has the lowest content (14.9%). Chicken manure has the highest cellulose content (32.3%), while SS sludge and pigeon had the lowest values (6.7 & 7.0%), respectively. hemicellulose ranged from 6.5 to 32.9%.

Effect of Manure Type and Salinity on N Mineralization

Week zero. Accumulation of NH_4^+- N, NO_3^- N and TMN (NH_4^+- N + NO_3^-) in the saline and non-saline soils are illustrated in (Fig. 1 to 6). In both soils, manure type had significant ($P \leq 0.0001$) effect on mineralization. Initially, the average mineral N content from CM and GM (163.6 & 158.3 mg N kg^{-1} soil), respectively was higher than all other manures. The lowest N was observed in soils amended with SS and FYM (106.9 & 92.4 mg N kg^{-1} soil), respectively. Mineral N release was in the order of CM > GM > PM > SS > FYM. Salinity was observed to have significant ($P \leq 0.0001$) negative effect on mineral N. Immediately after manures incorporation, mineral N in saline soil (86.7 mg N kg^{-1} soil) was about half that determined in non-saline soils (161.7 mg N kg^{-1} soil). All individual manures showed high mineral N in non-saline compared to saline soils.

Week two. In both soils, manure type had significant ($P \leq 0.0001$) effect on N mineralization. The average mineral N content from GM (360.9 mg N kg^{-1} soil) was significantly higher than all other manures. The lowest mineral N was observed in the soil amended with PM (136.0 mg N kg^{-1}

Table I. Initial chemical composition of the manures (average ± standard deviation)

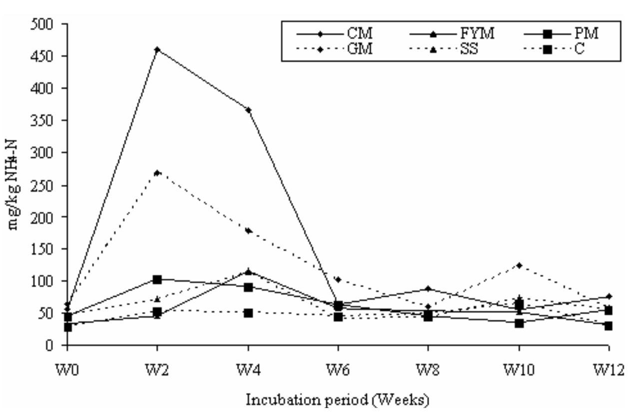
		%								
Manure type	**pH**	**OC**	**TN**	**C/N**	**Ca**	**Mg**	**P**	**Lignin**	**Cellulose**	**Hemi**
CM	6.7 ± 0.06	15 ± 0.6	4.0 ± 0.03	3.8 ± 0.1	0.17 ± o.o2	1.03 ± 0.04	2.8 ± 0.01	14.9 ± 1.1	32.3 ± 1.1	23.0 ± 0.5
PM	6.0 ± 0. 02	9 ± 0.3	9.2 ± 0.02	0.97 ± 0.1	0.03 ± 0.01	0.18 ± 0.01	2.8 ± 0.01	26.1 ± 1.2	7.0 ± 1.6	25.8 ± 0.6
FYM	7.4 ± 0.03	36 ± 0.5	1.9 ± 0.02	18.9 ± 0.4	0.04 ± 0.01	0.21 ± 0.02	2.9 ± 0.02	30.2 ± 1.1	18.2 ± 1.2	6.5 ± 1.9
SS	7.1 ± 0.10	24 ± 0.3	2.8 ± 0.03	8.75 ± 0.2	0.10 ± 0.01	0.23 ± 0.01	2.8 ± 0.04	26.5 ± 2.9	6.7 ± 2.9	32.9 ± 1.2
GM	5.9 ± 0.06	27 ± 1.0	7.2 ± 0.02	3.8 ± 0.1	0.04 ± 0.01	0.16 ± 0.01	2.8 ± 0.05	31.5 ± 05	11.7 ± 0.5	12.7 ± 0.7

CM: chicken manure, FYM: farm yard manure, PM: pigeon manure, SS: sewage sludge, GM: guano manure

Table II. Relationship between total Net mineral N and manure chemical composition under saline and non-saline soil conditions

