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Soil nitrate availability during incubation as affected by dairy cattle waste vermicompost

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Abstract Result indicated that there was significantly affected between dairy cattle waste vermicompost with the concentration of nitrate (NO_3^-) during the incubation time periods. The dairy cattle waste vermicompost had significantly affected on other variables such as total nitrogen, pH, CEC, and exchangeable Al from 3 weeks to 7 weeks after incubation. Inceptisols had higher nitrate, total nitrogen, and pH than Ultisols. The nitrate was significantly higher at 7 weeks after incubation, with an increasing nitrate from 5 weeks and the highest at 7 weeks. Ultisols was not significantly different on incubation. The dairy cattle waste vermicompost showed significant differences in nitrate, total N, and pH between 0-, 15-, and 30-tons ha^{-1}, but not in C/N. The significantly effect from improvement nitrate occurred after 5 weeks incubation on soils. The stable condition of nitrate availability through by the utilization of dairy cattle waste vermicompost occurred in 15-ton ha^{-1} dosage. The best dosage of dairy cattle waste vermicompost can produce a suitable environment for the nitrification process. This will lead to the accumulation of accessible mineral nitrogen compounds in soil.

Keywords: Vermicompost, Dairy cattle waste, Nitrate, Ultisols, Inceptisols

Introduction

Nowadays, we are facing various agricultural problems, starting from crop damage, crop failure, land degradation, and deteriorating soil quality. The lack of nutrients in soil is one of the problems in agriculture. This condition can be caused for any number of reasons, one of which was the agriculture system that was applied to these soils. The utilization of conventional agriculture systems can accelerate these phenomena, so as needed, a solution for minimalizing more severe soil damage can be found. Meanwhile, an organic farming system that has been developed is starting to be widely used as a response to the challenges of soil degradation that are already at a critical level. Principally, this system returns any form of organic matter back to the soil

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again and maintains the health and sustainability of life for the future (Yunan *et al*., 2018).

The utilization of agricultural land in Indonesia is directed towards the use of marginal land outside of Java particularly. The Inceptisols and Ultisols have unique characteristics, mainly in nutrient availability and organic matter. They have limited fertility for supporting plant growth without adding soil amendments. Therefore, we need another system for improving the capabilities of these soils so they can be used for the productivity of agriculture. According to Khresat (2005), The Cambisols (we used call as Inceptisols) can evolve on geological material that from young or old ages. Their formation process occurs on old geological material that might result from the late pedogenic processes acting upon these soils, which can be produced the active erosion or late weathering.

In organic farming system, all inputs that used in agriculture must from natural residual as organic matter or waste. It could be like cycles system where everything from the earth and must be return to earth. Vermicompost can be alternative output for organic input that increasing soil nutrient. This technic known as vermicomposting, where the earthworm plays a role as driver to change the organic matter. Vermicomposting has attracted global attention in the past few decades since its technical simplicity and effectiveness (Sharma and Garg, 2019). The organic molecules that breakdown by utilizing the feeding activity from earthworms known as vermicomposting. The vermicomposting will result the enriched beneficial soil microbes and essential plant nutrients like N, P, and K (Sridhar and Pilli, 2019). This was supported by Purba *et al*. (2021) that vermicompost, from dairy cattle can increase the availability of N in soil because of its capability to supply N as much as 1.66%.

Soils in Bengkulu inherently deficiency in N supply because of geographical location in strongly influenced by the condition of Indian Ocean, where if low pressure on the ocean will be impacted to high rainfall and strong winds. These climatic conditions will be impacted with soil characteristic, especially high leaching activity. According to Vitosh *et al*., (1995), the leaching losses of N occur when soils have more incoming output, there are water, irrigation, or wind that the soil cannot hold it. As water moves through the soil, the nitrate (NO_3^-) that is in soil solution moves along with the water. The N transformation and availability in soil is largely influenced by N fertilizer and organic manures (Dhawan *et al*., 2021).

The dairy cattle waste is an output livestock production system that supply nutrient to soil. This treatment can return organic matter to soil, while concentrating nutrients for easier and less costly uses (Sefeedpari *et al*., 2019). The modification this waste with vermicomposting technical can be a new concept in organic fertilizer as soil amendment for getting sustainable agriculture. The study aimed to determine the N-Nitrate availability after adding dairy cattle waste vermicompost in Ultisols and Inceptisols for 7 weeks.

Matterial and methods

Time and location

The research was carried out at Green House, Faculty of Agriculture, Bengkulu University. This research was conduct from March to April in 2019.

Research materials

Two types of soil, such as Ultisols and Inceptisols as source of observation. Dairy cattle waste vermicompost was used as organic matter. Polybag as soil incubation container, and Chemical material as analysis support.

