International Journal of Agricultural Technology 2022Vol. 18(1):281-292
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

# Soil nitrate availability pattern as influenced by the application of vermicompost supplemented with a liquid organic fertilizer

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Muktamar, Z., Larasati, T., Widiyono, H. and Setyowati, N. (2022). Soil nitrate availability pattern as influenced by application of vermicompost supplemented with a liquid organic fertilizer. International Journal of Agricultural Technology 18(1):281-292.

**Abstract** The result of the experiment revealed that the soil available nitrate decreased at the first four weeks of the incubation and increased from weeks 5 to 7. Soil pH did not change at the first 2 weeks of the incubation, however, raised for the rest of the incubation. At the end of the incubation, the application of vermicompost at the rate of 12.5 g $kg^{-1}$ supplemented with 100% LOF exhibited the greatest soil available nitrate. Also, the same treatment combination had the highest soil total nitrogen (TSN) and soil pH. This finding is significantly managed for nitrogen fertilization using vermicompost in Inceptisols.

**Keywords:** Soil nitrate pattern, Vermicompost, Liquid organic fertilizer, Inceptisols

## Introduction

The green revolution has increased crop productivity over the years, primarily due to synthetic agrochemicals supporting by intensive crop management such as soil tillage, pest control, and high-yield crop hybrids. According to Asosiasi Produsen Pupuk Indonesia (2020) in Indonesia, the consumption of synthetic fertilizer (NPK) for agriculture-related activities has increased from 7.2 million tons in 2016 to 8.1 million tons in 2018, even though it decreased to 7.3 million tons in 2019. The use of such fertilizers for a long period has been reported to reduce soil quality. Application of NPK synthetic fertilizer has lowered soil pH, soil organic matter, exchangeable Ca and Mg, microbial biomass carbon (MBC), and increased soil acidity (Coolon *et al.,* 2013; Wallenstein *et al.,* 2006; Savci, 2012; Wulandari *et al.,* 2017). Organic fertilizer is commonly used to improve the fertility of the soil. A previous study by Muktamar *et al.* (2017a) noted that applying liquid organic fertilizer improved soil pH and the availability of N, P, and K, even though it did not affect soil total organic carbon and exchangeable Al. Other studies also concluded that the organic amendment application also increased soil organic

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matter, total nitrogen, and ammonium (Joergensen *et al.,* 2010; Brown and Cotton, 2011; Amusan and Adetunji, 2013). Vermicompost is an organic material commonly used for the improvement of soil fertility. Such fertilizer contains complete plant nutrients as well as hormones as plant regulators. Vermicompost from dairy cattle wastes has 255.5 g kg $^{-1}$organic-C, 21.5 g kg $^{-1}$ nitrogen, 2.4 g kg $^{-1}$ phosphorus, and 5.5 g kg $^{-1}$ potassium (Muktamar *et al.,* 2017a). Another vermicompost from coffee pulp contains 167.8 g kg$^{-1}$ organic - C, 18.6 g kg$^{-1}$ nitrogen, 5.1 g kg$^{-1}$ phosphorous, 7.8 g kg$^{-1}$ potassium, 5.1 g kg$^{-1}$ calcium, and 2.9 g kg$^{-1}$ magnesium (Raphael and Velmourougane, 2011).

The main disadvantage of organic fertilizer is the slow release of nutrients so that they are not readily available at the early stage of plant growth. Low nutrient availability from the amendment is indicated by lower growth and yield of crops than those fertilized with synthetic fertilizer. A review study by Seufert *et al.* (2012) suggested that crop yield in the organic farming system was lower up to 34% than that of a conventional system. The organic farming system is highly dependent on organic fertilizer while the counterpart from a synthetic one.

Nitrogen is essential for plant growth and its availability at an early stage is crucial for crop productivity (Eghball *et al.,* 2002). A study by AyanfeOluwa *et al.* (2017) indicated that available N from compost in Alfisols was lower during the 2-6 weeks of incubation and higher at the 8-12 weeks compared to synthetic fertilizer. A different result was reported by Ebid *et al.* (2007) where in general, tealeaf, kitchen, and coffee composts released N very rapidly during 14-21 days of incubation. However, the release of nitrate from vermicompost in Inceptisols during the crop cycle period has not been studied intensively.

