International Journal of Agricultural Technology 2018 Vol. 14(7): 1999-2014
Available online http://www.ijat-aatsea.com
ISSN: 2630-0613 (Print) 2630-0192 (Online)

Effects of organic fertilizer application on the transformation of nitrogen in paddy soil

Supsuan, P., Surin, P. and Yampracha, S. *

Department of Plant Production Technology, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand.

Supsuan, P., Surin, P. and Yampracha, S. (2018). Effects of organic fertilizer application on the transformation of nitrogen in paddy soil. International Journal of Agricultural Technology 14(7): 1999-2014.

Abstract The effect of different types of organic fertilizer on the availability of nitrogen in paddy soil was determined. The soil samples were collected from an organic rice field in Nongchok District, Bangkok. The results showed that the soil pH of all treatments increased from 5.3 to 6.9 and 7.2. The cumulative N mineralization of sunn hemp was the highest (121.33 mg N/kg), but no significant difference was compared to for other organic fertilizers. The change of AHN was increased at the start of incubation and decreased after 70 days of incubation. It indicated that the AHN changed to ammonium. The potential N mineralization of control, cow manure, compost and sunn hemp were 95.34, 109.90, 107.23 and 114.53 mg N/kg, respectively. The K values indicated the mineralization rate of control, cow manure, compost and sunn hemp which were 0.2095, 0.2075, 0.2053 and 0.1992 mg N/kg, respectively.

Keywords: Nitrogen, Organic fertilizers, Paddy soil

Introduction

Nitrogen (N) is one of the essential macronutrients that may limit rice growth and yield (Duan *et al*., 2007). Organic fertilizers are organic compounds that contain plant nutrients and organic substances, which can improve the physical, chemical and biological properties of soil (Albiach *et al*., 2000). Organic fertilizer is a significant source of N for organic farming systems. Organic rice systems have a high nitrogen shortage because of the N in organic fertilizers that can be utilized when the process is decomposed by microorganisms (Kyuma, 2004). The N availability content, pattern and rate of mineralization are different depending on organic fertilizer properties, soil properties and the environment (Masunga *et al.*, 2016). Usually, N mineralization of organic fertilizer in aerobic conditions must be higher than the anaerobic conditions, such as in paddy soil (Dahlin *et al.*, 2005). Under anaerobic conditions, the decomposition of organic N is dependent on the

* **Coressponding Author:** Yampracha, S.; **Email:** sukunya.ya@kmitl.ac.th

availability of alternate electron acceptors such as ferric iron and sulfate, which are far less efficient electron acceptors than O_2 in aerobic conditions (Sahrawat, 2004).

The dynamic change of nitrogen in paddy soil is mineralization of organic compound to ammonium (NH_4^+). NH_4^+ will accumulate in the soil solution and the surface of the soil colloids, which can exchange (Wang *et al*., 1993). Thus, the ammonium nitrogen produced in paddy soil can be used as an index of N availability (Waring and Bremner, 1964). A major key for successive use of organic fertilizers in soil requires knowing the amount of N applied and the rate of N mineralization (Mikkelsen and Hartz, 2008). The pattern and rate of nitrogen mineralization depend on organic fertilizer properties such as C:N ratio, total N and chemical composition (Myint *et al*., 2011).

Farmyard manure, compost and green manure are some of the major sources of N fertilizer for organic rice cultivation in Thailand. The application of organic fertilizers stimulates the mineralization of labile organic N in the soil (Zhang *et al*., 2012). Wen *et al.* (1995) reported that apparent N mineralization was approximately 10% from manure compost over a field in growing season. Hartz *et al*. (2000) reported that the average N mineralization rate during incubation gave average available N at 20%, 9%, 6%, and 2% for dried chicken manure, other manure, manure compost, and plant residue compost, respectively. Short-term N immobilization commonly occurred with slow mineralization organic fertilizer such as manure (Hartz *et al*., 1996; Hartz and Giannini, 1998). Low N mineralization rates suggested that very large amendment application rates would be required to significantly increase short-term soil N supply. This was particularly true of composts and may help to explain the crop N deficiency frequently encountered in fields during transition to organic management. Commonly, N release from legume residue is rapid in the tropics (Perin *et al.*, 2006). Leguminous green manure crops may add N to crop systems through biological fixation, while the slow release of N from decomposing green manure residue may be well timed with plant uptake (Cline and Silvernail, 2002; Cherr *et al*., 2006). Cherr *et al*. (2006) reported that sunn hemp (*Crotalaria juncea* L.) produced 12.2 Mg/ha of fresh matter and added 172 kg N/ha in a 14-week period after being incorporated.

Various kinds of organic fertilizer may have different N mineralization in paddy soil, which means less mineralization than aerobic soil. Moreover, the estimation of N mineralization may be useful for N management and rice cultivation in organic systems. Usually, study of N mineralization was done in laboratory and transfer the results to the field by modeling (Sharifi *et al*., 2007; Griffin and Honeycutt, 2000; Griffin *et al*.,2005; Pereira *et al.*, 2005 and Rao *et al.*, 2009). Therefore, the objective of this research was to determine the effects of different types of organic fertilizer on the availability of nitrogen in paddy soil as well as establish a model for estimating N mineralization from organic fertilizers.