Experimental design

The experiment was used two factors factorial in Randomized Completely Block Design (RCBD) with replication three times. The first factor was types of soil consisting of Ultisols and Inceptisols, and the second factor was the dosage of dairy cattle waste vermicompost consisting of 0-, 15-, and 30-ton ha^{-1}.

The observational data were analyzed using the F test. If the treatment showed a significant effect at 5% level, the analysis was continued with Duncan Multiple Range Test (DMRT) at the level $\alpha = 5\%$.

Population and sample

There were 6 treatments and replicated three times, where the total number of experimental units were 18. Soil as much as 5 kg added dairy cattle waste vermicompost put in polybag according to the treatment. All polybags randomly placed in green house. The soil was weighed and added water as much as soil mass for keeping field capacity and incubated for 7 weeks.

Observation variable

The observed variables were nitrate (NO_3^-), pH, Total-N, Organic-C, cation exchange capacity (CEC), and exchangeable Aluminum (exchangeable Al).

Result

Relationship between dairy cattle waste vermicompost and soil types

The results showed that the dairy cattle waste vermicompost had significantly affected on the variables of nitrate, total nitrogen, pH, CEC, and exchangeable Al from 3 weeks to 7 weeks after incubation (Table 1). The soil types had significantly affected on nitrate after 3 weeks and 7 weeks, total nitrogen on 5 weeks, pH on 3 weeks to 7 weeks, and exchangeable Al after 7 weeks. The dairy cattle waste vermicompost was significantly affected nitrate from 3 weeks to 7 weeks after incubation; total nitrogen from 3 weeks to 7 weeks after incubation; pH at 7 weeks after incubation; CEC and exchangeable Al at the end of incubation. The interaction between soil and dairy cattle waste vermicompost had significantly affected on the variables of nitrate at 7 weeks after incubation, total nitrogen at 5 weeks after incubation, C/N at 3 and 5 weeks after incubation, and CEC at 7 weeks after incubation.

Table 1. Dairy cattle waste vermicompost and soil sample on nitrate-N, total nitrogen, pH, CEC, and exchangeable Al

Variables	Soil	Time series	Soil*Time series	DCWV	Soil*DCWV
Nitrate					
3 weeks	19.25**	3.06ns	2.88ns	31.28**	0.66ns
5 weeks	2.74ns	1.57ns	4.54*	4.67*	0.32ns
7 weeks	7.16*	0.25ns	0.17ns	45.62**	5.95*
Total N					
3 weeks	0.04ns	0.03ns	0.12ns	26.03*	2.67ns
5 weeks	7.51*	8.90**	1.40ns	25.11**	5.61*
7 weeks	3.45ns	1.27ns	1.84ns	9.63**	0.76ns
pH					
3 weeks	15.16**	0.74ns	1.03ns	1.61ns	1.66ns
5 weeks	32.89**	0.25ns	0.57ns	3.80ns	1.75ns
7 weeks	57.19**	0.03ns	1.32ns	10.81*	1.41ns
C/N					
3 weeks	0.00ns	0.08ns	0.62ns	0.79*	1.77*
5 weeks	0.05ns	0.53ns	0.92*	0.03ns	2.15*
7 weeks	0.40ns	0.12ns	1.08*	0.55ns	0.01ns
CEC	0.46ns	8.41*	6.87*	78.50**	55.28**
Exchangeability Al	598.17**	0.31ns	1.54ns	10.54*	8.81ns

Notes: *=significant effect based on F Table 0.05, ** = very significant effect based on F Table 0.01, ns = Not significant effect, DCWV = Dairy cattle waste vermicompost, CEC = Cation exchange charge, Al = Aluminum.

Relationship between soil types with nitrate, total nitrogen, and pH

Inceptisols had higher nitrate, total nitrogen, and pH than Ultisols. The nitrate was significantly higher at 3 and 7 weeks after incubation, with an increasing nitrate from 3 weeks to 5 weeks and the highest at 7 weeks. Ultisols was not significantly different on incubation. Total nitrogen was higher for Inceptisols in 5 weeks after incubation, but not found in 3 and 7 weeks (Table 2).