A nutrient from a quickly released source is necessary to accelerate the availability of nutrients at the early stage of crop growth. Liquid organic fertilizer (LOF) easily releases nutrients for plant growth. Liquid organic fertilizer as a supplement for vermicompost significantly increased the growth and yield of sweet corn at Bengkulu's highland (Muktamar *et al.,* 2017a). The study intended to examine the pattern of soil nitrate availability as affected by the application of vermicompost supplemented with a liquid organic fertilizer in Inceptisols.

## Materials and methods

### *Soil sampling and preparation*

The incubation study took place at the Soil Science Greenhouse, the University of Bengkulu, from January to April 2019. The soil sample was

collected from Air Duku Village, Rejang Lebong, Bengkulu, at 1054 meters above sea level. The soil in the location was classified as Inceptisols. A hundred and fifty kg of composite soil was sampled from 0-20 cm depth, air-dried for two days, and sieved using a 5 mm screen. A hundred g of fresh soil samples were taken and refrigerated until nitrate analysis. A portion of the sample was sieved using a 0.5 mm screen for analysis of the initial soil characteristics. The soil had 19.28 mg $kg^{-1}$ $NO_3$-N, 3.1 g $kg^{-1}$ total soil nitrogen (TSN), 21.1 g $kg^{-1}$ total soil organic carbon (TSOC), 31.76 cmol $kg^{-1}$ CEC, pH of 4.7, and sandy loam textural classification.

### *Experimental design*

The experiment assigned in Completely Randomized Design (CRD) with two factors. The first factor was vermicompost rates, consisting of 0, 6.25, and 12.5 g $kg^{-1}$ equivalent to 0, 31.25, and 62.50 g per polybags, respectively. The second factor was local-based liquid organic fertilizer (LOF), 0 and 100% LOF (with or without). The treatment combination was repeated three times.

### *Incubation experiment*

Five kg of air-dried soil was incorporated with vermicompost, placed in a polybag, and watered to field capacity. The polybags were randomly placed in a 1 m high wooden rack in the Greenhouse. The mixture was incubated for seven weeks. During incubation, the sample was retained in field capacity by watering every other day until reaching the moisture content. Liquid organic fertilizer was applied every week, beginning in the second week of the incubation. Each week, LOF treated soil samples received 200 ml of the fertilizer started in the second week until a week before the incubation ended (total of 1000 ml). Every week, the soil was sampled for analysis of $NO_3$-N and pH. Simultaneously, soil temperature was measured using a soil thermometer. At the end of the incubation, a fresh soil sample was collected for analysis of $NO_3$ using a method developed by Balai Penelitian Tanah (2009). The remaining soil was air-dried, sieved with a 0.5 mm screen, and analyzed for TSOC using Walky and Black Method, TSN using Kjeldahl Method, and CEC using extraction with Ammonium Acetat at pH 7 (Balai Penelitian Tanah, 2009).

### *Statistical analysis*

Data subjected to analysis of variance using SAS University Edition at a confidence level of 95%. Treatment means were separated using orthogonal

contrast at $p<0.05$. The nitrate treatment means during the incubation was separated using factorial repeated measurement at $p<0.05$

## Results

### *Soil pH and temperature*

Soil pH, in some ways, determines the availability of nutrients to plant, thereby influencing root activity and microorganisms. During the incubation study, soil pH for all treatments varied from 4.7 to 5.8. Figure 1 indicates the effect of vermicompost and LOF on the soil pH during the incubation period. In general, in the first two weeks of incubation, all treatments did not affect the soil pH, after which the application of vermicompost and LOF exhibited higher pH than the control. At weeks 3 to 7, vermicompost treatment combined with LOF had higher soil pH than those without combination. Higher pH is attributed to additional organic matter from LOF.

