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MITIGATION N_2O EMISSION THROUGH BEEF CATTLE WASTE FERTILISATION APPLICATION IN CORN FIELD

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Abstract: This study is aimed at explaining the pattern of N_2O emission from the use of Cattle Manure Fertiliser (bio-slurry, bio-urine and Trichocompost) on sweet corn (*Zea mays L. Saccharata*). This study used a Randomised Block Design (RBD) with four treatment groups and four replications. Each test consisted of 16 experimental units. The treatments consisted of combinations of chemical fertiliser (SP36, KCl, urea) and organic fertiliser (bio-urine and bio-slurry, Trichocompost), i.e., 100% chemical fertiliser (C_{100}), 75% chemical fertiliser+25% organic fertiliser ($C_{75}O_{25}$), 50% chemical fertiliser+50% organic fertiliser ($C_{50}O_{50}$) and 25% chemical fertiliser+75% Organic Fertiliser ($C_{25}O_{75}$). The observed variables were the pattern of N_2O flux after the first and second fertilisation and the emission of N_2O. The results showed that the highest N_2O flux in the first fertilisation resulted from $C_{75}O_{25}$ treatment, while in the second fertilisation, the highest N_2O flux was emitted from C_{100} and the lowest was emitted from $C_{25}O_{75}$. The lowest N_2O emission was from $C_{25}O_{75}$ treatment. In conclusion, using beef cattle waste fertiliser could decrease N_2O flux and emissions by 75% in sweet corn cropping.

Keywords: Beef cattle, manure, fertiliser, emission, global warming.

Introduction

The accumulation of greenhouse gases (GHG) such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) in the atmosphere causes climate change, also referred to as global warming. This increase can be caused by industrial activities, fossil fuel combustion, and the agricultural and livestock sectors (IPCC, 2013). In the livestock sector, beef cattle waste contributes up to 40% of greenhouse gases (GHG) in the atmosphere (Grossi *et al*., 2019) and agricultural sector also contributes around 10-12% to greenhouse gas emissions (Pramono *et al*., 2021). These greenhouse gas emissions are expected to continue to increase until 2030 as food demand increases. This increase in greenhouse gas emissions will contribute to global warming as CH_4 in the atmosphere is 25 times greater than CO_2, while N_2O is 298 times higher (Valero, 2019).

GHG emissions from the agriculture and livestock sectors are closely related to conventional farming. At present, beef cattle waste in the form of solid waste (cow manure) and liquid (urine) are not disposed of properly. The beef cattle waste will pollute the environment and potentially increase GHG emissions. The accumulation of beef cattle waste can produce high amounts of CH_4 gas, which contributes to global warming (Chadwick *et al*., 2011). Furthermore, the intensive use of chemicals by farmers increases the production costs and has the potential to contribute to GHG emissions in the form of N_2O gas (Nenobesi *et al*., 2017).

The large contribution of the livestock and agriculture sectors to global warming must be mitigated. By making solid and liquid beef cattle waste as sources of organic fertilisers in the form of trichocompost, bio-urine, and bio-slurry, GHG emissions could be reduced. As an organic material, trichocompost can improve agricultural land by adding nutrients that plants need. This is expected to increase productivity, lower the cost of chemical fertilisers, and preserve environmental quality (Hartati *et al*., 2016). Liquid fertiliser in the form of bio-urine, in addition to containing high amounts of nutrients, also contains natural growth regulators and pest and disease-repellent compounds. The natural growth regulator contains hormones from the IAA, Gibberellin, and cytokinin groups (Sirajuddin *et al*., 2015). Bio-slurry is the final product after processing beef cattle solid waste for biogas energy. The liquid bio-slurry has no damaging effect on the soil or plants, and can act as a binding agent so that the fertiliser solution applied to the soil surface can be directly utilised by plants. It also contains microbes facilitate the the fertilisation of the soil (Kabedey *et al*., 2023).

Therefore, it is necessary to assess how much of N_2O gas emissions are mitigated through the application of organic fertiliser based on beef cattle waste compared with chemical fertilisers.

