

Nitrogen Dynamic from Applied Rice Straw Compost in Flooded Soil

Dinamika Hara Nitrogen dari Aplikasi Kompos Jerami pada Tanah Tergenang

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INFORMASI ARTIKEL

Riwayat artikel:

Diterima: 1 April 2014

Disetujui: 15 Agustus 2014

Katakunci:

Kompos jerami

Amonium

Nitrat

Tanah tergenang

Keywords:

Straw compost

Ammonium

Nitrate

Flooded soil

Abstract. Nitrogen is the main fertilizer to increase rice production. Nitrogen fertilizer use efficiency is affected by organic matter content in the soil. Understanding decomposition and nitrogen release of plant materials is important to better manage organic inputs. The objective of this research was to study the nitrogen dynamics on flooded soil with rice straw compost application. The experiment was carried out in green house of Indonesian Soil Research Institute (ISRI) on October 2010 to January 2011. Soil samples were taken from Ciruas, Banten. The analysis of ammonium and nitrate were conducted 14, 20, 30, 40, 50, and 60 days after planting. The result showed that ammonium and nitrate in soil with straw compost applications were lower than that of chemical fertilizer application. After day 20, the concentration of ammonium in soil decreased to the same level for all treatments. The concentration of nitrate, after increase on day 40 decreased until the last observation (day 60). Nitrogen concentration in straw was higher under chemical fertilizer than that of straw compost application. In rice grain, N concentrations were not significantly different among the two treatments.

Abstrak. Nitrogen adalah pupuk utama untuk meningkatkan produksi beras. Efisiensi penggunaan pupuk nitrogen dipengaruhi oleh kandungan bahan organik dalam tanah. Pemahaman mengenai dekomposisi material tanaman adalah sesuatu yang penting untuk lebih baik dalam mengelola penambahan bahan organik. Tujuan dari penelitian ini adalah mempelajari dinamika hara nitrogen pada tanah sawah dengan penambahan bahan organik (kompos jerami). Penelitian dilakukan di rumah kaca, Balai Penelitian Tanah pada bulan oktober 2010 sampai Januari 2011. Sampel tanah berasal dari Ciruas, Banten. Analisis amonium dan nitrat dilakukan pada hari ke-14, 20, 30, 40, 50, dan 60 setelah tanam. Hasil penelitian menunjukkan bahwa amonium dan nitrat dalam tanah dengan penambahan kompos jerami lebih rendah dibandingkan dengan pupuk kimia. Umumnya setelah hari ke-20, konsentrasi amonium di dalam tanah menurun untuk semua tingkat perlakuan. Sedangkan konsentrasi nitrat, setelah meningkat pada hari ke-40 konsentrasi menurun hingga hari terakhir (hari ke-60). Konsentrasi nitrogen pada jerami menunjukkan bahwa aplikasi pupuk kimia lebih tinggi dibanding kompos jerami. Sedangkan konsentrasi N pada gabah padi tidak berbeda nyata.

Introduction

Rice is the staple food for the world's population in Asia which about one-half proportion. In South Asia, rice production has kept pace with or exceeded population growth from the mid-1960s to the early 1990s (Hossain and Fischer 1995). Nitrogen is an integral component of many essential plant compounds. It is a major part of all amino acids, which are the building blocks of all proteins, including the enzymes, which control virtually all biological processes. A good supply of N stimulates root growth and development, as well as the uptake of their nutrients (Brady and Weil 2008).

According to Sahrawat (2006), the intensified lowland rice systems make a major contribution to global rice supply. In Agricultural lands, nitrogen is one of major elements for crop productions and nitrogen supply for soil is important (Shuji *et al.* 2004). Nitrogen deficiency is the major constraint to increasing the productivity of lowland rice. The relationship between soil organic matter and N-supplying capacity of soils is crucial importance for determining the N fertilizer requirements of wetland rice and for efficient and judicious use of external N inputs. The increase in N fertilizer contributes to an increase in crop yield (Lei *et al.* 2005). Grain yield significantly increased with an increase in the level of N from control (no N) to 60 kg N ha⁻¹ (Gebrekidan and Seyoum 2006).

