N₂O Emissions from Rainfed Sugarcane Plantation

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Submitted: 31 March 2016; revised: 16 December 2016; accepted: 9 April 2017

ABSTRACT

Expansion of sugarcane areal to support enhancement production and fulfillment target of self-sufficiency for national sugar should be conducted to see environment impact, particularly related to greenhouse gases emission. The objective of this study was to figure out N₂O emission from conventional sugarcane plantation by farmer in rainfed area. The observation of N₂O gas was carried out in sugarcane plantation in Sidomukti Village, Jaken District, Pati, Central Java. Sampling of N₂O gas was conducted by close chamber method. The study showed that maximum fluxes of sugarcane plantation before and after fertilizer application are 4.011 and 223 µg N₂O m⁻² day⁻¹. Meanwhile, after fertilizer application the maximum and minimum fluxes of N₂O are 6.408 and 25 µg N₂O m⁻² day⁻¹. N₂O emission from sugarcane plantation recorded in rainfed area as 4.21 ± 2.53 kg N₂O ha⁻¹ year⁻¹ with potential of global warming number as 1.31 ton CO₂-e per hectar per year.

Keywords: Emission, N₂O, plantation, sugarcane

INTRODUCTION

Three major gases emission from agriculture sector are CH₄ around 67% from the total emissions from agriculture sector, following by N₂O (30%) and CO₂ (3%). Total emission from this sector in 2000 approximately 75.419.73 Gg CO₂-e. Between 2000 and 2005, emission from agriculture was increase as 6,3% (Ministry of Environment SNC 2009).

Dinitrogen oxide (N₂O) emissions not only contribute through GHG effect but also as a damage causes of statosfer ozon layers.

N₂O dari Pertanaman Tebu di Lahan Tadah Hujan

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ABSTRAK

Perluasan areal tanam tebu untuk mendukung peningkatan produksi dan pemanfaatan target swasembada gula nasional sudah dianggap perlu untuk melihat dampak lingkungan khususnya mengenai evaluasi emisi gas rumah kaca dari pertanaman tebu. Tujuan dari penelitian ini adalah untuk mengetahui emisi gas N₂O dari sistem pertanaman tebu secara konvensional petani di lahan tadah hujan. Pengamalan gas N₂O dilakukan pada lahan perkebunan tebu di Desa Sidomukti, Kecamatan Jaken, Kabupaten Pati, Jawa Tengah. Pengambilan sampel N₂O menggunakan metode sungkup tertutup. Hasil penelitian menunjukkan bahwa fluks maksimum pada pertanaman tebu sebelum pemupukan sebesar 4,011 µg N₂O m⁻² hari⁻¹ dan fluks minimum sebesar 223 µg N₂O m⁻² hari⁻¹, sedangkan fluks maksimum setelah pemupukan sebesar 6,408 µg N₂O m⁻² hari⁻¹ dan fluks minimum sebesar 25 µg N₂O m⁻² hari⁻¹. Emisi N₂O pertanaman tebu sebesar 4.21 ± 2.53 kg N₂O ha⁻¹ tahun⁻¹ dengan nilai potensi pemanasan global sebesar 1.31 ton CO₂-e per hektar per tahun.

Kata kunci: Emisi, N₂O, perkebunan, tanaman tebu
Almost 90% global N₂O emissions formed during the nitrate (NO₃⁻) and amoniac (NH₄⁺) microbe transformation in the soil and water. Globally, contribution from agriculture sector for N₂O emissions is 65–80 percent from total emissions, especially from nitrogen fertilizer in the soil management system, livestock, and manure. Agriculture contribution in Indonesian N₂O emissions estimated at 70 percent (SNC). N₂O emissions from soils comes from N productive loses. Nitrogen input (synthetic fertilizer and biomass) and also nitrogen mineralization in the soils which is reach of organic materials contribute to N₂O emissions. The N₂O emissions from rice fields depends on nitrogen fertilizer rates. Global Warming Potential (GWP) from greenhouse gases to carbon dioxide as big as 21 times for CH₄ and 310 for N₂O reported in IPCC Second Assessment Report National Standard of Indonesia/Standart Nasional Indonesia (SNI ISO 14064 2009).

In 2006–2012, the area of state sugarcane plantation in Indonesia have been expanded from 213.900 ha to 247.800 ha that support increase in sugar production as 1.028.700 ton in 2006 to 1.445.100 ton in 2012 (BPS 2015), while for private sugarcane plantation owned by big company decreased from 396.400 ha to 194.900 ha. Because of those expansion, environmental issues such as Greenhouse Gas’s (GHG’s) emission from cultivation practices should be evaluated. GHG’s emission from sugarcane plantation correlated with land use change, fertilization, irrigation and residue management (including litter burning), and fossil fuel use (Figueiredo & La Scala Jr 2011; Lisboa et al. 2011). Study in Brazil showed that N fertilizer is main contributor to GHG’s emission in sugarcane plantation (Lisboa et al. 2011).

