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Nitrogen Availability in Upland Soils Treated with Swallow Droppings

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Abstract

One of the problems in upland soils is poor in nutrient N. One effort to increase the availability of N in the soil is by providing swallow's droppings which has a high N content. Thus, the purpose of this research was to determine the availability of N on upland soil was by applying swallow manure. This research employed Completely Randomized Design (CRD) with single factors (several levels of swallow's manure: 0.0; 2.5; 5.0; 7.5; and 10.0 t ha^{-1}). The availability of N in the soil was observed through the experimental column leaching, where 20 g of Ultisols was mixed with 20 g of quartz sand and swallow's manure on a leaching column of 1-inch diameter and 20 cm height. Mineralized amounts of NH_4^+ and NO_3^- from the soil were determined by the percolation method (leaching) in every five days for 25 days. The results showed that the application of swallow's manure increased the availability of total-N in the soil in the form of NH_4^+ and NO_3^-, and produced the release pattern of NH_4^+ and NO_3^- which was still relatively high until the end of the testing period. The results of this study demonstrate that application of swallow's manure may be used as a slow-release fertilizer.

1. Introduction

Indonesia has a total area of 148 million hectares upland areas spread across Kalimantan, Sumatra, Maluku, Papua, Sulawesi, Java, and Nusa Tenggara. A total of 102.8 million hectares of them are acid soils (Mulyani, 2006). Not all upland soils are suitable for agriculture due to limiting factors such as shallow and rocky solum, steep slopes, or part of forest areas (Abdurachman et al., 2008). Upland soils have high potential to be developed into agricultural land. However, this land has considerable limitations to be used as agricultural land, due to its low soil fertility. Generally, Ultisols dominates upland areas with soil reaction (soil pH) around 5.5, low N and P content (N = 0.10% and available-P = 4.54 mg 100 g^{-1}), low organic matter content (around 1.46%), and low base saturation (Firman, 2016).

The loss of N in upland soil is caused by leaching as this type of soil is still in development process, has a rough texture, a small amount of organic matter, a low pH, and low CEC values. One effort to increase the availability of N and to improve soil quality is by providing organic materials. Organic material, according to Ndubuisi et al. (2011), plays an important role in increasing soil nutrients contents and water holding capacity, improving soil structure, and increasing the activity of its microorganisms. According to Tian et al. (2010), agricultural land generally lacks N, so it is often a major limiting factor in the process of plant growth and production. To overcome these N deficiencies, the addition of N in the form of artificial fertilizers and organic materials must be carried out.

One of nutrients that provides the most real and fast influence on plant growth is N. Nitrogen is needed in large amount compared to others, but its availability is always low, rapidly changing, or even lost due to high mobility in the soil. The transformation of organic-N into inorganic-N is called N mineralization. Ammonium (NH_4^+) and NO_3^- ions are inorganic-N, while N_2 and NO are lost from the soil as gases due to the denitrification process. Nitrogen absorbed by plants as NH_4^+ and NO_3^- as results from the organic matter decomposition and fertilization. Nutrient N loss can be through denitrification, volatilization, soil surface erosion, crop washing, and transportation (Paul, 2014). Walpola et al. (2010) states that the pattern of N mineralization of organic matter will differ depending on the type of animal waste applied to the soil.

Swallow dropping has the potential for upland to increase the availability of N. Observations by Hariyadi (2012) showed that bird droppings contain 4.20% N, and 51.14% organic-C, so they serve a source of N in the soil. Application of swallow droppings on the soil may increase the nutrients needed by plants in their growth and may reduce toxic elements in soils. Hardarani et al. (2021) reported that swallow droppings were slow-release organic fertilizer and always available whenever needed even in small amounts. Therefore, if applied earlier, microbes will be faster to decompose, making nutrients more available. These descriptions show the potential of swallow droppings as a source of N for upland. Swallow droppings can be used as organic fertilizer, so plants can grow and produce optimally (Nurhadiah, 2017). Hariyadi (2012) also stated that N was the main nutrient available in swallow droppings. However, until now information on the effect of swallow droppings application on the availability of N nutrients in soils in upland is not comprehensively available. Therefore, a study was conducted to determine the availability of N in upland treated with organic matter of swallow droppings.

