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EFFECT OF ORGANIC MATTER ON NITROGEN MINERALIZATION IN FLOODED AND DRY SOIL

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ABSTRACT

Organic matter is one of the sources of nitrogen in the soil. Nitrogen mineralization depends on application method, kind of organic matter, microbial activity, aeration and moisture. The objective of this study was to determine the amount of nitrogen mineralization in flooded and dry soils from organic matter application. The experiment was carried out in research and soil testing laboratory of Indonesian Soil Research Institute (ISRI). Soil sample were taken from Cipanas and Sajira Sub District, Rangkasbitung. Nitrogen mineralization was studied on flooded and dry soil. The kind of organic matter on this experiment was chicken manure, goat manure, straw and straw compost wich are nitrogen content around 1.15 to 1.76%. The analysis of ammonium and nitrate conducted at 2, 3, 5, 8, 10, 20, 30, and 40 days after organic matter application. Nitrogen release from organic matter was calculated by nitrogen total on the organic matter treatment minus control divided by nitrogen content on the 5 t organic matter. The results showed that N-NH_4^+ content on the flooded soil started at 3 days after organic matter application, increase and peak of nitrogen content reach at 30 days after organic matter application. The maximum concentration of N-NH_4^+ for chicken manure and straw compost are day 8, straw and control are day 5, and goat manure is day 2. The maximum concentration ranged from 59 to 72 mg N-NH_4^+ kg^{-1}. Under flooded soil, the maximum nitrogen mineralization on day 8, ranged from 4.33 to 7, 61 mg N-NO_3^- kg^{-1}. Under dry soil, the maximum concentration of N-NO_3^- reaches at 10 days after organic matter application.

Keywords: organic matter, ammonium, nitrate, flooded, dry soil.

INTRODUCTION

Nitrogen is one of the most difficult plant nutrients to manage, since losses may occur in both the oxidized and reduced soil layers, from the floodwater, by outflow and leaching and by biological forms in the soil (Mikkelsen *et al*., 1995). One of the critical nutrient control points is land application of manure. Over application of nutrients can lead to contamination of surface or ground water while under application results in reduced crop yield (Van Kessel and Reeves, 2002).

The plant takes up nitrogen as NO_3^--N or NH_4^+-N. Soil nitrogen supply trough organic carbon from plant material and animal residues are transformed by microbial activity to ammonium and further on to nitrate by nitrification during mineralization. Nitrogen mineralization is a relatively slow microbial process that is affected by factors such as aeration and moisture. N as nitrate is soluble and mobile and susceptible to transport to groundwater, which has become increasingly degraded by nitrate (Strebel *et al*., 1989; Spalding and Exner, 1993).

Decomposition rates of organic amendments in agricultural soils provide information on nutrient release and on changes in soil N stocks. They are usually determined using incubation of soil samples under controlled conditions. However, the extrapolation of these estimates to decomposition rates under field conditions is difficult because of the temporal and spatial variations of most factors controlling decomposition in the field (Rochette *et al*., 2006). Paddy soils are periodically flooded and thus temporarily under anaerobic conditions and field crops grown in dry soils are continuously aerobic. These contrasting systems not only provide different conditions for organic matter decomposition but also from the type and amount of organic residues available (Vityakon *et al*., 2000). The objectives of this study were to determine the amount of nitrogen mineralization in flooded and dry soils from organic matter application.

MATERIALS AND METHODS

The experiments were carried out in laboratory of ISRI. Representative sample of surface soil (0-20 cm depth) were collected from field (Cipanas and Sajira Sub District, Rangkasbitung District). The samples were air-dried and sieved through 2 mm sieve before incubation. N mineralization of soils were tested in pots at room temperature during 40 days. Two different conditions were applied to estimate N mineralization from soil. The first condition is flooded soil (anaerobic incubation) and the second condition is dry soil (aerobic incubation). Two kg of dry soil and distilled water were mixed with amounts of organic fertilizer (chicken manure, goat manure, straw, straw compost). The amount of organic matter to be added on the soil were 5 t ha^{-1}. N mineralization was evaluated by periodical quantification of mineral N in the mixtures.