Materials and methods

Soil and organic fertilizers

The soil samples were collected from an organic rice field in Nongchok District, Bangkok, Thailand (latitude 13º55ˈ23.0ˈˈ N longitude 100º54ˈ32.2ˈˈ E). The soil was classified into Bangkok soil series (very-fine, smectitic, nonacid, isohyperthermic Vertic Endoaquepts). The soil in this area has been used for rice cultivation for more than 30 years and transitioned to organic farming more than 10 years ago, with only farm yard manure, green manure and compost used. The surface soil was collected at a depth of 0-15 cm. Soil samples were air dried, ground to pass through a 2 mm sieve, and well mixed before analysis and incubation.

Soil and organic fertilizer analysis

The soil samples were analyzed for soil pH (soil: water, 1:1), electrical conductivity (EC soil: water, 1:5) (Richards, 1954) and total nitrogen (total N), which were determined using a CNS analyzer (LECO Coporation, 2016). Available phosphorus (P) was determined using a colorimetric method after extracting by the Bray II method (Bray and Kurtz, 1945). Exchangeable potassium (K), exchangeable calcium (Ca) and exchangeable magnesium (Mg) were extracted by 1*M* ammonium acetate pH 7 (Chongpraditnun, 2001). Exchangeable K, Ca and Mg were determined by inductively coupled plasma optical emission spectrophotometry (ICP-OES).

Three types of organic fertilizers consisting of cow manure, compost and sunn hemp (*Crotalaria juncea* L.) were used in this study. Cow manure and compost were collected from farm fields in Nongchok District, Bangkok. Compost was prepared from the decomposition of cow manure and rice straw at a ratio of 1:3 and decomposed for 60 days. Sunn hemp was collected at 50% of flowering stage from a paddy field in Ladkrabang District, Bangkok. All organic fertilizers were oven dried at 70 ℃ and sieved by passing through a 2 mm sieve. Organic fertilizers were analyzed for pH using a pH meter to measure the organic fertilizer to water ratio equal to 1:5, which usually should be measured at a ratio of 1:2. However, the organic fertilizers were saturated with water (Pan-in, 2008). Total nitrogen (total N) and total carbon (total C) were determined by CNS analyzer (LECO Coporation, 2016). Total phosphorus (total P_2O_5), total potassium (total K_2O), total magnesium (total Mg), total calcium (total Ca), were digested by $HClO_4$:HNO_3 (2:1) and concentration determined by ICP-OES.

Incubation experiment

The experiment was conducted in a laboratory. Organic rice soil was incubated with three organic fertilizers, i.e. cow manure, compost fertilizer and green manure, with a batch experiment. The experimental design was completely randomized with 3 replications. Four treatments consisted of 1) non-fertilizer application (control), 2) amended with cow manure, 3) amended with compost, and 4) amended with sunn hemp. Each organic fertilizer was amended at a rate of 300 mg N/kg. One hundred grams of soil sample was mixed with organic fertilizers and put in a 250 ml glass bottle. Subsequently, the 200 ml of distillation water was added to maintain the flooding condition. The bottles were then stored at a constant temperature of 30 ℃ for 120 days. The soil samples in each batch were collected at 0, 3, 5, 7, 14, 21, 28, 42, 56, 70, 98 and 120 days after incubation. The soil samples were analyzed for pH, ammonium (NH_4^+) and alkaline hydrolysable nitrogen (AHN). Soil samples were collected for analysis of total nitrogen and organic carbon at 0 and 120 days. Soil pH was measured using a pH meter (soil: water, 1:1), while extractable ammonium (NH_4^+) was determined by 2*N* KCl extraction and stream distillation (Miegroet, 1995). Alkaline hydrolysable N was determined using the method described by Khan *et al*. (2001) and Bushong *et al*. (2008). Total C and total N concentration were determined using a CNS analyzer (LECO Coporation, 2016).

Nitrogen mineralization model

The kinetic model used for calculation of soil mineralizable nitrogen is shown in equation (1) as described by Dessureault-Rompre ´*et al*. (2014):

$$Nt = N_0 \times (1 - e^{-kt}) \quad (1)$$

where Nt is the cumulative amount of nitrogen mineralization at time t, N_0 is potential mineralization nitrogen and k is the mineralization rate (Dessureault-Rompre ´*et al*., 2015, Thomas *et al*., 2015, Wijanarko and Purwanto, 2016 and Wang *et al*., 2017). N_0 and mineralization rate were calculated by non-linear regression model. The cumulative amount of nitrogen mineralization at the time of each organic fertilizer was estimated to examine the index of agreement (Willmott *et al.*, 2012) and modeling efficiency (Mohanty *et al.*, 2011).

The index of agreement (d) and modeling efficiency (EF) were evaluated to verify the precision of the N mineralization model. Typically, prediction data is compared with observation data. The methods used to calculate the index of agreement and modeling efficiency are described in equations (2) and (3) below:

$$d = 1 - \frac{\sum_{i=0}^{n}(P_i - O_i)^2}{\sum_{i=0}^{n}(|P_i - \bar{O}| + |O_i - \bar{O}|)^2} \quad (2)$$

$$EF = 1 - \left[\frac{\sum_{i=1}^{i=n}(P_i - O_i)^2}{\sum_{i=1}^{i=n}(O_i - \bar{O})^2}\right] \quad (3)$$

where Pi = predicted value, Oi = observed value, $\bar{O}$ = mean of the observed values and n = number of observation.