2. Materials and Methods

2.1. Soil and Swallow Dropping Sampling

Ultisols was taken with a depth of 0-20 cm in the Cempaka Village Banjarbaru City South Kalimantan Province. Swallow droppings were collected from a swallow-house in Samuda, Jaya Kelapa Village, Mentaya Hilir Selatan District, Kotawaringin Timur Regency, Central Kalimantan Province. The quartz sand (washed with 1N HCL, 1N NaOH, alcohol, distilled water) was heated in an oven at 60-70 °C for 48 hours (Miwa and Ji, 1992). Soil physico-chemical properties was carried out at the Laboratory of Chemistry and Soil Physics at the Faculty of Agriculture, Lambung Mangkurat University.

2.2. Column Leaching Experiment

This research was an incubation experiment with percolation procedures in a laboratory using a single randomized complete design (CRD). The incubation time used was 25 days. The treatment in this study was doses of swallow droppings, i.e., soil without (W0) and with swallow droppings of 2.5; 5.0; 7.5; and 10.0 t ha^{-1} (W1, W2, W3, and W4, respectively). All treatments repeated four times so that there were 20 experimental units.

Soil was air dried and then grounded and sieved using a 2-mm size sieve. Soil that passed the sieve was then weighed as much as 20 g mixed with swallow droppings according to the treatment and stirred until evenly distributed. As much as 20 g of quartz sand then added to a mixture of soil and swallow droppings and stirred until homogeneous. Furthermore, a mixture of soil, swallow droppings, and quartz sand is put into a percolation tube (PVC pipes, 1 inch in diameter and 20 cm high). Filter paper was placed at the bottom of the percolation tube to hold the soil mixture. The soil in the pipe had the same treatment, which was compacted 10 times. Then the percolation tube was placed on the test rack and the percolate container was set under the percolation tube. The percolate container was connected using a plastic hose to each percolation tube. When ready, washed with 0.1 M $CaCl_2$ as much as 100 mL to get a percolate, and then rinsed with distilled water as much as 100 mL. The percolate from rinsing then combined with the percolate of 0.1 M $CaCl_2$ for determination of available-N (NH_4^+ and NO_3^- content). Furthermore, the percolation tube was incubated for 25 days, with washing process for every five days. Observations were made once every five days for twenty-five days to determine the concentrations of NH_4^+ and NO_3^- in percolates.

2.3. Statistical Analysis

The data were analyzed by Bartlett variance homogeneity test. If the data is homogeneous, Anova was proceed between treatments if there are significant differences occurred, followed by LSD (Least Significance Difference) test at a 5% confidence level.

3. Results and Discussion

3.1. Characteristics of Soil and Swallow Droppings

Soil physico-chemical properties and nutrient content of swallow droppings are presented in Table 1. The soil used in this study has a pH of 5.32 which can be categorized as acidic and has sandy clay texture. Organic matter content in this soil is low (organic-C = 1.10%), low exchange bases, low N content (total-N = 0.11%), very low P (total-P = 2.57 mg P_2O_5 100 g^{-1} soil) and low K (total-K = 20.16 mg K_2O 100 g^{-1} soil). The organic-C and N content in swallow droppings were very high (organic-C = 37.22%) and (total-N = 10.87%). The classification of soil characteristics and organic material was referred to the Soil Research Center (1983).

Table 1. Soil physico-chemical and swallow dropping properties

No.	Properties	Values	Criteria*
Soil			
1.	Soil texture	32.37	Sandy clay
	- Sand (%)	32.37	
	- Silt (%)	14.89	
	- Clays	52.74	
2.	Bulk density (g cm^{-3})	1.39	-
3.	pH H_2O (1:5)	5.32	Acid
4.	Organic C (%)	1.10	Low
5.	Total N (%)	0.11	Low
6.	CEC (cmol kg^{-1})	6.60	Low
7.	Total P (mg P_2O_5 100 g^{-1})	2.57	Very low
8.	Total K (mg K_2O 100 g^{-1})	20.16	Low
9.	Exchangeable K (cmol kg^{-1})	0.29	Low
10.	Exchangeable Ca (cmol kg^{-1})	2.60	Low
11.	Exchangeable Mg (cmol kg^{-1})	0.08	Very low
12.	Exchangeable Na (cmol kg^{-1})	0.18	Low
Swallow Dropping			
1.	Nitrogen (%)	10.87	-
2.	Phosphorous (%)	2.06	-
3.	Potassium (%)	1.6	-
`4.	Organic C (%)	37.22	-
5.	Calcium (%)	0.19	-
6.	Magnesium (%)	0.47	-
7.	C/N ratio	3.42	-
8.	pH H_2O (1:5)	7.13	-