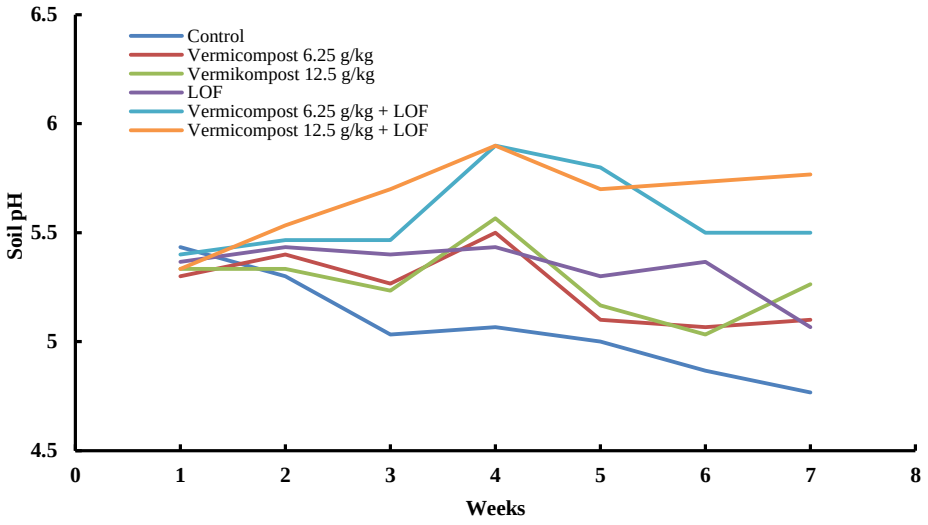


**Figure 1.** Soil pH during the incubation as affected by vermicompost and LOF

Soil temperature fluctuated during the incubation is indicated in Figure 2. On average, the temperature did not differ at the first 3 weeks, but sharply increased at four weeks of incubation, reaching around 33 $^{o}$C and declining afterward. During the incubation, there were not significant of all treatments on temperature.

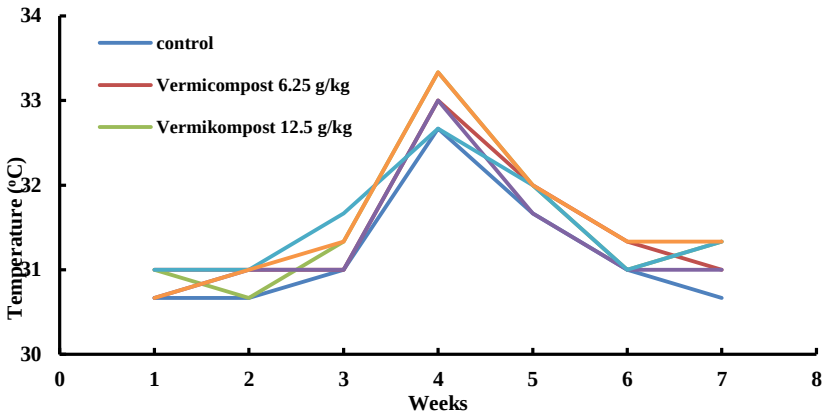


**Figure 2.** Soil temperature during the incubation

***Total soil organic carbon and C/N ratio***

Total organic carbon is an indicator of organic matter content in the soil. Orthogonal contrast analysis resulted in vermicompost and LOF markedly increased TSOC at weeks 3, 5, and 7 of the incubation (Figure 3). However, there was no different vermicompost effect at the rate of 6.25 and 12.5 g $kg^{-1}$ on TSOC. Also, higher TSOC was observed when the soil was fertilized with LOF. Previous studies indicated similar results where vermicompost and LOF increased TSOC (Muktamar *et al.*, 2017a; Muktamar *et al.*, 2018). The addition of soil organic matter would accelerate microorganism activity, releasing nitrate-N to the soil.

