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THE KINETICS OF NITRATE IN SOIL UNDER THE APPLICATION OF VERMICOMPOST

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ABSTRACT

Nitrogen is the most often deficient in the soil and will be impacted by farmers associated with the economic issue. Nitrogen exists in soil systems in many forms and changes, such as mineralization and mobilization, nitrification, denitrification, volatilization, runoff and erosion, and leaching. The Inceptisol has a pH of 5,5 (acid), impacting soil nutrients such as nitrogen, phosphor, potassium, and organic-C; meanwhile, Ultisols have high acidity and Al exchangeability. This study aimed to determine the rate of nitrate availability on Ultisols and Inceptisols added dairy cattle waste vermicompost. The experiment was arranged by Randomized Completely Design with two factors. The first factor was vermicompost with three doses; there were 0 ton/h, 15 tosn/ha, and 30 tons/ha and the second factor was two types of soils, Inceptisol and Ultisol. The experiment was conducted by three times. The result is on the R^2 value, the reaction order kinetics model, which best explains the relationship between vermicompost dosing and nitrate availability in Ultisols and Inceptisols, is a first-order equation. The constant nitrification rate was 0.04 to 0.06 daily with three dairy cattle waste vermicompost dose levels. The potential nitrification showed that a high-level dose increased high nitrate. In Ultisols, the nitrification potential has risen from 1.21 to 1.44 mg/kg NO_3^- in others, increasing from 1.36 to 1.41 mg/kg NO_3^-. Dairy cattle waste vermicompost can accelerate nitrification in acidic soil, especially Ultisols and Inceptisols. This biofertilizer can supply nitrate to the soil by enhancing microbial activity. Nitrate availability in the soil can be supported by 30 tons ha^{-1} dairy cattle waste vermicompost.

Keyword: *dairy cattle waste vermicompost, Inceptisols, nitrate, Ultisols*

ABSTRAK

[KINETIKA NITRAT DI DALAM TANAH PADA APLIKASI VERMIKOMPOS]. Nitrogen seringkali mengalami defisiensi didalam tanah dan berdampak terhadap produktivitas tanaman yang erat kaitannya dengan isu ekonomi saat ini. Nitrogen hadir didalam tanah melalui beberapa proses dan perubahan, seperti mineralisasi dan mobilisasi, nitrifikasi, denitrifikasi, volatilisasi, erosi dan limpasan, serta pencucian. Nitrat merupakan unsur nitrogen yang sulit tersedia bagi tanaman, karena sifatnya yang sangat mudah hilang oleh aktifitas organisme seperti immobilisasi, denitrifikasi, hingga proses pencucian/limpasan oleh air hujan. Selain itu, ketersediaan nitrat sangat tergantung oleh kemasaman didalam tanah sehingga unsur ini seringkali menjadi tidak tersedia bagi tanah masam, seperti Ultisol dan Inceptisol. Penelitian ini bertujuan untuk menentukan laju ketersediaan nitrat pada tanah Inseptisol dan Ultisol setelah pemberian beberapa taraf dosis pupuk vermikompos kotoran sapi. Penelitian ini menggunakan RAL (Rancangan Acak Lengkap) 2 faktor. Faktor pertama adalah dosis vermikompos kotoran sapi, yaitu 0, 15, dan 30 ton/ha dan faktor kedua adalah dua jenis tanah, yaitu Inceptisol dan Ultisol. Pengulangan dilakukan sebanyak 3 kali. Hasil penelitian menunjukkan bahwa proses nitrifikasi melalui ketersediaan NO_3^- pada tanah yang diinkubasi selama 7 minggu dan data yang dianalisis dengan *first order kinetic* model. Pada tanah Inceptisol, laju nitrifikasi (k) sejumlah 0,04 sampai 0,06 mg/kg perhari. Potensial nitrifikasi (N_0) menunjukkan 1,36-1,41 mg/kg/hari. Pada tanah ultisol, N_0 meningkat dari 1,21 sampai 1,44 mg/kg perhari dan k sebesar 0,04-0,06 per hari. Dosis vermikompos 30 ton/ha mampu meningkatkan nitrat di dalam tanah sebesar 1,44 mg/kg/hari untuk tanah Ultisol dan 1,41 mg/kg/hari untuk tanah Inceptisol. Vermikompos kotoran sapi dapat meningkatkan proses nitrifikasi pada tanaman masam, seperti Ultisol dan Inceptisol. Pupuk organik ini mampu meningkatkan ketersediaan nitrat melalui peningkatan aktifitas mikroorganisme.