Data analysis

The data were subjected to analysis of variance (ANOVA) and treatment means were compared by Duncan's multiple range test at $P \leq 0.05$.

Results

Soil properties before incubation

Soil properties before incubation were shown in Table 1. The soil texture was clay with strongly acidic (pH = 5.3). Electrical conductivity was 0.23 mS/cm. It was not affected plants growth (Table 1). Total nitrogen and total C were 2.41 and 23.90 g/kg, respectively. Available phosphorus, exchangeable potassium, exchangeable calcium, and exchangeable magnesium were 76.71, 251.53, 2998.79, and 661.96 mg/kg, respectively. The soil was high cation exchange capacity with 26.85 cmol/kg (Table 1).

Organic fertilizers properties before incubation

The pH of cow manure, compost, and sunn hemp were 8.20, 6.30 and 5.10, respectively (Table 2). Total N and total C of cow manure, compost, and sunn hemp were 7.80, 19.40 and 23.20 g/kg, respectively and 122.9, 260.70 and 432.90 g/kg, respectively for total C. Then, the C: N ratio of cow manure, compost, and sunn hemp were 15.76, 13.44 and 18.66, respectively. Alkaline hydrolysable N, easily N mineralization form, in cow manure, compost, and sunn hemp were 217.48, 95.61 and 273.67 mg/kg, respectively. Total K_2O, Ca and Mg of cow manure and sunn hemp was higher than compost (Table 2).

Table 1. Soil properties before incubation

Soil property	**Organic rice paddy soil (Bangkok soil series)**
Soil texture	Clay
Sand (%)	25.96
Silk (%)	24.72
Clay (%)	49.32
Soil pH (water: soil; 1:1)	5.30
Electrical Conductivity (water: soil; 1:5) (mS/cm)	0.23
Cation exchange capacity (cmol/kg)	26.85
Total Nitrogen (g/kg)	2.41
Total Carbon (g/kg)	23.90
C:N ratio	9.92
Available Phosphorus (mg/kg)	35.47
Exchangeable Potassium (mg/kg)	251.53
Exchangeable Calcium (mg/kg)	2,998.79
Exchangeable Magnesium (mg/kg)	661.96

Table 2. Organic fertilizer properties before incubation

Chemical property	**Cow manure**	**Compost**	**Sunn hemp**
pH (organic fertilizer: water; 1:5)	8.20	6.30	5.10
Total N (g/kg)	7.80	19.40	23.20
Total C (g/kg)	122.90	260.70	432.90
C:N ratio	15.76	13.44	18.66
Alkaline hydrolysable N (mg/kg)	217.48	95.61	273.67
Total P_2O_5 (g/kg)	0.48	0.23	0.25
Total K_2O (g/kg)	34.35	6.39	19.23
Total Mg (g/kg)	4.82	3.04	5.18
Total Ca (g/kg)	23.46	7.09	7.53

Soil pH during incubation period

The results showed that at the initial day of incubation (day 0), soil pH of the soil amended with cow manure was highest with pH value 5.8 (moderately acid. Meanwhile, soil pH of the soil amended with compost, sunn hemp and control were 5.7, 5.5 and 5.5, respectively (Figure 1). Soil pH during initial until 14 days of incubation increased rapidly and at fourteen days of incubation pH was highest in all treatments (Figure 1). Soil pH of control was significantly different with soil pH of the soil amended with cow manure, compost and sunn hemp which pH values were 7.1, 7.3, 7.4 and 7.4, respectively. After 14 days of incubation, soil pH of all treatment slightly decreased and stable with soil pH values around 6.9-7.3 until the end of incubation. However, soil pH of all treatment from 21 -120 days after incubation was not significantly different.

pH	Day after incubation											
	0	3	5	7	14	21	28	42	56	70	98	120
P-value	<0.0001	0.0085	0.0060	0.0567	0.0035	0.9566	0.3555	0.2573	0.2966	0.4697	0.0037	0.1514
CV (%)	0.61	0.95	0.63	0.40	0.82	1.08	0.50	0.78	1.15	0.79	0.41	1.80

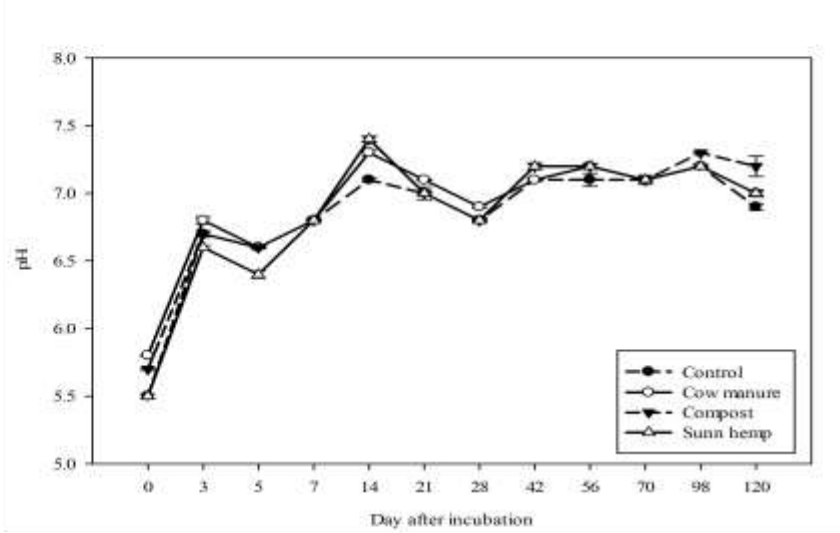

Figure 1. Change of soil pH during incubation period in paddy soil amended with and without different organic fertilizers (vertical bars indicate standard errors of means, n=3). The table above graph show analysis of variance of soil pH during incubation period