Table 2. The relationship soil types with variable nitrate, total N and pH during incubation

Soil	Nitrate			Total N			pH			C/N		
	3	5	7	3	5	7	3	5	7	3	5	7
	Weeks			Weeks			Weeks			Weeks		
Ultisols	33.31^{b}	36.18^{a}	51.58^{b}	2.85^{a}	2.94^{b}	2.88^{a}	4.48^{b}	4.77^{b}	4.93^{b}	17.78^{a}	12.63^{a}	9.91^{a}
Inceptisols	40.75^{a}	43.25^{a}	55.34^{a}	2.88^{a}	3.26^{a}	3.32^{a}	5.02^{a}	5.33^{a}	5.44^{a}	18.00^{a}	13.00^{a}	10.83^{a}

Note: Values followed by the same letter are not significantly different based on DMRT at level = 5%

Relationship between dairy cattle waste vermicompost dosages with nitrate, total nitrogen, and pH

The dairy cattle waste vermicompost showed significant differences in nitrate, total nitrogen, and pH between 0-, 15-, and 30-tons ha^{-1}, but not in C/N (Table 3). Soil treated with 30-ton ha^{-1} had significantly higher nitrate, total nitrogen, and soil pH than 15- and 0-ton ha^{-1}.

Table 3. The relationship dosages of dairy cattle waste vermicompost with nitrate, total nitrogen and pH

DCWV Dosage	Nitrate			Total N			pH			C/N		
	3	5	7	3	5	7	3	5	7	3	5	7
	Weeks			Weeks			Weeks			Weeks		
0 tons ha^{-1}	30.87^{b}	30.66^{b}	44.98^{c}	2.03^{b}	2.51^{b}	2.38^{b}	4.60^{a}	4.86^{a}	4.96^{b}	20.66^{a}	13.08^{a}	11.39^{a}
15 tons ha^{-1}	33.86^{b}	42.69^{b}	54.04^{b}	3.16^{a}	3.38^{a}	3.41^{a}	4.76^{a}	5.15^{a}	5.30^{a}	16.58^{a}	12.80^{a}	10.18^{a}
30 tons ha^{-1}	46.36^{a}	45.79^{a}	61.36^{a}	3.41^{a}	3.41^{a}	3.51^{a}	4.90^{a}	5.15^{a}	5.30^{a}	16.44^{a}	12.56^{a}	9.54^{a}

Note: Values followed by the same letter are not significantly different based on DMRT at level = 5%

Relationship between soil types and dairy cattle waste vermicompost with CEC and exchangeable Al in the Eed of incubation

The results showed that neither Ultisols nor Inceptisols had significantly differed in CEC, but only the dosage of 0-ton ha^{-1} dairy cattle waste vermicompost had significantly differed from 15 tons ha^{-1} and 30 tons ha^{-1} (Table 4). Meanwhile, both types of soil and dosage of dairy cattle waste vermicompost had significantly differed exchangeable Al, where 30 tons ha^{-1} dairy cattle waste vermicompost reduced the potential for Al toxicity in soil.

Table 4. The relationship between types of soil and dairy cattle waste vermicompost with CEC and exchangeable Al

Variables	**Types of Soil**		**Dairy Cattle Waste Vermicompost**		
	Ultisols	Inceptisols	0-ton ha^{-1}	15-ton ha^{-1}	30-ton ha^{-1}
CEC	45.43[a]	46.02[a]	38.16[b]	50.69[a]	48.33[a]
Exchangeable Al	0.25[a]	1.49[b]	1.01[a]	0.88[a]	0.72[b]

Note: Values followed by the same letter are not significantly different based on DMRT at level = 5%, CEC = Cation exchange capacity.

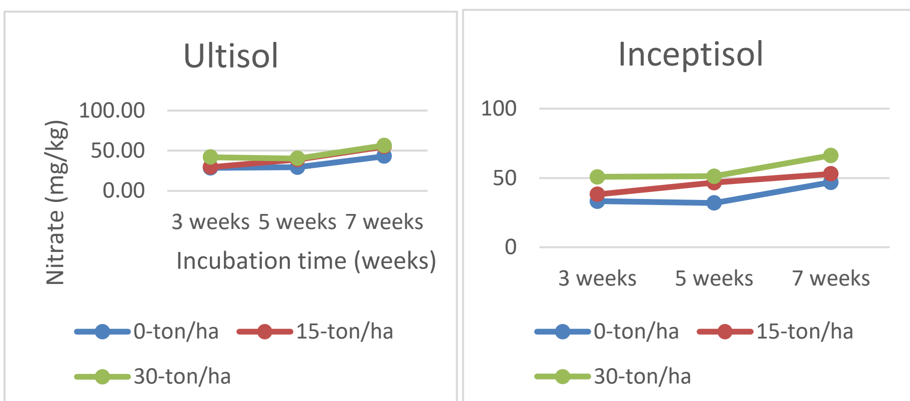

Figure 1. The dynamics mineralization nitrate between Ultisols and Inceptisols soils at 3, 5, and 7 weeks after incubation

Discussion

The significant correlation between soil and dairy cattle waste vermicompost showed that the nitrate variable was a significantly different on 7 weeks after incubation, total N on 5 weeks after incubation, C/N on 3 to 5 weeks after incubation, and at the end of incubation had CEC after application of dairy cattle waste vermicompost. Based on the data, we can conclude that the