Kata kunci: *vermikompos kotoran sapi, Inceptisol, nitrat, Ultisols*

INTRODUCTION

Global crises, such as climate change, unstable security, and various forms of environmental degradation, demand us to be ready for future strategic actions regarding our food security. Nowadays, the world faces serious food security challenges, adding more with the Ukraine-Russian conflict, thus causing an increase of about 17,1% in world grain commodity prices, like barley, wheat, and maize. Furthermore, Sumberg & Giller (2022) added global crisis would impact the health and welfare of livestock, agricultural workers, and farmers. More than 7,7 billion people worldwide must get nourishment which is humanity's most fundamental challenge (Tal, 2018). This condition must encourage us to share and promote the specific combinations of practices as alternative sustainability methods, like conservation agriculture, regenerative agriculture, System of Rice Intensification (SRI), Holistic Resource Management, and Organic Agriculture.

Almost 98,9% of food in the world has been produced by conventional agriculture, typically using synthetic and chemical input (Tal, 2018). Conventionally, this system is managed with high-input operations with heavy dependence on off-farm resources and significant capital investment. These systems have been oriented mainly on maximizing productivity and profitability, creating a fundamentally unsustainable situation for a rapidly growing global population (Fess & Benedito, 2018). As a conventional system, we can get maximum productivity and profitability, but on the other hand, it causes soil degradation, contaminates groundwater and decreased soil microorganisms inked with soil fertility (Kobierski *et al.*, 2020).

Sustainability is a complex concept consisting of several intertwining factors and lacking acceptance. Naturally, organic fertilizers are available in mineral sources that conceive sufficient essential plant nutrients. Organic fertilizers are slow-release nutrients that supply in lower amounts over an extensive period (Shaji *et al.*, 2021). Using biofertilizers can improve soil properties such as physical, chemical, and biological (Purbajanti & Setyawati, 2020). The increasing cation exchange capacity, the solubility of elements P, K, Ca, Mg, C-organic, and water absorption, reduce saturation Al and bulk soil density (BD) (Kuntyastuti *et al.*, 2018; Purbajanti & Setyawati, 2020). Organic fertilizers can be formed naturally (manure and slurry) or processed, like compost, vermicompost, humic acid, blood meal, natural enzyme-digested proteins, and others (Shaji *et al.*, 2021).

One of the organic fertilizers is vermicompost. This organic fertilizer is produced due to earthworm activity and has nutrient retention capacity, high porosity, microbial activity, ventilation and drainage, and water storage capacity. It is rich in vitamins, nitrogen and phosphor enzyme beneficial microorganisms and plant growth regulators such as auxins, gibberellins, and cytokinins (Esmaielpour *et al*., 2019). Vermicompost enriched with cow dung can increase the nitrogen available in the soil and its absorption (Purba *et al*., 2021).

Nitrogen has been needed to understand sustainable agriculture better in the environmental issue. Nitrogen is the most often deficient in the soil and will be impacted by farmers associated with the economic issue. Nitrogen exists in soil systems in many forms and changes, such as mineralization and mobilization, nitrification, denitrification, volatilization, runoff and erosion, and leaching. According to (Utami *et al*., 2021), accumulative N mineralization occurred in soil with high organic manures and integrated nutrient management. However, this is contrary to the characteristic of ultisol, where it has low fertility due to its low cation exchange capacity (CEC), Base Saturation (BS), and soil pH.

Furthermore, these soils have high acidity and Al exchangeability (Purwanto *et al*., 2021). Meanwhile, the inceptisol soil has a pH of 5,5 (acid), impacting soil nutrients such as nitrogen, phosphor, potassium, and organic-C (Syamsiyah *et al*., 2018). Therefore, this study aimed to determine the rate of nitrate availability on Ultisols and Inceptisols added dairy cattle waste vermicompost.

MATERIALS AND METHODS

The experiment was conducted greenhouse of the faculty of agriculture at the University of Bengkulu in January – March 2019. The experiment was arranged by Randomized Completely Design with two factors. The first factor was vermicompost with three doses; there were 0 ton/ha; 15 tons/ha, and 30 tons/ha. The second factor was two types of soils, Inceptisol and Ultisol. The experiment was conducted by three times.