Manure parameter	**Total mineral N (NH_4-N + NO_3-N)**			
	Saline soil		**Non-saline soil**	
	Equation	**R^2**	**Equation**	**R^2**
TN (%)	$Y= - 26.1 x^2 + 301.4 x – 452.4$	0.96	$Y= - 22.9 x^2 + 255.9.4 x – 356.6$	0.75
C/N	$Y= - 11.1 x + 284.4$	0.29	$Y = - 8.6 x + 240.0$	0.18
Lignin (%)	$Y= 3.4 x^2 – 163.0 x + 2012$	0.56	$Y = - 341.7 \ln (x) = 1278.1$	0.52
Cellulose (%)	$Y= 0.3 x^2 – 6.0 x+ 197.5$	0.20	$Y = 10.4 x + 19.9$	0.60
Hemicellulose (%)	$Y= - 1.2 x^2 + 46.9 x - 132.7$	0.43	$Y= -1.3 x^2 + 48.8 x - 175.2$	0.50
	Net Mineral N			
TN (%)	$Y= - 26.1 x^2 + 301.4 x – 560.6$	0.96	$Y= - 22.9 x^2 + 255.9.4 x – 439.1$	0.75
C/N	$Y= - 11.1 x + 176.4$	0.29	$Y = - 27.3 x + 177.3$	0.09
Lignin (%)	$Y= 3.4 x^2 – 163.0 x + 1903.9$	0.56	$Y= 3.2 x^2 – 162.0 x+ 2009.7$	0.89
Cellulose (%)	$Y= 0.3 x^2 + 6.0 x + 89.3$	0.20	$Y= 0.5 x^2 – 7.9 x + 64.5$	0.66
Hemicellulose (%)	$Y= - 1.2 x^2 + 46.9 x- 240.8$	0.43	$Y= -1.3 x^2 + 48.8 x - 257.6$	0.50

Fig. 1. NH_4-N (mg/kg soil) accumulated from manure in the saline soil



soil). The content was in the order of GM > CM > FYM > SS > PM. In this week, salinity was observed to have significant ($P \leq 0.0001$) positive effect on mineral N release. The average mineral N in saline soil (299.9 mg N kg^{-1} soil) was about double that determined in non-saline soils (126.737 mg kg^{-1} soil). All individual manures showed high mineral N in saline compared to non- saline soils.

Week four. Manure type had significant ($P \leq 0.0001$) effect on N mineralization. The mineral N content from C.M (415.6 mg N kg^{-1} soil) was statistically higher than all other manures. The lowest mineral N was observed in soils amended with PM (124.9 mg N kg^{-1} soil). The content was in the order CM > GM > SS > FYM > PM. Salinity was also, observed to have significant ($p \leq 0.0001$) positive effect on mineral N. Mineral N in saline soil (233.1 mg N kg^{-1} soil) was more than that determined in non-saline soils (209.7 mg N kg^{-1} soil). Most individual manures showed high mineral N in saline compared to non-saline soils.

Week six. N mineralization and in both soils, was still significantly ($P \leq 0.0001$) affected by manure type. Mineral N from CM (331.6 mg N kg^{-1} soil) was statistically higher than all other manures. The lowest mineralized N was observed in soils amended with SS and FYM (109.2 mg N kg^{-1} soil). The content was in the order CM > PM > GM > SS = FYM. After this week, salinity was observed to have a significant ($p \leq 0.0001$) negative effect on mineral N. Accordingly, mineral N in saline soil (180.4 mg kg^{-1} soil) was significantly lower than that in non-saline soil (201.7 mg N kg^{-1} soil).

Week eight. Similarly, manure type had significant ($P \leq 0.0001$) effect on N mineralization. The mineral N content from CM (599.1 mg N kg^{-1} soil) was statistically higher than all other manures. The lowest mineral N was observed in soils amended with PM and FYM (82.2-93.0 mg N kg^{-1} soil), respectively. The content of mineral N was in the order CM > GM > SS > FYM > PM. Salinity had no significant ($P \leq 0.2250$) effect on mineral N, where mineral N in saline soil (212.9 mg N kg^{-1} soil) and non-saline soils (203.4 mg N kg^{-1} soil) showed almost similar results.