Change of alkaline hydrolysable nitrogen

The change of alkaline hydrolysable N during the incubation period was shown in Figure 2. At the initial day of incubation, alkaline hydrolysable N in the soil amended with cow manure was significantly differed with other treatments with the value 162.78 mg N/kg. Whereas, the soil in control and the soil amended with compost and sunn hemp were 128.78, 117.02 and 117.55 mg N/kg, respectively. After that, the concentration of alkaline hydrolysable nitrogen slowly increased unit 21 days after incubation. Moreover, on the third day of incubation alkaline hydrolysable nitrogen of sunn hemp was lowest and significant difference with control (Figure 2). Fifth and seven days of incubation, alkaline hydrolysable N was higher than the soil amended with three organic fertilizers.

AHN	Day after incubation											
	0	3	5	7	14	21	28	42	56	70	98	120
P-value	0.0102	0.0006	0.1142	0.0111	0.0262	0.2145	0.0089	0.0101	0.0971	0.117	0.0428	0.0393
CV (%)	10.32	8.56	13.48	6.71	7.45	10.78	11.02	8.57	6.39	9.8	9.16	17.23

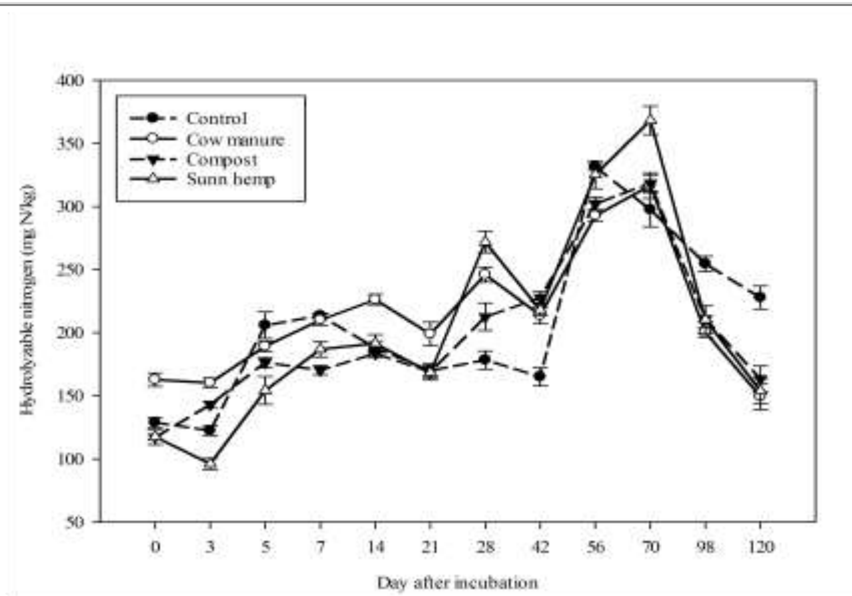

Figure 2. Change in alkaline hydrolysable nitrogen during incubation period in in paddy soil amended with and without different organic fertilizers (vertical bars indicate standard errors of means, n=3). The table above graph show analysis of variance of hydrolysable nitrogen during incubation period

After 21 days of incubation, alkaline hydrolysable N in control was significantly lower than other treatment until 56 days after incubation. After 56 days of incubation, alkaline hydrolysable N in control was fluctuation but it was clear significantly higher than the soil amended with three organic fertilizers (Figure 2). However, alkaline hydrolysable N in the soil amended with cow manure was higher than control until 56 days of incubation. Meanwhile, alkaline hydrolysable N in the soil amended with compost and sunn hemp at first seven days after incubation was lower than control. After 120 days after incubation, all amended soils were significantly differenced with control. Subsequently, the concentration of alkaline hydrolysable nitrogen in control, the soil amended with cow manure, compost, and sunn hemp were 227.97, 149.51, 163.32, and 153.82 mg N/kg, respectively (Figure 2).

Cumulative nitrogen mineralization

The cumulative N mineralization was calculated from extractable ammonium which releases each day of incubation. The cumulative N mineralization of all treatments is increased markedly with incubation time (Figure 3).