This experiment used two types of soil mixed with dairy cattle waste vermicompost. Inceptisols were randomly picked up from Air Duku village, Rejang Lebong district, and Ultisols from Kandang Limun District, Bengkulu City, Indonesia. The dairy cattle waste vermicompost was picked up from vermicomposting unit of the Department of Agronomy, Faculty of Agriculture, University of Bengkulu.

Preparation of soil

Inceptisol picked up from Selupu Rejang Lebong District as much as 75 kg at 1054 meters above sea level. Ultisol picked up from Kandang Limun District as much as 75 kilograms at 15 meters above sea level. Soil samples were wind-dried and then sieved with a 0.5 mm filter for pH, total-N, organic-C, exchangeable Al, KTK, and texture soil. Another fresh soil was prepared for NO_3^- analysis.

Soil incubation and sampling

As much as 5 kg of soil was added to dairy cattle waste vermicompost into a polybag. All polybags were stored in the greenhouse. They were arranged randomly. During incubation, the moisture content was kept by adding water equal to the soil moisture. All experiments were incubated for seven weeks.

A small weekly drill took the sample for pH and NO_3^- analysis. In an early experiment, the initial characteristics of soil were measured, such as organic carbon, total nitrogen, C/N ratio, and soil pH.

Analysis of soil characteristics

The soil was taken from a polybag weekly during incubation. Fresh soil for NO_3^- analysis and wind-dried sample for Organic C, Total N, and pH. Nitrate (NO_3^-) was measured using a spectrophotometry ion method; Organic C was measured using Walkley and Black method, total N was measured using a Kjehdahl method, soil reaction (pH-H_2O) was measured using a pH meter with a ratio of 1:5 for soil and distilled water (Soil Research Center, 2005).

Data analysis

All data were analyzed using ANAVA 5% and followed by the DMRT test.

RESULTS AND DISCUSSION

Soil nitrification

Using dairy cattle waste vermicompost on ultisol and inceptisol soils can solver in nitrate availability. In ultisol soil, the amount of nitrate produced reached its highest value at seven weeks of the incubation experiment (Figure 1). This was also not significantly different from inceptisol soil (Figure 2). After incubation for seven weeks, the average available nitrate showed that ultisol soil contained available nitrate of 56.54 mg/kg and inceptisol soil contained 66.28 mg/kg nitrate. Dairy cattle waste vermicompost at various dosage levels affected nitrate availability in both soils.

The initial characteristics of the soil used in this experiment showed in Table 1. The soil has an acidity level from acid to very acid and carbon content ranging from moderate to high. The C/N ratios for the two soil types were 13.53 and 6.8, respectively, for ultisols and inceptisols.

In Ultisol soil, the highest nitrate found in the treatment of using cow dung vermicompost at a dose of 30 tons/ha, namely from 33.34 mg/kg to 56.54 mg/kg, and this value was higher than the use of amounts of 0 and 15 tons/ha (Figure 1).

Table 1. Initial Soil Characteristics

Characteristic	Ulti-sol	Level	Incepti-sol	Level
Organic C (%)	4.6	High	2.1	Moderate
Total N (%)	0.34	Moderate	0.31	Moderate
C/N ratio	13.53	Moderate	6.8	Low
pH	4.3	Very	4.7	Acidic

Source: Soil Science Laboratory, University of Bengkulu

Meanwhile, for inceptisol, the highest found in the treatment of cow dung vermicompost at a dose of 30 tons/ha, namely from 27.09 mg/kg to 66.18 mg/kg, and this value was higher when compared to the two dose levels Others (Figure 2).