Nitrogen is one of the most mobile bioelements in soil which undergoes many transformations (nitrification,

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denitrification, ammonification, fixation from the air) caused by specific groups of microorganisms (Paul and Clark 2000). Ammonium released during the decomposition of organic matter and not used immediately by microorganisms is rapidly transformed into NO_3^- (Glinski *et al.* 2007). Based on the peak of N mineralization the rice straw should be applied 2-3 weeks before transplanting (Javier and Tabien 2003). N mineralization of crop residues is influenced by soil biological and chemical properties, temperature, moisture and the nature and chemical composition of the crop residues (Chaves 2006). N losses from agricultural systems through nitrate leaching, microbial denitrification and ammonia volatilization reduce crop N supply and simultaneously can threaten sustainability (Moller and Stinner 2009).

The yield of paddy resulting quantity of rice straw, which is rich in nitrogen, potassium and silicon. If the rice straw is reused in composting, the nutrients can be recycled (Zhu *et al.* 2004). The objective of our research was to study nutrient dynamics of nitrogen with rice straw compost application flooded soil.

Materials and Methods

Green house experiment was conducted during October 2010 to January 2011 in Indonesia Soil Research Institute. Representative sample of surface soil Inceptisol (0-20 cm depth) were collected from paddy field of Ciruas, Serang, Banten (106° 24' 02" E, 06° 11' 85" S).

Preparations of soil and fertilizer

The experiment consisted of five treatments : 1. four level of rice straw compost: 6.25, 12.5, 25 and 50 g pot⁻¹ (equal to 2.5, 5, 10, 20 t ha⁻¹); 2. chemical fertilizer with three replicates of each treatment.

The experiment was conducted in 15 containers with capacity 10 kg, Soil samples of 5 kg (dry matter basis) were mixed with appropriate amount of straw compost and placed in containers. Distilled water was added until saturated and 2 cm from soil surface. One week after straw compost application, paddy varieties IR-64 was planted. Chemical fertilizer such urea 100 kg ha⁻¹ (7, 21, and 30 day after transplanting (DAT)), KCl 25 kg ha⁻¹ (7 and 21 DAT), and SP-36 100 kg ha⁻¹ were added.

Soil sampling

The observation of soil inorganic N was evaluated by periodical quantification of nitrates and ammonium content. Soils were taken eight times during experiment period (at 7 day before planting and at 14, 20, 30, 40, 50, and 60 days after planting). Soil samples were taken for N and moisture content determination (105°C until constant

weight). Soil inorganic N was extracted by shaking the 10 g of fresh soil in 50 ml of 1 M KCl. Samples were shaken for 1 hour on reciprocal shaker, filtered, and the extracts were analyzed using visible spectrophotometer at 636 nm for NH_4^+ and 432 nm for NO_3^- .

Plant analysis

Plant sample consist of straw and grain was taken at harvesting time, then analyzed for N content. Nitrogen concentrations in plant tissue were determined by a wet oxidation digestion (Kjeldahl method). The Kjeldahl method used sulfuric acid, catalyst, and salts to convert organically bound N in plant tissue to ammonium (Donald and Robert 1998). The analysis of NH_4^+ after digestion can be performed by a Spectrophotometer.

Statistical analysis

Analysis of variance was performed to evaluate statistical differences in measured and estimated variables between treatments.

Results and Discussions

The soil properties

The soil properties were presented in Table 1, texture was silty loam, pH was acid, organic C and N were low. Available P (extract Bray 1) was low. Exchangeable calcium and magnesium were moderate, while exchangeable potassium and sodium were low. CEC was low. It may be concluded that in general the chemical soil fertility of the selected sites is low.

Table 1. Soil properties before organic matter application

Tabel 1. Sifat-sifat tanah sebelum diberi bahan organik

Soil characteristic	
Sand (%)	30
Silt (%)	53
Clay (%)	17
pH H ₂ O (1:5)	5.07
KCl 1 N (1:5)	4.35
Wakley and Black C (%)	1.22
Kejldahl N (%)	0.11
C/N	11
Bray 1 (P ₂ O ₅ ppm)	5.00
Ammonium acetate 1 M pH 7.0 (exchangeable bases cmol(+) kg ⁻¹):	
Ca	6.51
Mg	1.04
K	0.12
Na	0.18
CEC	5.78
BS (%)	>100

Soil inorganic nitrogen

Paddy rice yield is fundamentally affected by the total amount of N absorbed by plant (Tatsuya *et al.* 2009). Adequate supply of N fertilizer can promote plant growth and increase crop production. Supplying sufficient NH_4^+ and NO_3^- to meet plant requirement depends on the quantity of N mineralized from soil inorganic N with the remainder provided through fertilizer or organic N applications (Havlin *et al.* 2004).