Week ten. Mineral N content from CM (610.8 mg N kg^{-1} soil) was statistically ($P \leq 0.0001$) higher than all other manures. The lowest mineral N was observed in soils amended with PM and FYM (108.8-131.7 mg N kg^{-1} soil), respectively. The content of mineral N was in the order CM

Fig. 2. NH_4-N (mg/kg soil) accumulated from manure in the non-saline soil

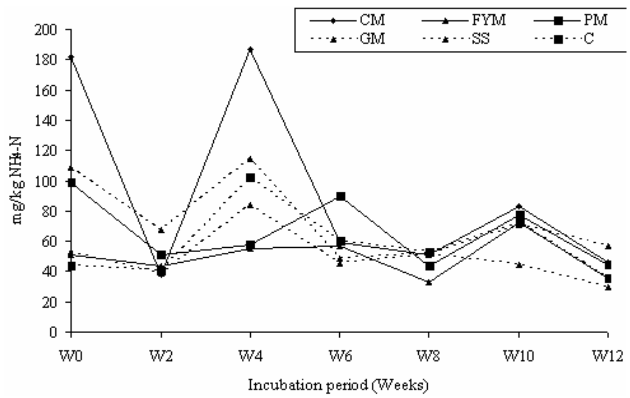


Fig. 3. NO_3-N (mg/kg soil) accumulated from manure in the saline soil

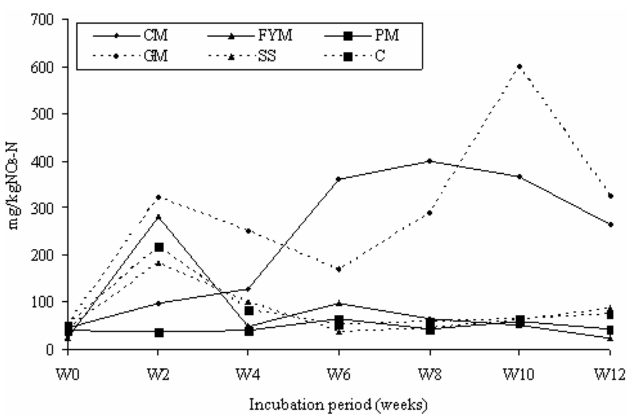
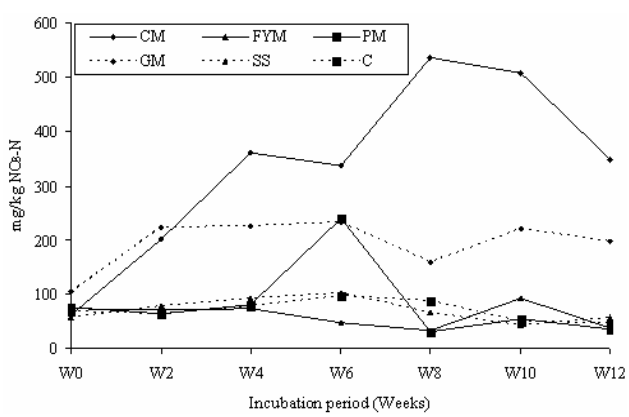


Fig. 4. NO_3-N (mg/kg soil) accumulated from manure in the non-saline soil



> GM> SS > FYM > PM. After this week, salinity was observed to have significant ($P \leq 0.0001$) negative effect on mineral N where mineral N in saline soil (243.8 mg N kg^{-1} soil) was significantly lower than that in non-saline soils (299.1 mg N kg^{-1} soil).

Week twelve. Mineral N content from CM (314.2 mg N kg^{-1} soil) was statistically ($P \leq 0.0001$) higher than that of other manures. The lowest mineral N was observed in soils amended with FYM (68.0 mg N kg^{-1} soil). The content of mineral N was in the order CM > GM > PM = SS > FYM. Salinity was observed, here to restore it's positive effect ($p \leq 0.0001$) on mineral N, where mineral N in saline soil (178.6 mg N kg^{-1} soil) was significantly higher than that in non-saline soil (146.6 mg N kg^{-1} soil).

Relationship between manure chemical composition and N mineralization. In the saline soils, N mineralization/immobilization (both TMN & net N) was best related to initial TN content, where the polynomial model showed the best fitting model (Table II). Relationship to initial lignin was found to come next to TN. However, the study showed weak relationship with other initial properties (e.g., C/N, cellulose & hemicellulose). However the situation in the non-saline shows that TMN is best related to both initial TN ($R^2 = 0.75$) and cellulose ($R^2 = 0.665$), whereas net N was best fitted to lignin ($R^2 = 0.89$), TN ($R^2 = 0.75$) and cellulose ($R^2 = 0.66$).