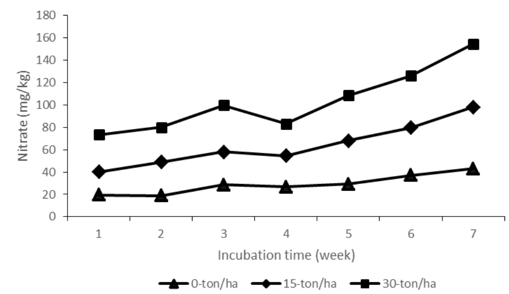

Figure 1. The dynamic of Nitrate on Ultisol

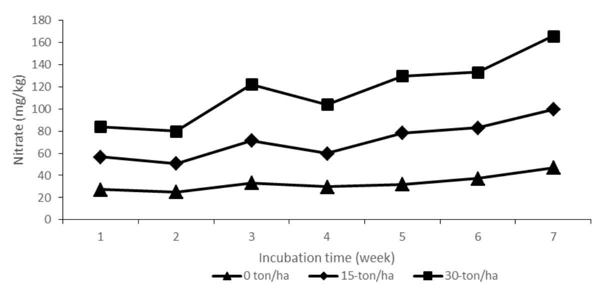

Figure 2. The dynamics of Nitrate on Inceptisol

The kinetics of nitrate availability

Cumulative Nitrate in soil at seven weeks was calculated by substracting mineral N-content of the soil at the start of incubation., i.e. a week time and then nitrification N-data was fitted to first order kinetic model to work out nitrate potential.

The constant nitrification rate was 0.04 to 0.06 daily with three dairy cattle vermicompost dose levels (Table 2). In Ultisols, the nitrification rate decreased using vermicompost doses of 30 tons/ha. Meanwhile, the highest vermicompost dose showed high nitrate on Inceptisol. The potential nitrification showed that a high-level dose increased high nitrate.

In Ultisols, the nitrification potential has risen from 1.21 to 1.44 mg/kg NO_3^- in others, and it increased from 1.36 to 1.41 mg/kg NO_3^-.

The acidity fluctuation in soils

The application of dairy cattle waste vermicompost in different dose levels showed a significant difference in the soil pH. The treatment showed significant differences without vermicompost. In this treatment, the pH value at the end of the incubation period showed the lowest value compared to the 15 tons/ha and 30 tons/ha treatments (Figure 3).

The different types of soil used in this experiment showed changes in pH values during the 7-week incubation. Inceptisol soil showed a higher pH value than ultisol soil. Inceptisols had an increase in pH of 10 points, which was higher than Ultisol soil, which had an increase of 0.31 points during seven weeks of incubation.

Table 2. The kinetics order of Nitrate in Ultisols and Inceptisols

Dose of Dairy Cattle Waste Vermicompost	Coef. Of Determination (R^2)		Rate of Nitrification (k) (/day)		Potential Nitrification [N_0] (mg/kg)	
	Ultisols	Inceptisols	Ultisols	Inceptisols	Ultisols	Inceptisols
First-Order						
0 ton/ha	0.91	0.81	0.06	0.04	1.21	1.36
15 ton/ha	0.88	0.75	0.06	0.05	1.28	1.38
30 ton/ha	0.57	0.78	0.04	0.06	1.44	1.41

Table 3. Statistical test of the relationship of vermicompost application at several dosage levels and different soil types to the value of pH fluctuations during seven weeks of incubation

	Incubation time (weeks)						
	1	2	3	4	5	6	7
Dose of Dairy Cattle Waste Vermicompost							
0 ton/ha	4.7^c	4.73^b	4.60^a	4.46^c	4.86^a	4.91^b	4.96^b
15 ton/ha	5.06^b	4.96^a	4.76^a	4.83^b	5.15^a	5.20^a	5.33^a
30 ton/ha	5.10^a	4.98^a	4.90^a	5.10^a	5.15^a	5.25^a	5.33^a
Type of Soils							
Ultisols	4.62^b	4.61^b	4.48^b	4.65^b	4.77^b	4.87^b	4.93^b
Inceptisols	5.33^a	5.17^a	5.02^a	4.94^a	5.33^a	5.36^a	5.44^a

value with the same letter showed not significant at $p<0.05$

Nitrification plays an essential role in the retention of nitrogen in ecosystems. Soil organisms are one of the critical factors for regulating nitrification. In this experiment, nitrate availability increased as the number of utilizing dairy cattle waste vermicompost in soils. Ultisol has the highest number, and there were 56.54 mg/kg NO_3^- on seven weeks of incubation with 30 tons/ha dairy cattle waste vermicompost (Figure 1). The increasing of nitrate availability was also in line with the increasing of soil pH during the incubation period (Table 1). This is in line with Pan *et al*. (2020), the effects of soil acidity on crop growth increases with decreasing soil pH, and its effect greatly increases below a critical soil pH value.