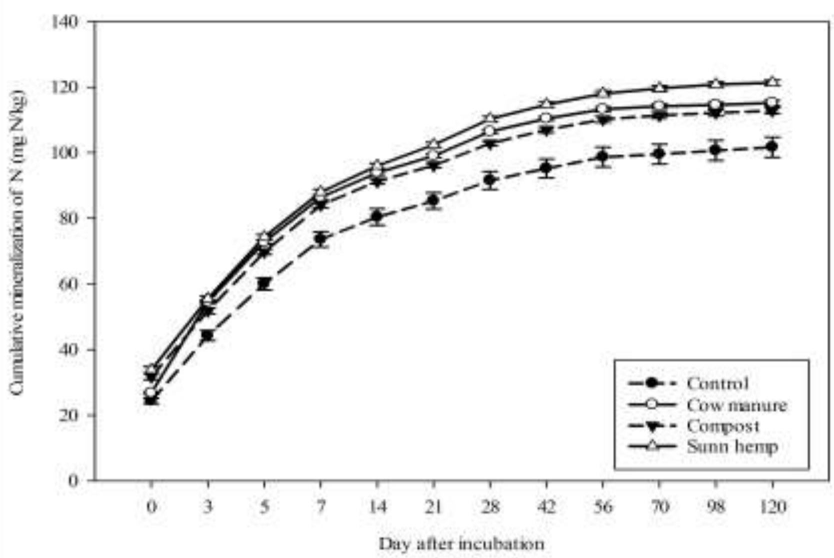

Figure 3. Cumulative N mineralized of nitrogen during incubation period in paddy soil with different organic fertilizers application (vertical bars indicate standard errors around means, n=3)

The cumulative N mineralization of control was lowest and significantly different from the soil amended with organic fertilizers throughout the incubation period (Figure 3 and Table 3). Nitrogen mineralization of soil amended with sunn hemp was highest but not significantly with another two organic fertilizers. Furthermore, cumulative N mineralization of cow manure was a little higher than compost (Figure 3). The cumulative N mineralization at the end of incubation period in control, cow manure, compost, and sunn hemp were 101.71, 115.21, 112.83 and 121.33 mg N/kg, respectively (Table 3). These results show that N in cow manure, compost, and sunn hemp mineralized 4.5, 3.71 and 6.54 percent of total N added, respectively.

Table 3. Effect of organic fertilizers on cumulative N mineralization during 120 days of incubation

Treatment	Days after incubation											
	0	3	5	7	14	21	28	42	56	70	98	120
Control	24.33a	44.25b	59.99b	73.61b	80.43b	85.35b	91.57b	95.27b	98.69b	99.57b	100.70b	101.71b
Cow manure	26.77b	54.54a	72.76a	86.42a	93.89a	96.07a	106.44a	110.42a	113.25a	114.17a	114.60a	115.21a
Compost	31.75a	51.79a	69.79a	84.10a	91.26a	96.19a	102.85a	107.00a	110.19a	111.41a	112.16a	112.83a
Sunn hemp	33.79a	55.47a	74.28a	88.03a	96.00a	102.40a	110.28a	114.66a	118.00a	119.61a	120.81a	121.33a
F-test	*	*	*	*	*	*	*	*	*	*	*	*
CV (%)	8.35	5.94	4.88	4.96	4.65	4.30	4.35	4.45	4.62	4.57	4.53	4.54

*Significant at $p \leq 0.05$, value followed by the same lowercase letter in the same column are not significantly difference at $p \leq 0.05$.

Nitrogen mineralization model

N mineralization potential and mineralization rate of soil with and without organic fertilizer amended were estimated using equation (1). The mineralization potential (N0) of control, cow manure, compost, and sunn hemp were 95.34, 109.90, 107.23 and 114.53 mg N/kg, respectively (Table 4). The N mineralization potential of control was significantly different with amended soils. The k values which indicated the mineralization rate of control, cow manure, compost, and sunn hemp were 0.2095, 0.2075, 0.2053 and 0.1992 mg N/kg, respectively (Table 4). The k value was not significantly different.

The predicted mineralization on the time was calculated from N0 and K value of each treatment. The index of agreement (d) and modeling efficiency were estimated from observed and predicted data. The index of agreement of the soil with and without organic fertilizer amended was close to 1 with the values 0.9859 - 0.9907 (Table 4). Meanwhile, modeling efficiency of control, the soil amended with cow manure, compost, and sunn hemp were 0.9591, 0.9631, 0.9424 and 0.9395, respectively (Table 4).

The 1:1 line between observed cumulative N mineralization and predicted cumulative N mineralization was indicated that the predicted cumulative N mineralization at low concentration was underestimated (Figure 4). The predicted cumulative N mineralization around 40 - 80 mg/kg seems to close the observed data (Figure 4). Whereas, the predicted cumulative N mineralization above 80 mg/kg was overestimated.

Table 4. Nitrogen mineralization potential and mineralization rate of soil with and without organic fertilizer amended, index of agreement and modelling efficiency

Treatment	N_0 (mg/kg)	*k*	Index of agreement	Modelling Efficiency
Control	95.34b	0.2095	0.9899	0.9591
Cow manure	109.90a	0.2074	0.9907	0.9631
Compost	107.23a	0.2053	0.9868	0.9424
Sunn hemp	114.53a	0.1992	0.9859	0.9395
F-test	*	ns		
CV (%)	4.42	7.55		

N_0 = N mineralization potential, k = mineralization rate.
*Significant at $p \leq 0.05$, ns = not significant, value followed by the same lowercase letter in the same column are not significantly difference at $p \leq 0.05$.