* Based on the Soil Research Center (1983)

3.2. Ammonium Nitrogen (NH_4^+)

The results showed that the application of swallow droppings had a significant effect on NH_4^+ concentrations in the soil (Figure 2). Swallow droppings increased the concentration of NH_4^+ in soil compared to soil without droppings. The more swallow of droppings added, the more the concentration of NH_4^+ content in the soil (Figure 2). The application of swallow droppings of 2.5 t ha^{-1} increased the concentration of NH_4^+ to 106.48 mg N kg^{-1} soil. However, the application of droppings of 5.0 t ha^{-1} was not significantly different from 2.5 t ha^{-1} and 7.5 t ha^{-1} but was significantly different from the addition of 10.0 t ha^{-1} in organic matter. Organic swallow droppings at 10.0 t ha^{-1} produced the highest NH_4^+ concentrations compared to other treatments.

Based on the results of the soil chemical analysis in Table 1, the soil used for this study had a low N content of 0.11%, while the N in swallow droppings was 10.87%. This study indicated that an increase in swallow droppings affected the availability N in the soil. The higher the droppings, the more NH_4^+ produced from the process of organic-N mineralization. This is because organic matter of swallow droppings has a high content of C and N. Nitrogen in the form of NH_4^+ in this study was formed through the process of ammonization or the formation of amino compounds from organic matter (protein) by various heterogenous microorganisms (Hardjowigeno, 1987).

One important factor affecting the rate of N release from organic matter is the quality or chemical composition of the organic material. Decomposition of organic matter and N mineralization will be faster depending on the C/N ratio (Handayanto et al., 2007). Organic matter of swallow droppings in this study had a C/N ratio of 3.42 (Table 1). If organic material has a small C/N value, it will undergo a faster decomposition process compared to that of high C/N value (Muhammad et al., 2011). Widowati and Hartatik (2006) stated that if the C/N ratio >20, the mineralization process will be low and N sources in the soil will be immobilized by microorganisms. If the C/N ratio <20 then the N undergoes a mineralization process, in such circumstances causing the decomposition process to run quickly resulting in reduced N assimilation by bacteria.

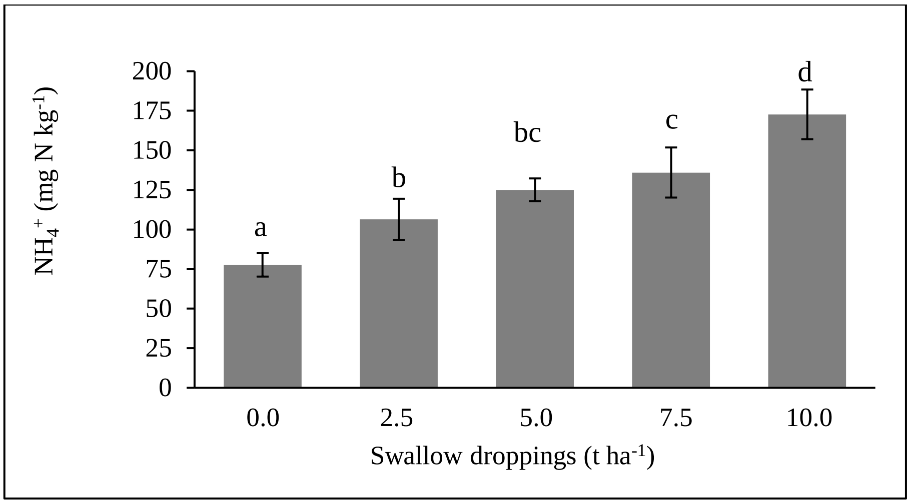

Figure 2. Ammonium concentration due to swallow droppings with different doses. The line above the bar is the standard deviation of the mean (n = 4). The same letters above the line indicates no differences based on LSD test at *P* <0.05

3.3. Nitrate Nitrogen (NO_3^-)

The analysis of variance showed that the administration of swallow droppings had a significant effect on the concentration of NO_3^- in the soil (Figure 3). The droppings increased NO_3^- concentration in the soil compared to soil without the droppings. The application of swallow droppings of 2.5 t ha^{-1} increased the concentration of NO_3^- by 20.10 mg N kg^{-1} soil. The application of droppings of 5.0 t ha^{-1} and 10.0 t ha^{-1} each was not significantly different. Thus, an increase in swallow droppings was not followed by an increase in NO_3^- concentration.