Materials and Methods

Materials

The research was conducted in Pudak Community Economic Zone, Kumpeh Ulu Village, Muaro Jambi Regency, Jambi Province, Indonesia. The materials used were Bonanza F1 seed (sweet corn type), *Bio-urine, Bio-slurry, Trichocompost* as Organic Fertiliser and KCL (*Kalium Chloride*), Dolomite, Urea as Chemical Fertiliser. The gas measurement apparatus comprised N_2O gas closed chamber (50cm x 30cm x 25cm), vial storage, bubble wrap, septum rubber, thermometer, aluminium foil paper and 10 ml syringe.

Research Method

Land Preparation

A 0.25 ha plot planted with sweet corn was prepared. The ground was tilled using a hand tractor that was divided into 16 pillows around 100 cm in height of ± 10 cm. Two rows of plants were planted in each pillow designed in a randomised complete block design, consisting of four treatments and eight replications. The soil type was Alluvial with a pH of 4.7 and chemical composition of N 0.05%; P 5.3 ppm; K 0.05%; and C 1.0%.

Planting Process

Corn seeds were planted into the soil at a depth of 3 cm using the *legowo* row system. Each pillow had two rows of plants with a spacing 25 cm x 50 cm. If a seed did not grow or the seedling died, a replacement plant prepared in the reserve yard was planted.

Fertilisation

Chemical and organic fertilisation applications in sweet corn fields according to the treatments are presented in Table 1.

Chemical Fertiliser Applications

The chemical fertilisation was done by digging a hole about 5 cm from the plants. Dolomite is applied 3 days before planting. For KCl and SP36 fertilisation, they were applied at 14 DAPs, Urea were applied 2 times at 14 DAPs and 30 DAPs

Organic Fertilisers

The organic fertiliser used in this study is a combination of solid and liquid waste from beef cattle, which includes Trichocompost, bio-urine, and bio-slurry. Trichocompost is processed beef cattle feces that have been treated with the decomposer *Trichoderma harzianum sp* which was isolated at the Jambi Province Food Plant Pest Disease Laboratory. Trichocompost was applied by sprinkling it on the planting holes that had been prepared according to the treatment given, 3 days before planting at the beginning of planting. Bio-urine is beef cattle urine that has undergone fermentation for approximately 1 month, while bio-slurry is the final product of biogas. Bio urine is applied first, followed by bio slurry by spraying it onto each plant from

Table 1: Application of chemical and organic fertilisers in sweet corn fields (*Zea mays* L.Sacc)/0.25 ha

No.	Treatment	3 Days Before Planting	Total (Kg^{-1} 0.25 ha)	14 Day After Planting DAPs)	Total (Kg^{-1} 0.25 ha)	30 DayAfter Planting (DAPs)	Total (Kg^{-1} 0.25 ha)
1.	CF_{100}	Dolomit	500	SP_{36}	50		
				KCL	25		
				Urea$_1$	37.5	Urea$_2$	37.5
2.	$C_{75}O_{25}$	Trichocompost	125	SP_{36}	37.5		
				KCL	18.75		
				Urea$_1$	28.13	Urea$_2$	28.13
3.	$C_{50}O_{50}$	Trichocompost	250	SP_{36}	25		
				KCL	12.5		
				Urea$_1$	18.75	Urea$_2$	18.75
				Biourine$_1$	12.5 ltr (Kg^{-1}ha)	Biourine$_2$	12.5 ltr (Kg^{-1}ha)
4.	$C_{25}O_{75}$	Trichocompost	375	SP_{36}	12.5		
				KCL	6.25		
				Urea$_1$	9.375	Urea$_2$	9.375
				Biourine$_1$	12.5 ltr (Kg^{-1}ha)	Biourine$_2$	12.5 ltr (Kg^{-1}ha)
				Bio-slurry$_1$	12.5 ltr (Kg^{-1}ha)	Bio-slurry$_2$	12.5 ltr (Kg^{-1}ha)

Note: *Recommended use of chemical and organic fertilisers in sweet corn crops: Super Phosphate (SP36) 200 kg^{-1}ha, Potassium Chloride (KCL) 100 kg^{-1}ha, Urea 300 kg^{-1}ha, dolomite 2000 kg^{-1}ha (Nurmegawati et al., 2015). Trichocompost 2000 kg^{-1}ha, bio-urine 100 ltr^{-1}ha, bio-slurry 100 ltr^{-1}ha (Tani, 2017).

the tip of the leaves to the ground. Bio urine and bio slurry applications were applied at 14 DAPS and 30 DAPS.