The observation of nitrogen mineralization was conducted at 2, 3, 5, 8, 10, 20, 30 and 40 days after organic matter application. Mineral nitrogen was measured on fresh soil samples immediately after sampling. Ammonium (NH_4^+) was extracted from 10 g soil using 50 mL of 1 M KCl. Samples were shaken for 1 hour on reciprocal shaker, filtered, and the extracts analyzed using visible spectrophotometer at 636 nm. Nitrate (NO_3^-) ions

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were determined with 0.01 M $CaCl_2$ by ultraviolet spectrophotometer at 210 nm and 275 nm.

Concentration of total nitrogen in organic fertilizer ranged from 1.15 - 1.76 % (Table-1). Nitrogen content on the straw compost highest, and followed goat manure>chicken manure>straw.

Table-1. Nitrogen concentration (dry matter basis) on organic matter to be applied.

Organic fertilizer	N Kjeldahl	N content on 5 t organic matter
	%	kg
Straw compost	1.76	88,0
Straw	1.15	57,5
Chicken manure	1.67	83,5
Goat manure	1.68	84,0

Nitogen release from organic matter will be calculated by nitrogen total ($N\text{-}NH_4$ + $N\text{-}NO_3$) on the organic matter application minus treatment of control divided by nitrogen content on the 5 t organic matter to applied.

RESULTS AND DISCUSSIONS

The soil properties

The soil properties from Sajira (dry soil) are shown in Table-1, texture was clay loam, pH was acid, organic C and N were low. Available P (extract Bray 1) was low. Exchangeable calcium and magnesium were moderate. Exchangeable potassium and sodium were low. It may be concluded that in general the chemical soil fertility of the selected sites is high due to values of CEC, organic matter and available P.

Soil properties of flooded soil, soil texture were clay loam, pH was slightly acid, organic C and N was low. Available P (extract Bray 1) was low. Exchangeable calcium and magnesium were high. Exchangeable potassium and cation exchange capacity were low. Base saturation was high, it may be concluded that in general the soil of the selected sites is dominated by base cation.

Table-1. Soil properties before organic matter application.

Soil characteristic	Dry soil	Flooded soil
Sand (%)	26	16
Silt (%)	38	22
Clay (%)	36	62
pH (H_2O)	5.0	4.5
KCl 1 N	4.1	3.6
C (%)	1.48	1.99
N (%)	0.10	0.18
C/N	15	11
Bray 1 (P_2O_5 ppm)	0.44	6.41
Exchangeable bases (mol(+)/kg)		
Ca	11.90	8.49
Mg	1.13	1.44
K	0.12	0.09
Na	0.10	0.09
CEC	14.87	16.11
BS (%)	89.00	63.00

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Concentration of N-NH_4^+

Organic forms (plant or animal residues) are the source of N which under the biological processes, can be transformed into inorganic forms as follows:

$NH_4^+ \rightarrow NH_2OH \rightarrow NOH \rightarrow NO_2^- \rightarrow NO_3^-$ (Glinski *et al*., 2007).

The mineralization of soil organic N begins with ammonification. The ammonium concentrations in flooded soil are shown in Figure-1. In general, the soils showed their lowest mineralization rates at the beginning of the incubation followed by maximum concentration on day 30 was as follows; straw compost > goat manure > control > chicken manure > straw. The maximum concentration ranged from 141 to 221 mg N-NH_4^+ kg^{-1}. At the end of the incubation, amounts of ammonium were decrease for all organic fertilizer.