Fig. 5. Total mineral N (NH_4-N + NO_3-N) mg/kg soil accumulated from manure in the saline soil

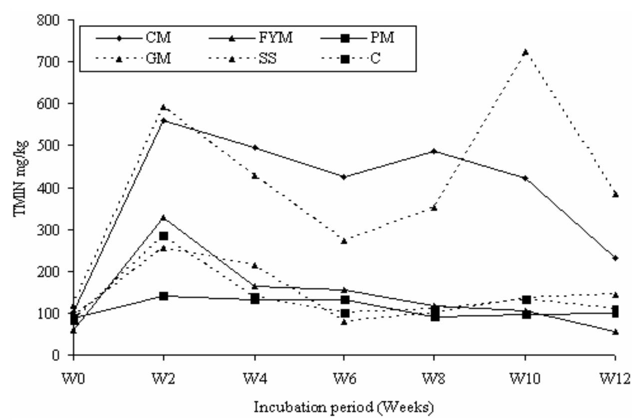
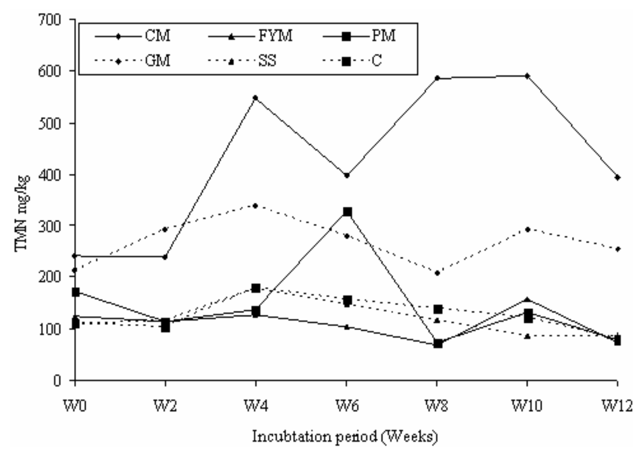


Fig. 6. Total mineral N (NH4-N + NO3-N) mg/kg soil accumulated from manure in the non-saline soil



DISCUSSION

N mineralization/immobilization from manures. In this study, NO_3-N was the dominant form of inorganic N, which did not agree with that reported by Maithani *et al.* (1998) and Calderon *et al.* (2004), who found that the NH_4-N was the dominant form of inorganic N. This could be due to slightly alkaline nature of the soil pH (>7.0), which may have increased the growth and activity of autotrophic nitrifiers in the soils (Chao *et al.,* 1993).

The fluctuations of NH_4-N release during the first two weeks of incubation suggest a loss of NH_4-N from the manure by NH_3 voltalization. The decline in soil NH_4-N between weeks zero and week two can be explained by an event of rapid nitrification combined with denitrification. The fact that the soil NO_3-N did not increase between week one and two of the incubation interval suggests that the NO_3-N was taken up by the denitrifiers as soon as it was produced, preventing an increase in the standing NO_3-N pool, because of restricted aeration, which encourages denitrification (Calderon *et al.,* 2004). This close coupling between nitrification and denitrification has been observed by others and resulted in a high proportion of the mineralized N to be lost as N gas (Nielsen & Revsbech, 1998; Meyer *et al.,* 2002).

The total amount of N released from the control and manures treatments was 225.06 and 56.28 to 385 mg N kg^{-1} soil, respectively for saline soil and 121.5 and 79.8 to 323.8 mg N kg^{-1} soil, for non-saline soil, respectively. These values are comparable with some of the results reported in the literature, but are different from others. For example, Lindemann and Cardenas (1984) showed that 137.4 and 182.6 mg N kg^{-1} soil was released at SS rates of 330 and 600 mg N kg^{-1} soil, respectively. These variations are likely to be due to the differences in soils, waste materials, C/N ratios, application rates, and environmental conditions used for the different studies.