Meanwhile, Inceptisols had the highest number of NO_3^- at seven weeks of incubation, there was 66.28 mg/kg (Figure 2). Besides these dates, we can show that the nitrification process in Inceptisol was higher than in Ultisols. If we compared both soils, Inceptisol had soil acidity (pH) higher than Ultisols, where ultisol had more acidity than Inceptisol (Table 1). Li *et al*. (2020) state that soil pH is another important global soil nitrification rate driver. First, the lower soil pH dampens soil microbial activity of nitrification. The richness and diversity of autotrophic oxidizing bacteria and archaea decrease with soil pH ranging from 8.5 to 4. The increasing soil pH could significantly increase ammonia-oxidizing abundance and potential nitrification.

First order kinetics is one of the appropriate kinetics to determine the kinetic reaction in this experiment (Table 2). The first order kinetic showed similar conditions with nitrification processes. This is in line with the experimental of Ali Bhat *et al*., (2015) that higher mineralization of N in soil amended with organic matter due to slighty higher amounts of residual organic nitrogen in vermicompost. However, Hasanudin *et al*., (2021) added dairy cattle waste vermicompost had pH range 6.5-7.2, N 2.7%, P 2.4%, and K 3.8%. Dulal *et al*. (2021) added as a excreta of earthworm, vermicompost improved soil health and nutrient status. The utilization of vermicompost can be as eco-friendly treatment in crop production.

The utilizing dairy cattle waste vermicompost on 30 tons/ha showed enhanced nitrate on both soils (Figure 2). As statistically, this dose had the highest nitrate until final incubation (Table 3). This dose caused stimulator microbial activity and substrate supply for nutrient cycles. These results align with Sridhar & Pilli (2019) that dairy cattle waste vermicompost was considered a high-nutrient biofertilizer with diverse microbial communities. Moreover, it is enriched with all beneficial soil microbes. It contains essential plant nutrients like N, P, and K. Furthermore, Sharma & Garg (2019) added fruit and vegetable waste vermicomposting and reported higher bacterial and fungal densities in the vermicompost. Actinobacteria and ammonia-oxidizing bacteria were more in vermicompost than in the control group. They revealed that earthworm mucus significantly accelerated the mineralization and humification process, microbial activity, and bacterial population in different feedstocks.

Soil pH of Ultisol and Inceptisol improved until end of incubation, mainly on 30 tons/ha vermicompost dose (Figure 3). The increasing of soil pH caused by liven up of microoganisms and promoted their living. This is same as Singh *et al*. (2020) that the benefits on vermicompost are as follows, the increasing soil temperature and water retention and increasing soil fertility and productivity. Vermicompost plays a crucial role in influencing the nutrient cycling by microbial activity.

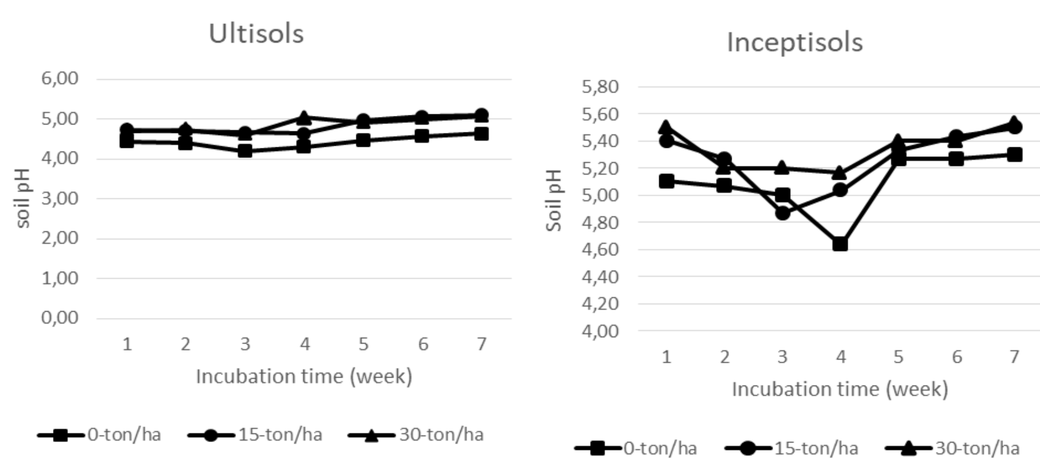

Figure 3. The acidity fluctuation on Ultisols and Inceptisols

CONCLUSION

Dairy cattle waste vermicompost can accelerate nitrification in acidic soil, especially Ultisols and Inceptisols. This biofertilizer can supply nitrate to the soil by enhancing microbial activity. Nitrate availability in the soil can be supported by 30 tons/ha dairy cattle waste vermicompost.

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