Nitrous Oxide Gas (N_2O) Measurement

During this research, the N_2O gas sampling was implemented in two stages. The first stage consisted of 3,6,9 days after the first fertilisation with 14 DAPs and the second stage also being done in 3,6,9 days after the second fertilisation with 30 DAPs. The stages of $N_2$0 emission were running in these steps: Placing $N_2$0 gas capture chamber (50 cm x 30 cm x 25 cm) between 2 (two) corn plants within the same pillow and the gas capturing process was conducted in the morning.

(a) Installing a thermometer to measure the temperature after the gas taking has been completed. The range of time that being set as benchmark were in 10, 20, 30, 40 and 50 minutes.

(b) N_2O gas sampling process was running by injection of 10 ml with wrapping the syringe surface by aluminium foil to prevent gas leaking during the process.

(c) Immediately closing the syringe that contains the gas to ensure the leakage of captured gas.

(d) Analysing the gas concentration in Greenhouse Gas Laboratory by using chromatography gas.

Research Design

This research was carried out by using a randomised complete block design (RCBD) where it has been implemented in four treatment groups where each group included two experimental units. The treatment process consisted of these elements:

(1) C 100 : 100% Chemical Fertiliser
(2) $C_{75}O_{25}$: 75% Chemical Fertiliser + 25% Organic Fertiliser
(3) $C_{50}O_{50}$: 50% Chemical Fertiliser + 50% Organic Fertiliser
(4) $C_{25}O_{75}$: 25% Chemical Fertiliser + 75% Organic Fertiliser

Observed Variables

The flux of N_2O gas in the first and second fertilisation pattern measured in kg $ha^{-1}day^{-1}$ and N_2O gas emissions measured in kg $ha^{-1}season^{-1}$.

Data analysis

Flux data and N_2O emissions are calculated with the (IAEA, 1992):

$$E = dc/dt \times Vch/Ach \times mW/mV \times 273.2/(273.2 + T)$$

where
E = N_2O gas emission (mg/m2/ day)
dc/dt = the difference N_2O per time given(ppm/minute)
Vch = the Volume of Box (m3)
Ach = the Box Area (m2)
mW/mV = Gas molecular weight/molecular volume constant N_2O (22.41 1)
T = Average temperature measured during sampling (^{0}C)
The 273.2 value = Kelvin temperature constant degree

Greenhouse gas emission (N_2O) were being calculated and measured in Analysis of Variance and if there were discrepancies between treatments, they were tested further by using Duncan's test. The data processing in this research was conducted in System Analysis Stasitic (SAS) software.

Results and Discussion

Patterns of N_2O Flux from Application of Chemical Fertiliser and Organic Fertiliser at First Fertilisation in Sweet Corn Fields

The N_2O flux emitted from various levels of trichocompost, bio-urine and bio-slurry applications on sweet corn plantation (Zea mays *L. Saccharata*) in the first fertilisation is presented in Figure 1.

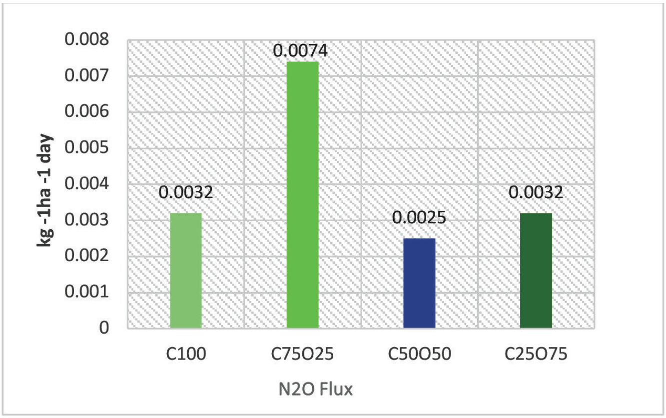

Figure 1: N_2O Flux in First Fertilisation with four treatments: 100% Chemical (C_{100}); 75% Chemical+25% Organic ($C_{75}O_{25}$); 50% Chemical+50% Organic ($C_{50}O_{50}$); 25% Chemical+75% Organic ($C_{25}O_{75}$), respectively