Ammonium

The changes in the forms of N following application of straw compost or chemical fertilizer into soil was showed in Figure 1 and 2. In Figure 1, the ammonium concentration was highest for soil with additional of chemical fertilizer on day 14. Inorganic N, which can be directly absorbed by irrigated paddy rice, is derived from N of chemical fertilizer and inorganic N of organic fertilizer. The chemical fertilizer is more soluble. The low concentration for soil with straw compost because of the low N content in straw compost and the mineralization process takes much longer, other than that microbes need N sufficient to change organic N become inorganic N.

Meanwhile soil with different amount of straw compost showed the ammonium concentration of soil with 20 t ha⁻¹ was higher than others on day 20. Because 0-14 DAT is the early growth so the paddy rice is not require more nutrient. Almost all treatments showed ammonium decreased to the same level after day 20. Concentration of ammonium was decrease because of total N requirement of plant stages are different. According to Buresh (2008), 23-28 DAT is active tillering and 42 DAT is panicle initiation, thus plant is require more nutrient.

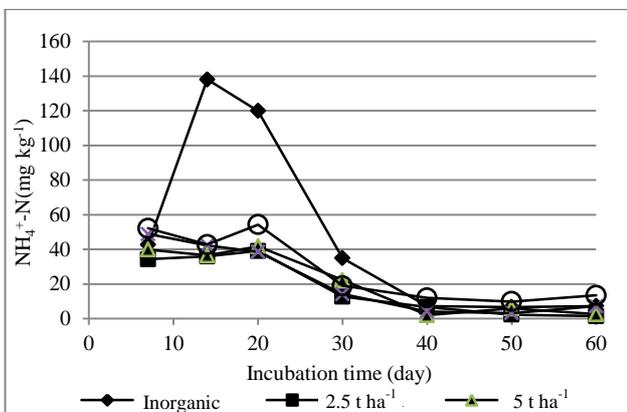


Figure 1. $\text{NH}_4^+\text{-N}$ transformations in soil
 Gambar 1. Transformasi $\text{NH}_4^+\text{-N}$ di dalam tanah

Base on peak of N mineralization, compost of rice straw can be incorporate two weeks before transplanting. While the rice straw (uncomposted) to be applied not

earlier than three weeks before transplanting in the lowland area (Javier and Tabien 2003).

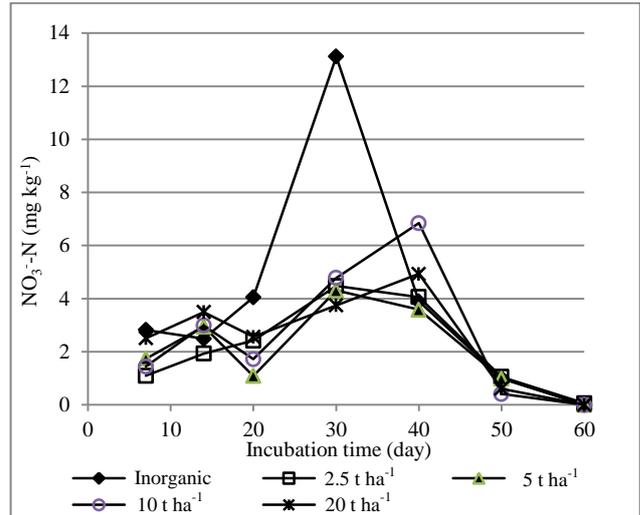


Figure 2. $\text{NO}_3^-\text{-N}$ transformations in soil
 Gambar 2. Transformasi $\text{NO}_3^-\text{-N}$ di dalam tanah

Nitrate

In general, the soils showed their nitrate concentration was highest for soil with additional of chemical fertilizer on day 30. The maximum nitrate concentration for soil with 2.5 and 5 t ha⁻¹ on day 30. Meanwhile, soil with 10 and 20 t ha⁻¹, the maximum nitrate concentration on day 40. The amounts of nitrate were decrease for all fertilizer treatments on the last day the observation. High microbial activity during initial manure mineralization can cause a reduction of available N below the plan needed.