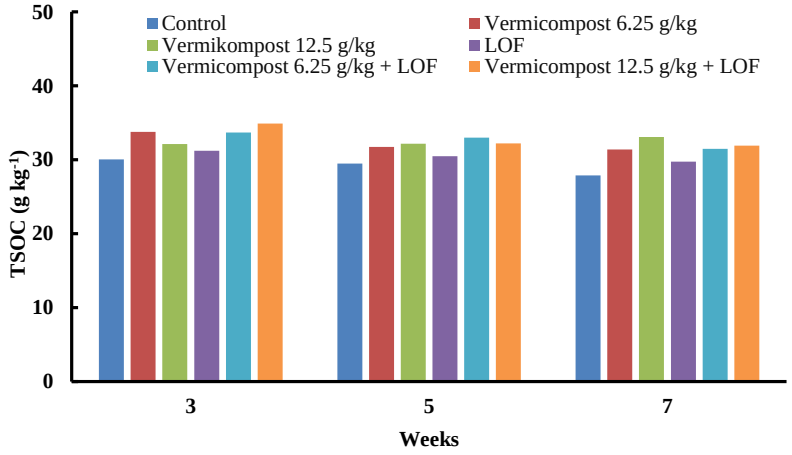


**Figure 3.** Total soil organic carbon at 3, 5, and 7 weeks of the incubation

The ratio of C/N is an indicator of the organic decomposing process. During the decomposition, carbon is released into the atmosphere, causing the decline of TSOC. Our experiment showed that, in general, the C/N ratio decreased during the incubation. C/N ratio was lower at week seven than weeks 3 and 5 (Figure 4).

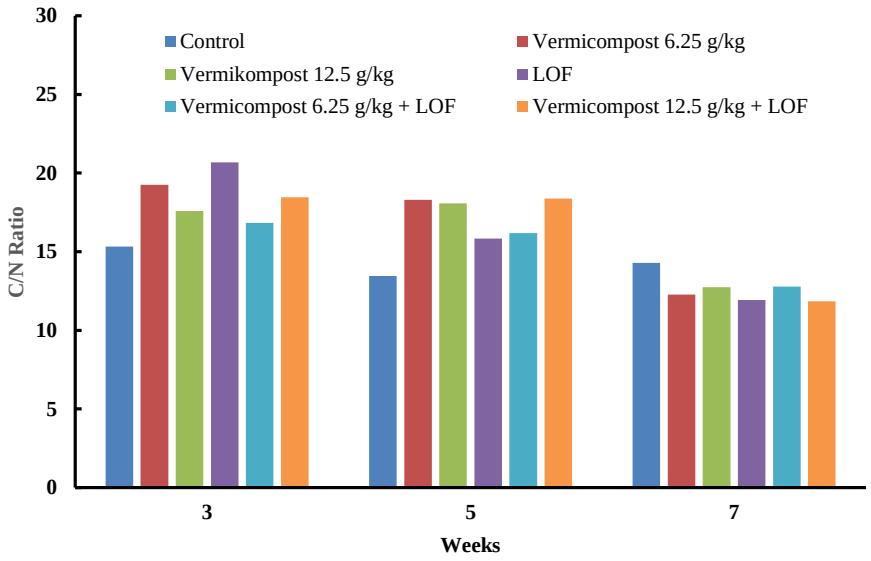


**Figure 4.** C/N ratio during the incubation

***Available nitrate-n and total soil nitrogen***

Soil nitrate fluctuated during the incubation is shown in Figure 5. Nitrate-N considerably decreased in the first 4 weeks of the incubation and continuously increased afterward. Figure 5 also indicated that vermicompost and LOF had a significant effect on nitrate-N concentration. At weeks 1 and 2, rates of 6.25 and 12.5 g $kg^{-1}$ vermicompost considerably increased nitrate-N, however, did not affect that at weeks 3, 4, and 5. Afterward, the effect was also significant.

In general, the addition of LOF accelerated the release of nitrate-N to the soil, as indicated in Figure 5. The addition of N from LOF reflected the increase in nitrate-N. As time lapsed, the combination of vermicompost and LOF released nitrate higher than vermicompost or LOF alone.