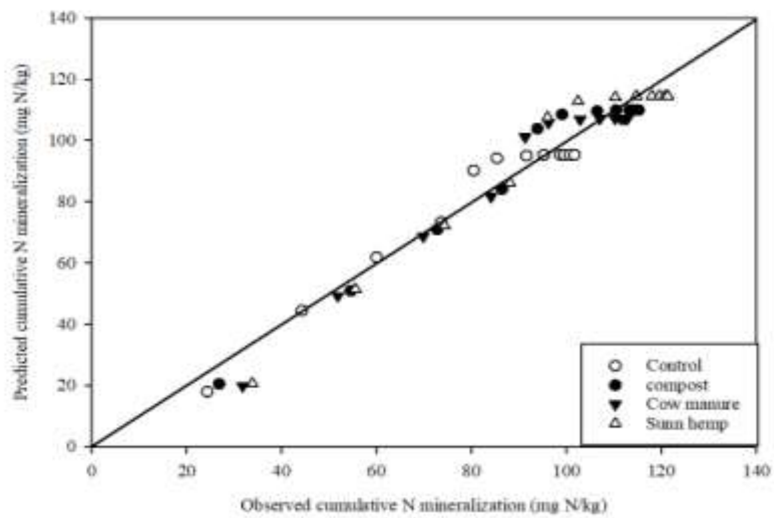

Figure 4. The 1:1 line between observed cumulative N mineralization and predicted cumulative N mineralization

Discussion

Effect of organic fertilizers on soil pH

The soil pH tended to increase and stability after 14 days of incubation. Soil pH of the soil with and without organic fertilizer amended become neutral after 14 days of incubation as the influence by the reduction reaction (Kyuma, 2004; Attanandana, 2007). In addition, the application of organic fertilizers could increase soil alkalinity (Dong *et al*., 2012). The application of cow manure showed that the soil pH at initial incubation was higher than compost and sunn hemp due to high pH of cow manure. Moreover, the change of soil pH to neutral may confirm that the soil with and without organic fertilizer amended during the incubation period under reduction condition. It might notice that the soil pH increased rapidly at the initial of flooding resulted by high organic carbon in soil and organic fertilizer (Attanandana, 2007). The optimum pH for ammonification reaction, the first step of N transformation from organic N to NH_4^+, was between 6.5 and 8.5 (Hopkinson and Giblin, 2008). So, the soil pH condition in this experiment was suitable for N transformation.

Effect of organic fertilizers on nitrogen mineralization

The application of organic fertilizers stimulated the mineralization of labile organic N in the soil (Zhang *et al*., 2012). Alkaline hydrolysable nitrogen may be an indicator for determined N transformation. The change of AHN fluctuated, for example, the initial day of incubation AHN in sunn hemp lower than control. It might be mentioned that N immobilization occurred. Short-term N immobilization was common with urban yard waste compost, with slow net mineralization thereafter (Hartz *et al.*, 1996; Hartz and Giannini, 1998). Whereas, 7 – 70 days of incubation AHN in control was lower than other treatments. At the end of incubation AHN in control was higher and significantly different with the soil amended with organic fertilizer.

The cumulative N mineralization of control was significantly changed by the soil amended with organic fertilizers. Effect of organic fertilizers (cow manure, compost, and sunn hemp) on cumulative N mineralization was non-significant differences due to high clay and organic matter content in soil. At the end of incubation, nitrogen mineralization of three organic fertilizers was lower than 10 percent of total N added (300 mg/kg) (Table 3) as similar to the results of Wen *et al.* (1995). Chivenge *et al*. (2011) reported nitrogen transformation rates of added organic N sources are generally faster in coarse than fine-textured soils. Soil total N concentration was also higher in the clay than the sandy-loam soil, but soil available N was greater in the sandy-loam soil. (Luce *et al*., 2014). Mineralization rates of nitrogen in soil textures that are rich in silt and clay related to soil organic carbon and total N contents. Thus, the amount and type of clay in a soil affected N mineralization process (Najmadeen, 2011; Nieder *et al.*, 2011; Ram ́ırez *et al*., 2016). However, cumulative N mineralization of sunn hemp was higher than cow manure and compost and the sequence was sunn hemp > cow manure > compost. This sequence may relate to AHN content of organic fertilizer. Differences in organic-N mineralization may be due to the specific characteristics of the organic materials (Zhang *et al*., 2012). Commonly N release from legume residues is rapid in the tropics (Perin *et al.*, 2006).

Simulation of Nitrogen mineralization

Nitrogen mineralization potential found similar results as well as the cumulative N mineralization at the end of incubation. The N mineralization model fit well with observed data as indicated by an index of agreement and modeling efficiency. Nevertheless, the 1:1 line indicates that at low and high cumulative N mineralization was underestimate and overestimate, respectively. However, the N mineralization model helped to reduce N fertilization and N leaching, while saving considerable amount of N fertilizer (Heumann *et al.*, 2013). The ability of laboratory incubation to predict N mineralization in the field could be better evaluated and more reliable results were obtained in the field (Delphin, 2000).