The concentration of nitrate during 7-20 DAT in paddy soil was ten times lower than ammonium because in flooded condition in which the oxygen was low or absence, thus aerobic nitrifying bacteria will not produce NO_3^- (Havlin *et al.* 2004). In this research incorporation of crop residues will help maintain or improve soil aeration. The research of Lilik *et al.* (2008) show that ammonium is dominant than nitrate in flooded soil with application of rice straw and rice straw compost.

Plant

Nitrogen uptake

The results of N concentration determined at harvests showed that application of chemical fertilizer raised N concentrations in crop (Figure 3). Nitrogen concentration in straw showed that application of chemical fertilizer was higher than straw compost, meanwhile N concentrations in rice grain was not significant different (Table 2).

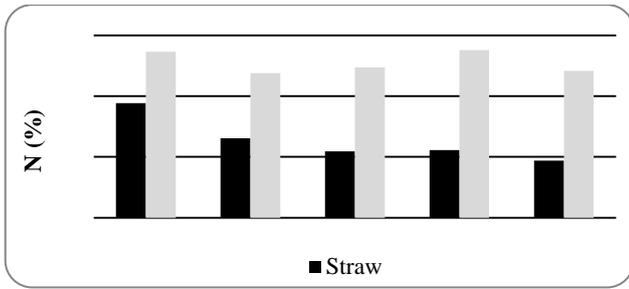


Figure 3. Nitrogen uptake under chemical fertilizer and different rates of rice straw

Gambar 3. Penyerapan Nitrogen di bawah pengaruh pupuk buatan dan dosis jerami

Table 2. Nitrogen uptake

Tabel 2. Penyerapan nitrogen

No.	Treatment	Nitrogen uptake	
		Straw	Rice grain
	 %	
1.	Chemical fertilizer	0.86 a	1.36 a
2.	Straw compost 2,5 t/ha	0.61 b	1.19 a
3.	Straw compost 5 t/ha	0.48 c	1.24 a
4.	Straw compost 10 t/ha	0.55 d	1.38 a
5.	Straw compost 20 t/ha	0.53 e	1.21 a
CV (%)		18.8	11

Note : Number in a column followed by the same letter are not significantly different at the level of 5%

Plant height, tillering, and panicle

On Table 3, Results showed plant height during observation was the same for all treatments from day 14 to day 30 after planting . The difference of plant height was found on day 40, in which plant height was the same for treatment chemical fertilizer, 5, and 20 t ha⁻¹ straw compost. On day 50, plant height was highest from chemical fertilizer treatment. Plant height was the same high for chemical fertilizer and 20 t ha⁻¹ on day 60.

Table 3. Plant height measurement as affected by straw compost application in green house experiment

Tabel 3. Ukuran tinggi tanaman sebagai pengaruh dari perlakuan kompos jerami pada percobaan rumah kaca

No.	Treatment	Plant height (days after planting)					
		14	20	30	40	50	60
	 cm					
1.	Chemical fertilizer	37.8 a	47.5 a	64.6 a	70.3 a	72.8 a	72.9 a
2.	Straw compost 2.5 t ha ⁻¹	36.8 a	47.3 a	60.5 a	64.7 b	65.7 b	65.7 b
3.	Straw compost 5 t ha ⁻¹	36.0 a	47.4 a	63.2 a	70.7 a	70.5 ab	70.6 ab
4.	Straw compost 10 t ha ⁻¹	36.0 a	47.0 a	61.6 a	66.5 b	67.4 ab	68.1 ab
5.	Straw compost 20 t ha ⁻¹	37.3 a	49.8 a	64.9 a	70.3 a	71.5 ab	71.8 a
CV (%)		5.3	4.8	3.5	2.6	4.3	3.6

Note : Number in a column followed by the same letter are not significantly different at the level of 5%

On Table 4, the panicle number was highest from the treatment of chemical fertilizer, followed by straw compost 10 and 20 t ha⁻¹ > 2.5 and 5 t ha⁻¹. Almost the same for tillering that chemical fertilizer was higher than straw compost. According to Mae (1997), nitrogen is required by rice plants during the vegetative stage to promote growth and tillering, which determines the potential number of panicles.