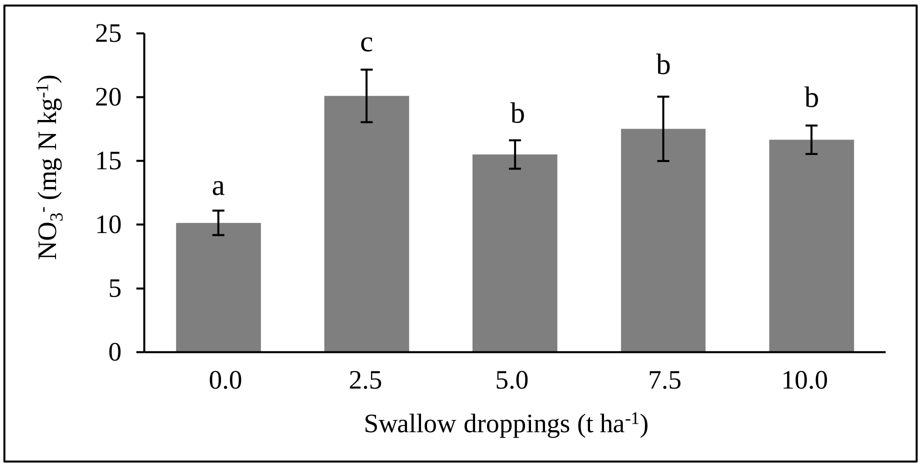

Figure 3. Nitrate concentration due to swallow droppings with different doses. The line above the bar is the standard deviation of the mean (n = 4). The same letters above the line indicates no differences based on LSD test at *P* <0.05

The low NO_3^- content in this soil was due to the slow process of nitrification, indicating limited population of nitrifying bacteria. These bacteria can be found in almost all soil types, but in this study the amount maybe too little to support the nitrification process. This study conducted percolation method with $CaCl_2$ and distilled water extracts with closed PVC pipe. This condition might create limited O_2 supply to make autotrophic nitrification bacteria produce more NO and N_2O (Handayanto et al., 2007). High water content can also made O_2 deprivation resulting in low microorganism activity which ultimately leads to a decrease in decomposition of organic matter and affect N mineralization (Perakis et al., 2011). In this study the texture of the soil was sandy clay, this will also affect soil porosity. According to Paul (2014) clay soils will drain badly if they contain many micro pores causing bad soil aeration. Soil aeration is related to O_2 in the soil and will be related to the breathing of microorganisms in the soil. Hence, soil aeration affects the number, population, and microbial activity in the soil.

3.4. Total Mineral Nitrogen

Total mineral-N is the amount of organic-N mineralized to inorganic-N during the incubation period, meaning that the total amount of mineral N in the form of NH_4^+ added to the total NO_3^-. The results showed that the provision of swallow droppings significantly affected the total mineral N in the soil (Figure 4). The application of dropping increased the total mineral N in the soil compared to without the droppings (control). The increase number of droppings followed by an increase in the total mineralized N in the soil (gross mineralization). The application of swallow droppings of 2.5 t ha^{-1} increased total mineral N to 126.58 mg N kg^{-1} soil compared to control which was 87.81 mg N kg^{-1} soil. Total mineral N in the soil with 5.0 t ha^{-1} dropping were not significantly different compared that of 2.5 t ha^{-1} and 7.5 tons ha^{-1}. Organic swallow droppings of 10.0 t ha^{-1} resulted in the highest total mineral N compared to other treatments.