The N_2O flux from the application of a combination of chemical fertilisers and organic fertilisers (Trichocompost, bio-urine and bio slurry) on sweet corn fields was quite varied, where at the beginning of fertilisation (1st fertilisation) the combination of CF+OF (75% and 25%) emitted higher N_2O than the application of chemical fertiliser (100%), CF+OF (50% +50%) and CF+OF (25% and 75%). This shows that after the first fertilisation, the N_2O flux from the plots $C_{75}O_{25}$ was highest than others the plots, may caused by the organic fertiliser was still undergoing decomposition and still supplies energy for denitrification. N from fertiliser, dissolved organic carbon and inorganic N from soil organic matter decomposition and N mineralisation also contribute to N_2O production (Wu *et al.,* 2017). Fertilisation is a major factor that contributes to the release and addition of N_2O. The higher N_2O flux pattern in $C_{75}O_{25}$ is due to chemical fertilisers that can cause pollution and global warming. Chemical fertilisers themselves contain nitrogen needed by plants, but not all nitrogen is absorbed by plants. Some of the nitrogen will be broken down by microorganisms or flows with water and binds with oxygen to form nitrous oxide gas (N_2O) (Dalman *et al*., 2021).

N_2O Production Pattern at The Time of Second Fertilisation in Sweet Corn Field

In the second fertilisation, the use of organic fertiliser (beef cattle waste) consisting of trichocompost, bio-urine, and bio-slurry with a combination of $C_{75}O_{25}$, $C_{50}O_{50}$, and $C_{25}O_{75}$ was seen to decrease while the use of 100% chemical fertiliser (C_{100}), N_2O flux was seen to be the highest of the other treatments. This result shows that at the age of 15 days after fertilisation, the absorption of fertilisers by plants has gone well., The pattern of the decline in N_2O flux is presented in Figure 2.

The results showed that the application of 100% chemical fertiliser (C_{100}) on sweetcorn fields increased the highest N_2O flux compared to the treatment with organic fertiliser (beef cattle waste). The application of NPK fertiliser can increase the level of nitrogen (N) in the soil so that the demand for N for the bacterial transformation process can be met in the long term (Jain *et al*., 2010). Nitrogen is the main component in the formation of N_2O, where N_2O is formed from the conversion of ammonium to nitrate through the process of nitrification and then to N_2O through the process of denitrification (Suntoro *et al*., 2013). N_2O fluxes increase with increasing soil N (Weitz *et al*., 2001). N is required for plant growth in two forms,

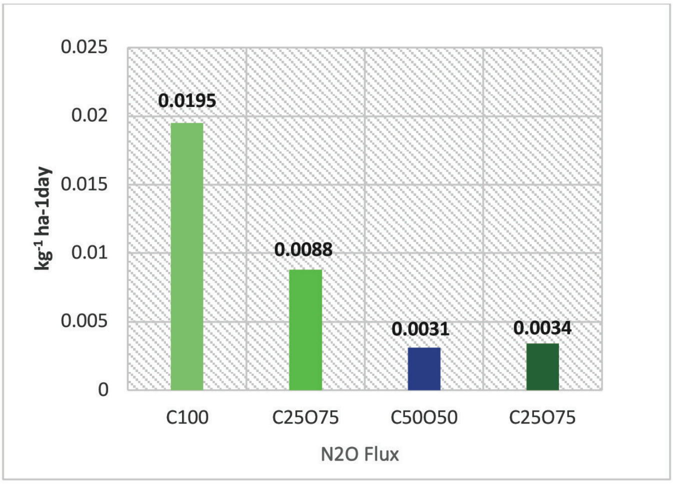

Figure 2: N_2O Flux in second fertilisation with four treatments: 100% Chemical (C_{100}); 75% Chemical+25% Organic ($C_{75}O_{25}$); 50% Chemical+50% Organic ($C_{50}O_{50}$); 25% Chemical+75% Organic ($C_{25}O_{75}$), respectively