Table 4. Total tillering and panicle

Tabel 4. Jumlah anakan dan malai

No.	Treatment	Tillering	Panicle
		day 60	day 100
	 sheet	
1.	Chemical fertilizer	22 a	17 a
2.	Straw compost 2.5 t ha ⁻¹	13 b	9 b
3.	Straw compost 5 t ha ⁻¹	13 b	9 b
4.	Straw compost 10 t ha ⁻¹	15 b	11 b
5.	Straw compost 20 t ha ⁻¹	16 b	11 b
CV (%)		15,7	13,4

Note : Number in a column followed by the same letter are not significantly different at the level of 5%

Rice production

The yield components are showed on Table 5, The chemical fertilizer treatment significantly improved yield components as compared as other treatments. The grain yield as follows; chemical fertilizer > 10 t ha⁻¹ > 20 t ha⁻¹ and 5 t ha⁻¹ > 2.5 t ha⁻¹ straw compost. For straw yield as follows: chemical fertilizer > 20 t ha⁻¹ > 10 t ha⁻¹ and 2.5 t ha⁻¹ > 5 t ha⁻¹ straw compost. Based on the study of Tuyen and Tan (2001), the effect of rice straw incorporate in the soil may increase of rice yield after 2nd season.

The addition of straw compost into soil may increase grain yield. The maximum grain yield was observed for 12,03 g pot⁻¹ straw compost application (Figure 4). Optimum dose of straw compost is 9 t ha⁻¹. According to

Zayed *et al.* 2013, the positive impact of organic fertilizers on soil fertility improvement might be due to decomposition and mineralization of nutrients present in the organic material.

Table 5. Yield components under different treatments

Tabel 5. Komponen hasil di bawah pengaruh perlakuan

No.	Treatment	Yield components	
		Grain	Straw
	 g pot ⁻¹	
1.	Chemical fertilizer	18.59 a	50.11 a
2.	Straw compost 2.5 t ha ⁻¹	8.90 c	23.63 bc
3.	Straw compost 5 t ha ⁻¹	10.04 bc	22.68 c
4.	Straw compost 10 t ha ⁻¹	11.14 b	27.56 bc
5.	Straw compost 20 t ha ⁻¹	11.00 bc	30.49 b
	CV (%)	9	11.1

Note : Number in a column followed by the same letter are not significantly different at the level of 5%.

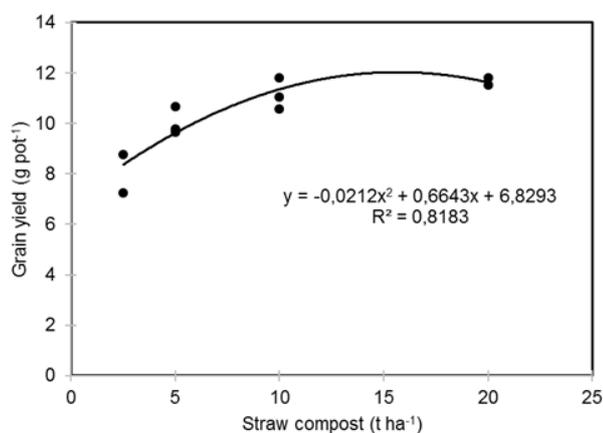


Figure 4. Effect of straw compost rates on grain yield

Gambar 4. Pengaruh dosis kompos jerami terhadap hasil biji

Conclusions

1. The concentration of $\text{NH}_4^+\text{-N}$ is higher than $\text{NO}_3^-\text{-N}$, in paddy soil. The highest peak of $\text{NH}_4^+\text{-N}$ mineralization from application of 20 t ha⁻¹ straw compost occurred 20 day after transplanting. Ammonium-N decreased after day 20 and $\text{NO}_3^-\text{-N}$ after day 40.
2. The concentration of $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ in soil with straw compost applications were lower than that of chemical fertilizer.

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