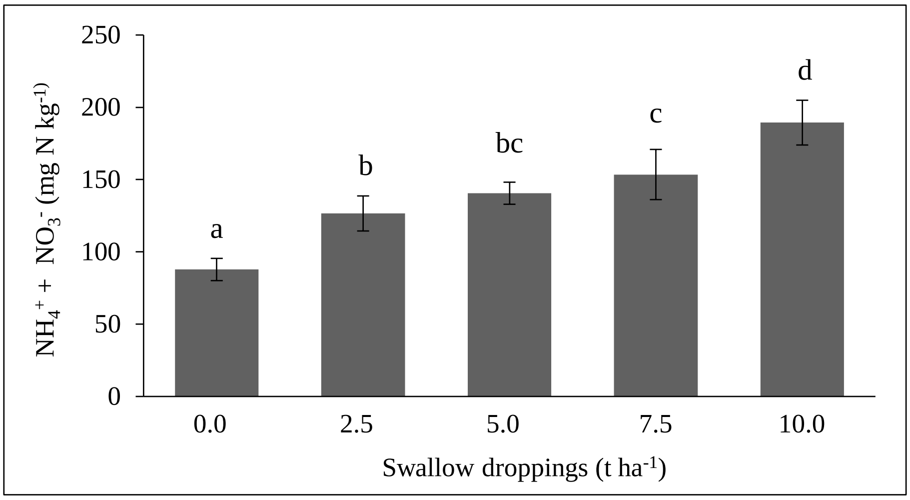

Figure 4. Total mineral N (NH_4^+ and NO_3^-) concentration due to swallow droppings with different doses. The line above the bar is the standard deviation of the mean (n = 4). The same letters above the line indicate no differences based on LSD test at $P < 0.05$

The provision of swallow bird manure with an amount of 2.5 t ha^{-1} has been able to increase mineralized total-N minerals in the soil. Mineralization of organic matter in the form of NH_4^+ is the main source of plant N but N in the form of NO_3^- which is more absorbed by plants (Barchia, 2009). Swallow droppings organic matter have a low C/N ratio, which is 3.42 (Table 1), so that the N mineralization process that occurs is high enough to produce a significant increase in soil N-inorganic. The high rate of mineralization, nitrification and immobilization provides an indication of the rapid N-cycle recycling process that occurs in soil systems.

Urakawa et al. (2016) states that the rate of nitrogen transformation is very significantly influenced by the content of organic matter and mineral soil layers, which represent the availability of substrates. The main factor of soil organic matter content in Japanese forest soils is influenced by soil parent material, because the type of soil is Andosol soil which is derived from volcanic sediments and contains high soil organic matter which causes high transformation and nitrogen mineralization in Japanese forests.

3.5. Dynamics of Ammonium

The amount of NH_4^+ from the mineralization results of soil which was applied with swallow droppings at different doses during the incubation period (25 days) is presented in Figure 5. Availability of N in the form of NH_4^+ at all levels of organic matter addition of swallow droppings shows a decrease pattern at 15 days first incubation period. The availability of NH_4^+ then increased again on the 20 days after incubation and then decreased in the remaining incubation time. In soils without the addition of organic matter (control) visible patterns of release of NH_4^+ which tends to decrease after the fifth day of incubation.

The results of the study during the 25 days incubation period showed that the amount of NH_4^+ in all treatments on the fifth day was still high and then started to decrease until the 15th day. Then increased again on the 20th day and then decreased in the remaining incubation time. Twice decline indicated the presence of two groups of organic-N in swallow droppings with different patterns of mineralization. The first group of organic-N was in ammonification within 15 days, while the second group was after 20 days. In soils fed with fresh organic material, the number of microbes initially may increase very quickly until maximum and eventually decreases again

(Haryono, 1989). Hidayat (2009) stated that the incubation process in closed PVC pipes can cause substandard aeration (anaerobic conditions) on the soil to increase. This can cause a denitrification process and changing NO_3^- to NH_4^+, resulting in more NH_4^+ concentrations in the soil. The denitrification process produces NH_4^+, O_2, electrons, and water will improve aerobic conditions so that the nitrification process occurs and the NH_4^+ concentration decreases again.