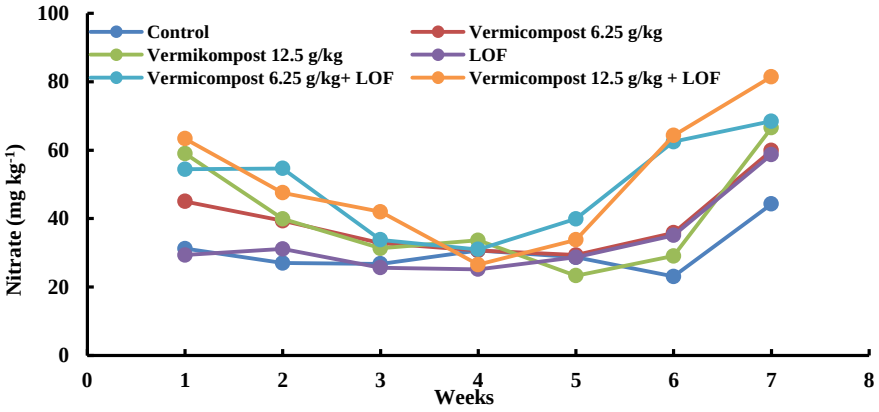


**Figure 5.** Nitrate-N availability during the incubation as influenced by vermicompost and LOF

In line with the nitrate-N, TSN continuously increased during the incubation (3, 5, and 7 weeks of the incubation), as shown in Figure 6. During the incubation, organic matter decomposition indeed releases N to the soil through ammonification and nitrification. The experiment also showed that higher TSN resulted in vermicompost application of 6.25 and 12.5 g $kg^{-1}$ compared to the control, even though there were no differences between both rates. The addition of LOF provided higher TSN, mainly at a vermicompost application rate of 12.5 g $kg^{-1}$ than the other treatments. Using soils from the different length of cassava cultivation, Wijanarko and Purwanto (2017) observed that TSN was higher in soil incubated with 5 Mg $ha^{-1}$ groundnut and corn mass than the control.

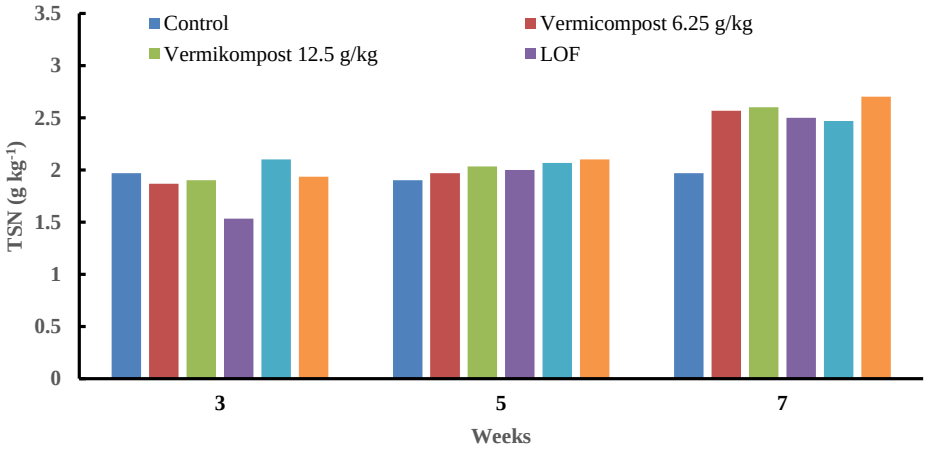


**Figure 6.** Total soil nitrogen at 3, 5, and 7 weeks of the incubation

## Discussion

Application of organic matter to soil has effects on soil chemical properties as the amendment decomposes. Incubation of soil with vermicompost and LOF, either combined or alone for 7 weeks had a significant effect on nitrate-N, soil pH, TSOC, TSN, and C/N. The study revealed that at the first 2 weeks of the incubation, soil pH was independent on all treatments but as time lapsed, vermicompost and LOF applied in combination or alone increased the pH as compared to control. This result might be associated with the intense organic matter decomposition indicated by a decrease in TSOC, leading to the formation of $NH_4$ from ammonia solubility. Also, organic matter decomposition releases organic acids mainly humic and fulvic which covalently bond metals, lowering their hydrolysis (Spark, 2003). As a result, the soil pH raises. A somewhat similar result was found by Ebid *et al.* (2007) where during the incubation for 63 days, soil treated with compost had higher soil pH than control.