Effects of manure and soil salinity on N mineralization. The differences in N mineralization among the manures studied; CM, FYM, PM, GM and SS were larger as expected from their initial characterization. Manuring soils is sometimes followed by an extended period where N immobilization limits N availability (Kirchmann & Lundvall, 1993). Other workers have found that laboratory incubations of manured soil lasting for weeks may result in negative N mineralization values (Eneji *et al.,* 2002), while longer incubations resulted in positive values (Hadas & Portnoy, 1994). However, waiting for more than 10 weeks for positive N mineralization would miss the period of high N demand of most crops if the soils are planted soon after manuring the field (Calderon *et al*., 2004).

The net N mineralization/immobilization ($N_{m/i}$) was significantly correlated with the initial N concentration of the manures in both saline and non-saline soils. The positive response of N mineralization/immobilization ($N_{m/i}$) to the manure N concentration in the presence of salinity reveals that N content of the manure is still a limiting factor for decomposer population; even when they have been exposed to salinity stress as high as 10dSm^{-1}. In this study the significant correlation among net rates of N transformation and N concentration in each of the manures is consistent with previous studies (Seneviratne, 2000; Trinsoutrot *et al*., 2000).

A significant polynomial relationship was observed between net Nm/i in saline and non-saline soils. Cellulose correlated positively with N mineralization under the non-saline soils. This could have been a result of the alkaline pH of the soil (pH>7). The pH optima for the activity of the cellulose degrading enzymes in most terrestrial fungi lie between 3.5 and 5 (average 4.3), whereas those of the cellulose degrading enzymes range from 4 to 7 (Seneviratne *et al.,* 1999). In this study, C/N was found to be not a good predictor of N mineralization as previously reported by Thurie`s *et al.* (2001).

CONCLUSION

In crux, NO_3-N was the dominant form of inorganic N in non-saline soils for all the manures and also, in saline soils. Nitrogen mineralization depends on initial content of manure N, lignin and cellulose. N, in general is affected negatively by salinity.

REFERENCES

Ali, M.A. and O.A.A. Fadil, 1977. Irrigation of a saline-sodic site in the Sudan Gezira. II. Salt movement and sodicity changes. *Trop. Agric*., 54: 279–283

Al Yassin, A., 2005. Adverse Effects of Salinity on Citrus. *Int. J. Agric. Biol*., 4: 668–680

Anjum, R., A. Ahmed, Rahmatullah, M. Jahangir and M. Yousif, 2005. Effect of soil salinity/sodicity on the growth and yield of different varieties of cotton. *Int. J. Agric. Biol*., 4: 606–608

Brady, N.C. and R.R. Weil, 2000. *Elements of the Nature and Properties of Soils*, pp: 252–289. Prentice Hall, Inc.: Englewood Cliffs, NJ

Bremner, J.M. and C.S. Mulvaney, 1982. Nitrogen-total. *In:* AL-Page, R.H. Miller and D.R. Keeny (eds.), *Methods of Soil Analysis, Part2: Chemical and Microbiological Properties, Agronomy Monograph No. 9,* 2nd edition, pp: 595–622. American Society of Agronomy, Madison, WI

Calderon, F.J., G.W. McCarty, J.A. Van Kassel and J.B. Reeves, 2004. Carbon and nitrogen dynamic during incubation of manured soil. *Soil Sci. Soc. American J*., 68: 1592–1599

Chao, W.L., K.D. Gan and C.C. Chao, 1993. Nitrification and nitrifying potential of tropical and subtropical soils. *Biol. Fertil. Soils*, 15: 87–90

Eneji, A.E., T. Honna, S. Yamamoto, T. Saitr and T. Masuda, 2002. Nitrogen transformation in four Japanese soils following manure+urea amendment. *Comm. Soil Sci. Plant Anal*., 33: 53–66

Garcia, C., 2000. Microbial activity in soils of SE Spain exposed to degradation and desertification processes. Strategies for their rehabilitation. *In:* Garcia, C. and M.T. Hernandez (eds.), *Research and Perspectives of Soil Enzymology in Spain*, pp: 93–143. CEBAS-CSIC, Spain

Hadas, A. and R. Portnoy, 1994. Nitrogen and carbon mineralization rates of composted manures incubated in soil. *J. Environ. Qual*., 23: 1184–1189