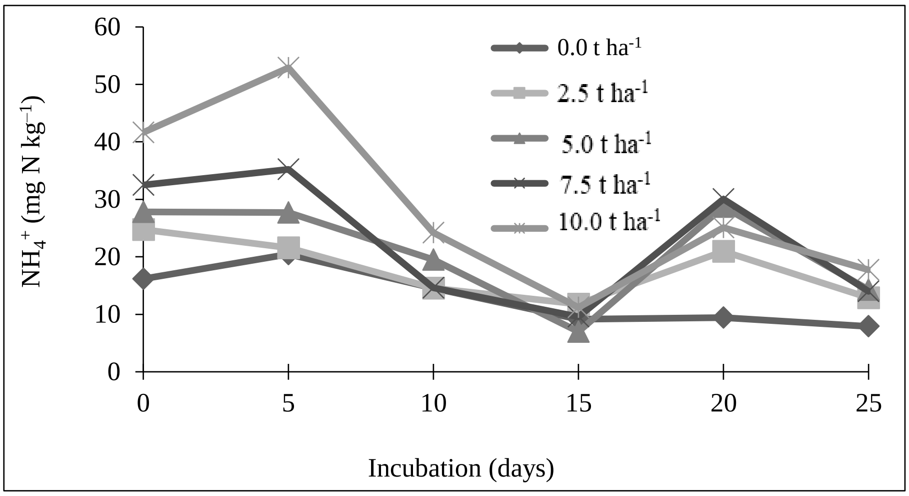

Figure 5. Ammonium pattern in soil with swallow droppings during incubation.

Unlike soils treated with swallow droppings, soils without droppings addition (control) showed a decrease in NH_4^+ during the 25-day incubation period. This showed the difference between organic-N in soil and in organic matter from swallow droppings, where organic-N in soil consists of only one group that had been ammonified since the first day of incubation.

3.6. Dynamics of Nitrate

The amount of NO_3^- from mineralized soil with different swallow droppings during the incubation period (25 days) is presented in Figure 6. Nitrate-N at all levels of droppings showed a declining pattern in the first five days of the incubation period except for 7.5 t ha^{-1}, then increased again on the 10th day except for 5.0 t ha^{-1}. On the 25th day of incubation period decreased again.

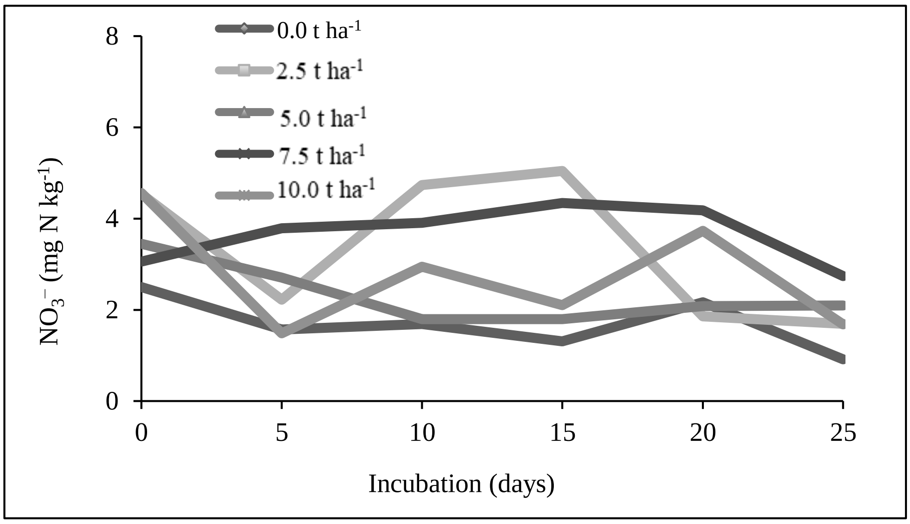

Figure 6. Nitrate pattern in soil with swallow droppings during incubation.

The release pattern of N for NO_3^- was different from NH_4^+. Production of NO_3^- increased with incubation time due to more activity of *Nitrosomonas* and *Nitrobacter* (autotrophic obligate bacteria group). The amount of NH_4^+ concentration in the soil was closely related to the increase in nitrifier microbial activity, where the higher amount of NH_4^+ in the soil followed by an increase in NO_3^- in the soil (Nainggolan et al., 2009). Shibata et al. (2013) stated that, if the air temperature is low, it will increase the N mineralization process while the nitrification process will decrease. Moreover, N mineralization is influenced by the amount, population, and microbial activity strongly associated with soil temperature and humidity (Tian et al., 2010).

4. Conclusion

Based on the results above, it can be concluded that the application of swallow droppings can increase the amount of N in the form of NH_4^+ and NO_3^- in the soil. The increase in the amount droppings will be followed by an increase in mineralized N. Swallow droppings released NH_4^+ and NO_3^- in the soil relatively high even until the end of the testing period, making it possible to be used as a slow-release fertilizer.

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