N-mineralization occurred at early week after incubation, and after that would be followed by nitrification NO_3^-. It might be caused by the opposite interaction between ammonium and nitrate when mineralization. At the initial stage, high compound of cellulose from dairy cattle waste will stimulate mineralization. This statement was supported Utami *et al*. (2021), where the highest release of NO_3^- occurred at 30 days after incubation, while the lowest release NH_4^+ occurred at this time. Mineralization NH_4^+ and NO_3^- had been opposite interaction, in which the mineralization of NH_4^+ was slowed in the presence of NO_3^-. Moreover, according to Azam *et al*. (1995), NH_4^+ was immobilized in preference to NO_3^-, and this inhibitory effect might be contributed to the difference between NH_4^+ and NO_3^-. Hachiya and Sakakibara (2017) stated that the reciprocal effect of nitrate and ammonium was significantly inhibited by the co-provision of ammonium as compared to that observed with nitrate alone.

Ultisols are a type of soil with an advanced level of development, characterized by the presence of argillic or candic horizons, an increase in soil clay content (illuviation) in the lower soil pedon, and low base saturation (Purwanto *et al*., 2021). In this experiment, Ultisols had significantly differed to the effects on 5 weeks after incubation for nitrate and total nitrogen variables and had significantly increased after 5 weeks. This is the same result that was conducted by Okoh *et al*. (2020) who stated that cow dung application, showed that the highest nitrate found in 35 days after incubation. It was evident in 35 days after treatment application, which showed that the decomposition occurred by anaerobic bacteria. At high moisture content, biological activity and decomposition rates are decreased through a lack of oxygen. Moreover, N from compost was slowly released, justifying the ability of compost to maintain long-term N availability in soils. Composts affected the mineralization of N in soil because of the presence of stable N compounds present in them (Erhunmwunse *et al.*, 2019).

The C/N ratio on the type of soil and dairy cattle waste vermicompost showed that they were not significantly different in all variables. As we know, C and N in residues and in decomposing microbial biomass are important factors controlling the occurrence of net N mineralization or net N immobilization. However, organic residues with similar C to N ratios may mineralize different amounts of N because of differences in composition that are not reflected by the C to N ratio. Because the C to N ratio by itself cannot explain all differences in N mineralization, many efforts have been released by different compounds or groups of compounds on characterization in organic residues (Cabrera *et al*., 2005).

Soil cation exchange capacity (CEC) is an important physical and chemical property of soils, which reflects not only the surface properties of soil colloids, but also the retention and supply capacity of soil. CEC is used as an indicator for evaluating soil fertility, crop growth, and pollutants' partition and transport in soils (Yunan *et al*., 2018). The relationship between types of soil and dairy cattle waste vermicompost to CEC showed that both soils had no significantly different CEC. Both Ultisols and Inceptisols had similar the same properties, primarily high organic matter content, high leaching rate, high acidity, and high exchangeable Al (Purwanto *et al*., 2021; Syamsiyah *et al*., 2018). The fact that they have the same characteristic could explain why the CEC values from both soils are not significantly different. According to Fatai *et al.* (2017), the dominant low-activity clays like kaolinite associated with caution of low activity of CEC in the soil. The presence of gibbsite, hematite, and goethite will contribute to the low CEC value. Furthermore, soil with high acidity had low organic matter due to silicate clay 1:1 dominance as same as 10 me/100g CEC (Swanda *et al*., 2015).

Adding dairy cattle waste vermicompost to CEC revealed a significant difference between 0- and 15-tons ha^{-1}. Meanwhile, after 15 tons ha^{-1}, there was no significant difference to CEC. The CEC increasing on 15-ton ha^{-1} of dairy cattle waste vermicompost dosage might be caused by increasing pore space in soil through improvement soil physic and would be improved the microbial activity. The production of humic and fulvic acid from vermicompost decomposition will contribute to the increase in negative charges, consequently, soil CEC. Dulal *et al*. (2021) supported this experimental that improvement production per plot and per hectare that used vermicompost was 15 tons ha^{-1}. It might be due to the availability of microbes that can supply nutrients and humic acid by earthworm activity. These microbes can accelerate the mineralization of soil nutrient, humification and release the organic acid that tying Al in the soil.

The utilizing dairy cattle waste vermicompost increased nitrate, total N, CEC, and lowered exchangeable Al in Ultisols than Inceptisols. Nitrate had significantly affected in 3-7 weeks after incubation. The highest dosage of dairy cattle waste vermicompost (30-ton ha^{-1}) was significantly increased nitrate in soil. The dairy cattle waste vermicompost can stimulate the availability of nutrient and microbial activities, as a results, the improvement N-mineralization.

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