Keeny, D.R. and D.W. Nelson, 1982. Nitrogen-Inorganic forms. *In:* Eds. AL-Page, R.H. Miller and D.R. Keeny (eds.), *Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties, Agronomy Monograph No. 9,* 2nd edition, Vol. 64, pp: 36–98. American Society of Agronomy, Madison, WI

Kirchmann, H. and A. Lundvall, 1993. Relationship between N immobilization and volatile fatty acids in soil after application of pig and cattle slurry. *Biol. Fertil. Soils*, 15: 161–164

Lindemann, W.C. and M. Cardenas, 1984. Nitrogen mineralization potential and nitrogen transformation of a sludge amended soil. *Soil Sci. Soc. American J*., 48: 1072–1077

Maithani, K., A. Arunachalam, R.S. Tripathi and H.N. Pandey, 1998. Influence of leaf litter quality on N mineralization in soils of subtropical humid forest re-growths. *Biol. Fertil. Soils*, 27: 44–50

Meyer, R.L., T. Kjaer and N.P. Revsbch, 2002. Nitrification and denitrification near a soil-manure interface studied with a nitrate-nitrite biosensor. *Soil Sci. Soc. American J*., 66: 498–506

Nakhone, L.N. and M.A. Tabatabai, 2008. Nitrogen mineralization of leguminous crops in soils. *J. Plant Nutr. Soil Sci.,* 171: 231–241

Nielsen, T.H. and N.P. Revsbech, 1998. Nitrification, denitrification and N-liberation associated with two types or organic hot-spots in soil. *Soil Biol. Biochem*., 30: 611–619

Nourbakhsh, F. and A.R. Hossein, 2006. Plant residue quality influences the response of N mineralization to salinity. *Archiv. Agron. Soil Sci*., 52: 571–577

Paul, E.A. and F.E. Clark, 1989. *Soil Microbiology and Biochemistry*. Academic Press, San Diego, CA

Reed, J.D., P.J. Horvath, M.S. Allen and P.J. Van Soest, 1985. Gravimetric determination of soluble phenolics including tannins from leaves by precipitation with trivalent ytterbium. *J. Sci. Food Agric.*, 36: 255–261

Rowell, D.M., C.E. Prescott and C.M. Preston, 2001. Decomposition and nitrogen mineralization from bio-solids and other organic materials: Relationship with initial chemistry. *J. Environ. Qual.*, 30: 1401–1410

SAS Institute Inc., 1987. *SAS/STAT. Guide for Personal Computers*, *Version 6*. SAS Institute Inc., Cary.

Seneviratne, G., L.H.J. Van Holm, L.J. Balachandra and S.A. Kuiasooriya, 1999. Differential effects of soil properties on leaf nitrogen release. *Biol. Fertil. Soils*, 28: 238–243

Seneviratne, G., 2000. Litter quality and nitrogen release in tropical agriculture: a synthesis. *Biol. Fertil. Soils*, 31: 60–64

Soil Survey Staff, 1996. *Keys to Soil Taxonomy,* 7th edition. United States Department of Agriculture, Washington, D.C. USA

Sommers, L.E., D.W. Nelson, C. Parker and J. Graveel, 1980. *Optimum Utilization of Sewage Sludge on Agricultural Land*. Annual Report from Purdue Agriculture Experimental Station to Regional Project W-124. Agricultural Experiment Station, Purdue Univ., West Lafayette, IN

Thurie`s, L., M. Pansu, C. Feller, P. Herrmann and J.C. Re´my, 2001. Kinetics of added organic matter decomposition in a Mediterranean sandy soil. *Biol. Fertil. Soils*, 33: 997–1010

Trinsoutrot, I., S. Recous, B. Bentz, M. Linères, D. Chèneby and B. Nicolardot, 2000. Biochemical Quality of Crop Residues and Carbon and Nitrogen Mineralization Kinetics under Non-limiting Nitrogen Conditions. *Soil. Sci. Soc. American J*., 64: 918–926

Walkley, A. and I.A. Black, 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid method. *Soil Sci*., 37: 29–38

Zaman, M., K.K. Cameron, J. Dih and M.J. Noonan, 1998. Nitrogen mineralization rates from soil amended with dairy pond waste. *Australian J. Soil Res*., 36: 217–230

(Received 17 March 2009; Accepted 05 May 2009)