It concluded that the incubation experiment with 120 days indicated the soil pH increased from 5.3 (strongly acidic) to 6.9-7.2 (neutral). The cumulative N mineralization and potential N mineralization in the soil amended with green manure as sunn hemp was the highest. The effect of organic fertilizer properties was not affected cumulative N mineralization and potential N mineralization. It may be due to high clay content and organic carbon in the organic rice soil. Soil with high clay content and organic carbon was less mineralization. The model for predicting cumulative N mineralization can be used and field experiment is needed to evaluate the precision of the model

Acknowledgement

This research was supported by Graduate Research Fund Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand.

References

Albiach, R., Canet, R., Pomares, F. and Ingelmo, F. (2000). Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. Bioresource Technology. 75:43-48.

Attanandana, T. (2007). Basic of chemical reaction in paddy soils. In: Paddy soil science, Department of Soil Science, Kasetsart University, Bangkok. pp. 29-46.

Bray, R. H. and Kurtz, L. T. (1945). Determination of total organic and available forms of phosphorus in soil. Soil Science. 59:39-45.

Bushong, J. T., Roberts, T. L., Ross, W. J., Slaton, N. A. and Wilson, C. E. (2008). Evaluation of distillation and diffusion techniques for estimating hydrolysable amino sugar-nitrogen

as a means of predicting nitrogen mineralization. Soil Science Society of America. 72:992-999.
Cherr, C. M., Scholberg, J. M. S., and McSorley, R. (2006). Green manure as nitrogen source for sweet corn in a warm-temperature environment. Agronomy Journal. 98:1173-1180.
Chivenge, P., Vanlauwe, B., Gentile, R. and Six, J. (2011). Comparison of organic versus mineral resource effects on short-term aggregate carbon and nitrogen dynamics in a sandy soil versus a fine textured soil. Agriculture, Ecosystems and Environment. 140:361-371.
Chongpraditnun, P. (2001). Soil exchangeable base cation analysis. In: Department of Agricultural ed. Handbook of soil and plant analysis, Chatuchak, Bangkok, The Agricultural Co-operative Federation of Thailand LTD. pp.24-32.
Cline, G. R. and A. F. Silvernail. (2002). Effects of cover crops, nitrogen and tillage on sweet corn. HortTechnology. 12:118–125.
Dahlin, S., Kirchmann, H., Kätterer, T., Gunnarsson, S. and Bergström, L. (2005). Possibilities for improving nitrogen use from organic materials in agricultural cropping systems. Ambio: A Journal of the Human Environment. 34:288-294.
Delphin, J. E. (2000). Estimation of nitrogen mineralization in the field from an incubation test and from soil analysis. Agronomie. 20:349-361.
Dessureault-Rompre ́, J., Zebarth, B. J., Burton, D. L. and Georgallas, A. (2015). Predicting soil nitrogen supply from soil properties. Canadian Journal of Soil Science. 95:63-75.
Dong, W., Zhang, X., Wang, H., Dai, X., Sun, X., Qiu, W. and Yang, F. (2012). Effect of different fertilizer application on the soil fertility of paddy soils in red soil region of Southern China. PLOS ONE. 7: 1-8.
Duan, Y. H., Zhang, Y. L., Ye, L. T., Fan, X. R., Xu, G. H. and Shen, Q. R. (2007). Responses of rice cultivars with different nitrogen use efficiency to partial nitrate nutrition. Annals of Botany. 99:1153-1160.
Griffin, T. S., and Honeycutt, C. W. (2000). Using growing degree days to predict nitrogen availability from livestock manures. Soil Science Society of America Journal. 64:1876-1882.
Griffin, T. S., He, Z. and Honeycutt, C. W. (2005). Manure composition affects net transformation of nitrogen from dairy manures. Plant and Soil. 273:29-38.
Hartz, T. K. and Giannini, C. (1998). Duration of composting of yard wastes affects both physical and chemical characteristics of compost and plant growth. HortScience 33:1192-1196.
Hartz, T. K., Costa, F. J and Schrader, W. L. (1996). Suitability of composted green waste for horticultural uses. HortScience. 31:961-964.
Hartz, T. K., Mitchell, J. P. and Giannini, C. (2000). Nitrogen and carbon mineralization dynamics of manures and composts. HortScience. 35:209-212.
Heumann, S., Fier, A., Haßdenteufel, M., Höper, H., Schäfer, W., Eiler, T. and Böttcher, J. (2013). Minimizing nitrate leaching while maintaining crop yields: insights by simulating net N mineralization. Nutrient Cycling in Agroecosystems. 95:395-408.
Hopkinson, C. S. and Giblin, A. E. (2008). Nitrogen dynamics of coastal salt marshes. In: Capone, D. G., Bronk, D.A., Mulholland, M. R., and Carpenter, E.J. eds. Nitrogen in the Marine Environment (second edition). Academic Press. pp. 991-1036.
Khan, S. A., Mulvaney, R. L. and Hoeft, R. G. (2001). A Simple Soil Test for Detecting Sites that are Nonresponsive to Nitrogen Fertilization. Soil Science Society of America Journal. 65:1751-1760.
Kyuma, K. (2004). Paddy Soil Science. Kyoto, Kyoto University Press and Trans Pacific Press, 280 pp.

LECO Corporation. (2016). Operation. In: Trumac CNS/NS Carbon/Nitrogen/Sulfur Determinators Instruction Manual, U.S., LECO Europe B.V. pp. 1-56.