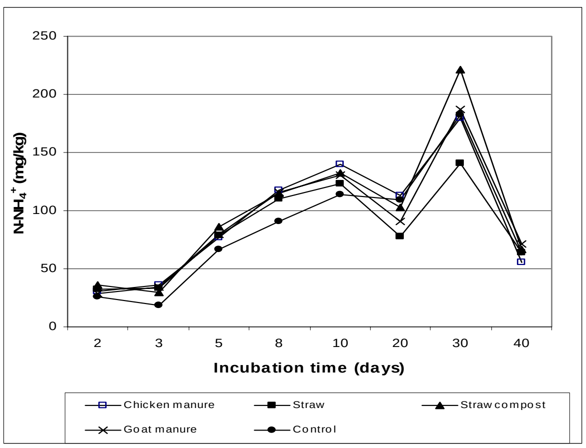

Figure-1. Change in N-NH_4^+ of flooded soil during incubation.

Meanwhile N-NH_4^+ in dry soil have different day for maximum concentration (Figure-2). The maximum concentration for chicken manure and straw compost are day 8, straw and control are day 5, and goat manure is day 2. In dry soils with aerobic condition the ammonification occurs faster than the oxidation of ammonium to nitrate, resulting in a minimum nitrate accumulation.

The maximum concentration ranged from 59 to 72 mg N-NH_4^+ kg^{-1}. At the end of the incubation, amounts of ammonium were decrease for all organic fertilizer.

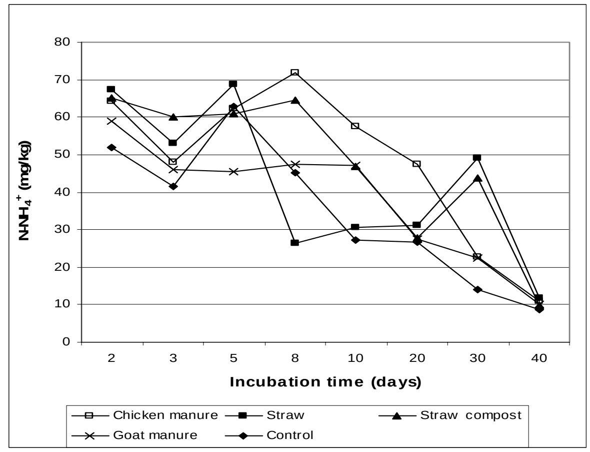

Figure-2. Change in N-NH_4^+ of dry soil during incubation.

N-NH_4^+ was the dominant form of inorganic N in flooded soil during this incubation study which would indicate there were rapid rates of ammonification. In moist, warm, well aerated soils, soil solution NO_3^- is generally greater than NH_4^+. Both move to plant roots by mass flow and diffusion (John *et al*., 2004).

Concentration of N-NO_3^-

Under flooded condition, concentration of N-NO_3^- was decreased at the end of incubation (Table-2). The maximum mineralization rates were on day 8. Meanwhile, the maximum mineralization in dry soils was variation. Generally, the maximum concentrations of N-NO_3^- reach at 10 days after organic matter application.

Table-2. Quantities of N-NO_3^- in flooded soil at different times during incubation.

Days	Chicken manure	Straw	Straw compost	Goat manure	Control
--------------------------- mg N-NO_3^- kg^{-1} -----------------------------					
2	0.44	0.49	0.63	0.75	1.06
3	2.59	2.52	2.13	3.42	5.31
5	0.62	0.68	0.28	0.32	0.56
8	7.61	6.25	7.11	4.33	6.02
10	1.46	1.51	2.97	1.76	1.34
20	0.12	0.19	0.10	0.42	0.28
30	0.30	1.28	0.87	0.86	0.87
40	0.00	0.00	0.00	0.00	0.00

At the end of incubation, there was an increase of $N\text{-}NO_3^-$ concentration for chicken manure and control in dry soil (Figure-3). Glinski *et al*., 2007 found near the end of incubation, there was an increase of $N\text{-}NO_3^-$ concentration and no relation was found between NO_3^-, pH and soil organic matter.