ammonium (NH^{4+}) when the soil is wet and nitrate (NO^{3-}) when the soil is dry In addition, N_2O can be formed by natural processes, namely the activity of microorganisms. N_2O is formed naturally through the processes of nitrification and denitrification as by-products of the nitrogen cycle (Bracmort, 2010).

Nitrification is the aerobic reduction of NH_3 to nitrite and nitrate. The first step in the nitrification process is the oxidation of NH_3 to NO_2 by ammonia oxidising bacteria such as Nitrosomonas. The next stage is the oxidation of NO_2 to NO_3 by nitrite oxidising bacteria such as Nitrobacter. The formation of N_2O occurs when Annamox bacteria reduce ammonia to N2 gas with the electron acceptor NO_2 (Bernhard, 2010). Denitrification is the process of reducing NO_3^- to NO_2^- and further to NO, N_2O and N_2, with N_2 being the main product of the denitrification process. N_2O can be formed by natural processes, namely the activity of microorganisms. N_2O is formed naturally through nitrification and denitrification processes as by-products of the nitrogen cycle (Bracmort, 2010). Nitrification is the aerobic reduction of NH_3 to nitrite and nitrate. The first step in the nitrification process is the oxidation of NH_3 to NO_2 by ammonia oxidising bacteria such as Nitrosomonas. The next stage is the oxidation of NO_2 to NO_3 by nitrite oxidising bacteria such as Nitrobacter. The formation of N_2O occurs when Annamox bacteria reduce ammonia to N_2 gas with the electron acceptor NO_2 (Bernhard, 2010). Denitrification is the process of reducing NO_3^- to NO_2^- and further to NO, N_2O and N_2, with N_2 being the main product of the denitrification process. This process is also referred to as enzymatic denitrification, which is different from the assimilatory reduction of NO_3^- carried out by various biota for their growth, and also different from the dissimilatory reduction of NO_3^- to NH_4^+ carried out by some microbes in the absence of oxygen (Hadisudarmo, 2009). The process of nitrification by producing N_2O in small amounts. Whereas NO_3^- can be reduced through denitrification in a slightly aerobic state to N_2O, in this process N_2O are formed (Ramos *et al.*, 2019).

The decrease in N_2O flux production in the second fertilisation in sweet corn land, the application of organic fertiliser based on Beef Cattle waste (trichocompost, bio-urine and bio-slury) by 25% ($C_{25}O_{75}$), 50% ($C_{50}O_{50}$) and 75% ($C_{75}O_{25}$), the higher the amount of organic fertiliser used, the lower the N_2O flux value. Shao *et al.* (2017) stated that the soil N_2O emission flux decreased as the proportion of organic fertiliser increased. Organic fertilisers are able to maintain land fertility and productivity in a sustainable manner. The combination of inorganic and organic fertiliser applications can increase land productivity sustainably, increase N use efficiency, and reduce environmental pollution. The combination of inorganic and organic N fertilisation can maintain soil fertility and crop productivity in the long term (Eche *et al.*, 2013).

Effect of the Organic Fertiliser Application on Greenhouse Gas (N_2O) Emissions

The N_2O emissions generated from the four application patterns of chemical fertiliser and beef cattle waste fertiliser (organic fertiliser), it can be seen that the higher the organic fertiliser applied to sweet corn fields (75%) can reduce N_2O emissions. Results are presented in Figure 3.