Luce, M. S., Whalen, J. K., Ziadi, N. and Zebarth, B. J. (2014). Labile organic nitrogen transformations in clay and sandy-loam soils amended with 15N-labelled faba bean and wheat residues. Soil Biology and Biochemistry. 68:208-218.

Masunga, R. H., Uzokwe, V. N., Mlay, P. D., Odeh, I., Singh, A., Buchan, D. and Neve, S. D. (2016). Nitrogen mineralization dynamics of different valuable organic amendments commonly used in agriculture. Applied Soil Ecology. 101:185-193.

Miegroet, H. V. (1995). Inorganic nitrogen determined by laboratory and field extractions of two forest soils. Soil Science Society of America Journal. 59:549-553.

Mikkelsen, R. and Hartz, T. K. (2008). Nitrogen sources for organic crop production. Better Crops. 92:16-19.

Mohanty, M., Reddy, K. S., Probert, M. E., Dalal, R. C., Rao, A. S. and Menzies, N. W. (2011). Modelling N mineralization from green manure and farmyard manure from a laboratory incubation study. Ecological Modelling. 222:719-726.

Myint, A. K., Yamakawa, T., Zenmyo, T., Thao, H. T. and Sarr, P. S. (2011). Effects of organic-manure application on growth, grain yield, and nitrogen, phosphorus, and potassium recoveries of rice variety Manawthuka in paddy soils of differing fertility. Communications in Soil Science and Plant Analysis. 42:457-474.

Najmadeen, H. H. (2011). Effects of soil organic matter, total nitrogen and texture on nitrogen mineralization process. Journal of Al-Nahrain University. 14:144-151.

Nieder, R., Benbi, D. and Scherer, H. (2011). Fixation and defixation of ammonium in soils: a review. Biology and Fertility of Soils. 47:1-14.

Pan-in, P. (2008). pH analysis. In: Department of Agricultural ed. Handbook of organic fertilizers Analysis, Ladprao, Bangkok, Quick Print Offset, pp. 5-6.

Pereira, J. M., Muniz, J. A. and Silva, C. A. (2005). Nonlinear models to predict nitrogen mineralization in an Oxisol. Scientia Agricola . 62:395-400.

Perin, A., Santos, R. H. S., Urquiaga, S. S., Cecon, P. R., Guerra, J. G. M. and Freitas, G. B. (2006). Sunnhemp and millet as green manure for tropical maize production. Scientia Agricola. 63:453-459.

Ram ́rez, M. V., Rubilar, R. A., Montes, C., Stape, J. L., Fox, T. R. and Allen, H. L. (2016). Nitrogen availability and mineralization in Pinus radiata stands fertilized mid-rotation at three contrasting sites. Journal of Soil Science and Plant Nutrition. 16:118-136.

Rao, L. E., Parker, D. R., Bytnerowicz, A. and Allen, E. B. (2009). Nitrogen mineralization across an atmospheric nitrogen deposition gradient in Southern California deserts. Journal of Arid Environments. 73:920-930.

Richards, L. A. (1954). Diagnosis and Improvement of Saline and Alkali Soil. USDA Agriculture. Handbook 60. Washington, D. C.

Sahrawat, K.L. (2004). Ammonium production in submerged soils and sediments: The role of reducible iron. Communications in Soil Science and Plant Analysis. 35:399-411.

Sharifi, M., Zebarth, B. J., Burton, D. L., Grant, C. A. and Cooper, J. M. (2007). Evaluation of some indices of potentially mineralizable nitrogen in soil. Soil Science Society of America Journal. 71:1233-1239.

Thomas, B. W., Sharifi, M., Whalen, J. K. and Chantigny, M. H. (2015). Mineralizable nitrogen responds differently to manure type in contrasting soil texture. Soil Science Society of America Journal. 79:1396-1405.

Wang, J., Zhuang, S. and Zhu, Z. (2017). Soil organic nitrogen composition and mineralization of paddy soils in a cultivation chronosequence in China. Journal of Soils and Sediments. 17:1588-1598.

Wang, M. Y., Siddeqi, M. Y., Ruth, T. J. and Glass, A. D. M. (1993). Ammonium uptake by rice roots. I. Kinetics of $^{13}NH_4^+$ influx across the plasmalemma. Plant Physiology. 103:1259-1267.

Waring, S. A., and Bremner, J. M. (1964). Ammonium production in soil under water logged conditions as an index of nitrogen availability. Nature. 201:951-952.

Wen, G., Thomas, E. and Voroney, R.P. (1995). Evalution of nitrogen availability in irradiated sewage sludge, sludge compost and manure compost. Journal of Environmental Quality. 24:527-534.

Wijanarko, A. and Purwanto, B. H. (2016). Comparison of two kinetics models for estimating N mineralization affected by different quality of organic matter in Typic Hapludults. Journal of Degraded and Mining Lands Management. 3:577-583.

Willmott, C. J., Robeson, S. M. and Matsura, K. (2012). Short Communication A refined index of model performance. International Journal of Climatology. 32: 2088-2094.

Zhang, J. B., Zhu, T. B., Cai, Z. C., Qin, S. W. and Muller, C. (2012). Effects of long-term repeated mineral and organic fertilizer applications on soil nitrogen transformations. European Journal of Soil Science. 63:75-85.

(Received: 12 September 2018, accepted: 31 October 2018)