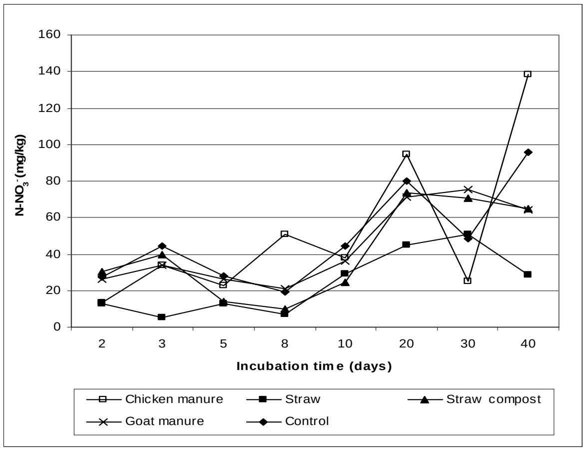

Figure-3. Change in $N\text{-}NO_3^-$ of dry soil during incubation.

Nitrogen release from organic matter

The release of nitrogen from organic matter application showed that nitrogen release tend to increase during time of incubation. Amount of net N mineralization (mineralized N ((NO_3^- + NH_4^+ - (control soil)/ton organic matter)) was greatest from straw compost (Table-3) on day 30. The maximum release of nitrogen between 0.278 - 0.443%. In general, 20 days after organic matter application nitrogen release minus, indicated mineral N immobilization. Towards the end of the experiment, a positive net N mineralization was observed from goat manure and straw compost. On the other hand, it has been shown that organic matter of varying sources can be used to regulate the timing of nitrogen availability and to estimate the best time for planting rice.

Table-3. Nitrogen release from organic matter application on the flooded soil.

Days	Chicken manure	Straw	Straw compost	Goat manure
	....%..			
2	0.052	0.112	0.109	0.032
3	0.183	0.212	0.100	0.180
5	0.120	0.211	0.213	0.152
8	0.342	0.334	0.285	0.278
10	0.313	0.159	0.223	0.207
20	0.046	-0.558	-0.070	-0.213
30	-0.031	-0.706	0.443	0.059
40	-0.108	-0.017	0.034	0.083

Meanwhile in dry soil, Net N mineralization in straw, straw compost and goat manure treatments were positive on day 2 after apllication. While net mineralization of chicken manure resulted in negative values indicating immobilization of mineral N relative to the control (Table-4).

The differences between flooded and dry soils with straw or straw compost treatments were probably due to accumulation of organic matter from surroundings during flooding. In which the lignin content of straw is little degraded under anaerobic conditions (Zeikus, 1980). The paddy soil was richer in organic matter than the upland soil. This was likely due to its heavier texture which is more favorable for organic matter retention and protection. Nitrogen mineralization was affected by aeration. Vityakon *et al*., 2000 found that net N mineralization was higher under lowland than under upland conditions. On the other hand, N immobilization was negligible under flooded lowland as compared to the upland condition.

Table-4. Nitrogen release from organic matter application on the dry soil.

Days	Chicken manure	Straw	Straw compost	Goat manure
	....%..			
2	-0,012	0,017	0,182	0,071
3	-0,060	-0,504	0,148	-0,083
5	-0,072	-0,157	-0,182	-0,238
8	0,707	-0,539	0,125	0,048
10	0,287	-0,226	0,000	0,131
20	0,431	-0,539	-0,068	-0,095
30	-0,180	0,643	0,591	0,405
40	0,539	-1,130	-0,341	-0,369

CONCLUSIONS

a) Concentration of $N\text{-}NH_4^+$ in flooded soils were higher than in dry soils, meanwhile concentration of $N\text{-}NO_3^-$ in flooded soils were lower than dry soils.
b) The maximum concentration of $N\text{-}NH_4^+$ in flooded soil on day 30 for all organic matter.
c) $N\text{-}NH_4^+$ in dry soil have different day for maximum concentration.
d) The maximum concentration of $N\text{-}NO_3^-$ in dry soils was variation.
e) Organic matter of varying sources can be used to regulate the timing of nitrogen availability and to estimate the best time for planting.

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