The results showed that using 100% chemical fertiliser (C_{100}) produced the highest N_2O emissions followed by application of Organic Fertiliser 75% ($C_{75}O_{25}$), 50% ($C_{50}O_{50}$) and 25% ($C_{25}O_{75}$). The high N_2O emissions at 100% Chemical Fertiliser application (C_{100}) are due to N_2O emitted from nitrogen-fertilised soils due to nitrification and denitrification processes. Agricultural land has the potential to increase its N_2O gas emissions when the amount of N available for microbial transformation is increased through inorganic N fertilisation, return of organic fertilisers and crop residues to the soil, mineralisation of soil biomass and other forms of organic matter (Efosa *et al.*, 2023). Besides fertilisation, some factors that can affect N_2O emissions are temperature, soil type, vegetation type, different climatic and soil conditions, location, sampling time.

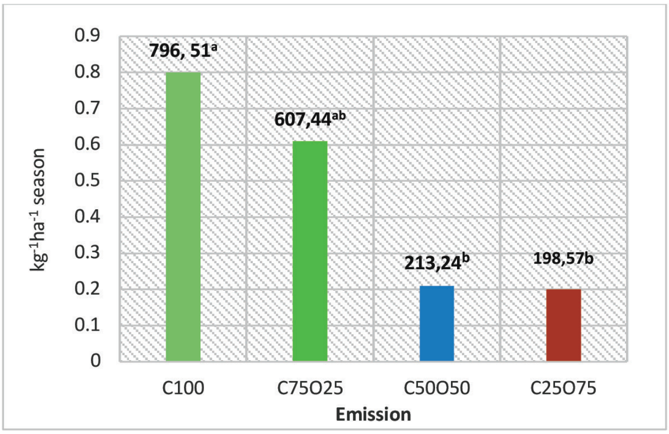

Figure 3: N_2O Emission (kg CO_2^{-e} ha^{-1} $season^{-1}$) on Sweet Corn Fields with four treatments: 100% Chemical (C_{100}); 75% Chemical+25% Organic ($C_{75}O_{25}$); 50% Chemical+50% Organic ($C_{50}O_{50}$); 25 % Chemical+75 % Organic ($C_{25}O_{75}$), respectively

The amount of soil-borne N_2O emissions correlates with the amount of nitrogen (N) available in the soil. Adding organic matter such as compost and manure to the soil in maize crops has the potential to increase soil C storage while providing a source of N. Replacing synthetic N fertilisers with organic matter will also reduce the environmental costs associated with N fixation by recycling large amounts of available N resources. Inorganic fertilisation causes an increase in N_2O flux (Mishra *et al.*, 2012). Organic fertilisation with biochar can reduce greenhouse gas emissions and increase land productivity. Charcoal is beneficial for soil management, carbon sequestration, and immobilising pollutants (Kajitani *et al.*, 2013). Charcoal can reduce the rate of N_2O production by improving soil physical properties (diffusion, aggregation, water-holding capacity), soil chemical properties (acidity, available nitrogen nutrients from minerals and organic matter, dissolved organic carbon), and soil biological properties (number of microorganisms, activity of macrofauna) (Lorenz and Lal, 2014). The organic fertiliser used in this study contains charcoal, which is very useful for improving soil fertility and increasing plant growth. Charcoal has specific properties that, when incorporated into the soil, increase soil pH and nutrient holding capacity, making fertilisation more efficient (Wang *et al.*, 2017). The use of solid and liquid beef cattle waste in food crops on tidal swamp can reduce N_2O emissions (Tani, 2017). N_2O production increases, both through the process of nitrification and through the process of denitrification, when the soil is given an excessive application of N fertiliser (Tracy *et al.*, 2017).

Conclusion

The highest N_2O flux in the first fertilisation was resulted from $C_{75}O_{25}$ treatment, while in the second fertilisation, the highest N_2O flux was emitted from C_{100} and the lowest was $C_{25}O_{75}$. By applying organic fertiliser (Beef Cattle Waste) to substitute N fertiliser rate on corn cropping could reduce N_2O emission 23-75% in our field. The highest reduction was reached by combining 25% chemical fertiliser and 75% organic fertiliser. Fertiliser management could be key factors to reducing GHG emissions in tropical regions. The application of beef cattle waste fertiliser could reduce N_2O flux and emission up to 75% from sweet corn cropping.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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