The rate of organic matter decomposition is dependent on soil temperature, as reported by some researchers (Kirschbaum, 2010; Kirschbaum, 2006). A previous study by Katterer (1998) noted that Q10 of 2 was sufficient to describe the dependency of organic matter decomposition on the temperature range of 5-35 $^{o}$C even though the conclusion is tentative. In this study, soil temperature increased substantially at week 4. The temperature might have an influence on the nitrogen dynamic during the organic matter decomposition process.

The concentration of nitrogen in the soil is highly dependent on the decomposition of organic matter. The addition of organic matter will eventually increase the nutrient through the mineralization by soil microorganisms. Total soil organic carbon (Figure 3) decreased over time, indicating the occurrence of soil organic matter decomposition. Another indication is the decrease in the C/N ratio of the soil (Figure 4). As time lapsed, microorganisms had decomposed the organic amendment. A previous study by Muktamar *et al.* (2020) also noted that the C/N ratio of soil-treated vermicompost and chicken manure decreased during the incubation period. The decomposition of vermicompost and LOF increased nitrate and TSN.

Nitrate-N availability declined at the first four weeks, then steadily increased. The decrease was more prominent when the soil was fertilized with the organic amendment, so did the increase (Figure 5). The decrease might have been associated with the immobilization process during the period. Mineralization of organic N is highly dependent on microbial activity, which also requires nitrogen; after that, nitrogen is immobilized to form organic-N. A previous study confirmed that drastic N immobilization was observed in the

first two weeks of incubation, being the highest was the soil fertilized with the highest concentration of glucose (Romero *et al.,* 2015). In this study, the decrease in $NO_3$-N was observed until week 4 of the incubation. A more prolonged decline might also be reflected by N volatilization at week four, as soil temperature reached more than 33 $^oC$ (Figure 2). The formation of ammonia during the ammonification of organic-N might volatilize to the atmosphere, causing the lower formation of $NO_3$ from the nitrification process. According to He (1999) ammonia volatilization significantly increased at the first 20 days of fertilizer and soil incubation. Also, the process was soil temperature dependence. The volatilization was higher at a soil temperature of 45 $^oC$ than 25$^oC$. This result is similar to that observed by Ebid *et al.* (2007) where nitrate-N was not affected by applying several composts up to week 3, except kitchen compost, then significantly increased up to 63 days.

The decrease in soil nitrate was prominent as the vermicompost rate higher. This result indicates that the immobilization of nitrate was more intensive at a higher rate of vermicompost, so was the process of volatilization. An increase in the rate of vermicompost accelerated the activity of microorganisms. During weeks 6 and 7, available nitrate-N was higher as the vermicompost rate was increased. However, available nitrate-N was not different between 6.25 and 12.5 g $kg^{-1}$ vermicompost. The increase in nitrate-N is associated with the addition of organic matter to the soil. A similar result was observed by Murugan and Swarnam (2013) where nitrogen release to the soil increased as the vermicompost rate higher.

Application of LOF to soil enhanced the release of nitrate to the soil. An increase in nitrate-N, by applying LOF was also observed by Muktamar *et al.* (2015). The supplementation of LOF is increasingly essential for nitrogen fertilization due to the nutrient's slow release from solid organic fertilizer. Liquid organic fertilizer releases N faster than solid organic fertilizer so that the availability of N to the plant will assure better plant growth, mainly at an early stage. A study by Muktamar *et al.* (2017b) confirmed that supplementation of LOF to organic amendment improved the growth and yield of sweet corn in the organic environment.

In summary, soil available nitrate-N fluctuated during seven weeks of the incubation. It decreased from week 1 to 4, then steadily increased to week 7 of the incubation. The nitrate-N decline was more intensive when the soil was incorporated with vermicompost and LOF. So did the increase after week 4 of the incubation. At the end of the incubation, nitrate-N was most significant at treating vermicompost 12.5 g $kg^{-1}$ supplemented with LOF. This finding has a substantial contribution to nitrogen fertilization management using vermicompost in Inceptisols.

## Acknowledgments

Sincere appreciation goes to technicians at the Laboratory of Soil Science, University of Bengkulu, for their assistant during this project's soil analysis.

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(Received: 9 August 2021, accepted: 27 December 2021)