Studies on GHG’s emission in sugarcane plantation, particularly in rainfed area are limited. Therefore we conducted a research aimed to figure out N₂O emission from sugarcane plantation conventionally conducted by the farmer in rainfed area.

**MATERIALS AND METHOD**

Observation was conducted in the state of sugarcane plantation in Sidomukti village, District of Jaken, Pati City, Central Java Province in 2014. Sampling was carried out in existing sugarcane plantation owned by farmer of those village that consist of three blocks distinguish by water pathways and four replication with “Bulu Lawang” cultivar. The plant was one month days after showing. Before sampling, base for chamber was set up in each point observation (Figure 1) for reduce gas leakage from cracked soil. N₂O was captured use 40 cm length x 20 cm width x 30 cm height close chamber, 6 times during observation (each of 3 times before and after fertilizer application). Chamber placement in sugarcane plantation was showed in Figure 2. Taking the gas sampling in erly morning at 06.00 AM with time interval for N₂O sampling was 10, 20, 30, 40, and 50 minute. The point of observation for N₂O sampling was in row and between crops. Sampling was conducted every month before fertilization and after second fertilizer application in 3, 7, and 15 days after fertilization (DAF). Gas samples were analyzed using Greenhouse Gas (GHG) Chromatography type Varian 450 equipped by Electron Capture Detector (ECD) as N₂O detector with Argon (Ar), Hydrogen (H₂), Helium (He), and Nitrogen (N₂) as the carrier gas.

N₂O emissions were calculated by using equation below (Lantin et al. 1998):

$$ E = \frac{dc}{dt} x \frac{Vch}{Ach} x \frac{mW}{mV} x \frac{273,2}{(273,2 + T)} $$

![Figure 1. Base for chambers observation](image-url)
A Hervani et al.: $\text{N}_2\text{O}$ Emissions from Rainfed Sugarcane Plantation

Figure 2. Position of base and chambers observation in the sugarcane plantation

Table 1. The results of soil analyze from Sidomukti Village, Jaken District, Pati City 2014

<table>
<thead>
<tr>
<th>No</th>
<th>Kinds of analyze</th>
<th>Method</th>
<th>Unit</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Textures</td>
<td>3 fractions by pipeting</td>
<td></td>
<td>42.03</td>
</tr>
<tr>
<td></td>
<td>Silt</td>
<td></td>
<td></td>
<td>33.37</td>
</tr>
<tr>
<td></td>
<td>Dust</td>
<td></td>
<td></td>
<td>24.59</td>
</tr>
<tr>
<td></td>
<td>Clay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>C-organic</td>
<td>Walky and black extract with spectrophotometry</td>
<td></td>
<td>1.47</td>
</tr>
<tr>
<td>3</td>
<td>N-Total</td>
<td>N-Kjedahl titrimetry</td>
<td></td>
<td>0.09</td>
</tr>
<tr>
<td>4</td>
<td>P-Total</td>
<td>HNO$_3$ nitrat acid extract and HClO$_3$ perchlorat analyze with Spectrophotometry</td>
<td></td>
<td>0.21</td>
</tr>
<tr>
<td>5</td>
<td>K-Total</td>
<td>HNO$_3$ nitrat acid extract and HClO$_3$ perchlorat analyze with AAS</td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>6</td>
<td>Ca-Total</td>
<td>HNO$_3$ nitrat acid extract and HClO$_3$ perchlorat analyze with AAS</td>
<td></td>
<td>0.46</td>
</tr>
<tr>
<td>7</td>
<td>Mg-Total</td>
<td>HNO$_3$ nitrat acid extract and HClO$_3$ perchlorat analyze with AAS</td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>8</td>
<td>Fe-Total</td>
<td>Ammonium asetat extract pH 7 with titrimetri</td>
<td>(cmol/kg)</td>
<td>7.99</td>
</tr>
<tr>
<td>10</td>
<td>Cation Exchange Capacity (CEC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Base saturation</td>
<td>HNO$_3$ nitrat acid extract and HClO$_3$ perchlorat analyze with AAS</td>
<td></td>
<td>91.37</td>
</tr>
<tr>
<td>12</td>
<td>ESP (Na)</td>
<td>HNO$_3$ nitrat acid extract and HClO$_3$ perchlorat analyze with AAS</td>
<td></td>
<td>52.56</td>
</tr>
<tr>
<td>13</td>
<td>pH</td>
<td>H$_2$O extract (1:5) analyze with pH meter</td>
<td></td>
<td>5.54</td>
</tr>
<tr>
<td></td>
<td>H$_2$O</td>
<td>H$_2$O extract (1:5) analyze with pH meter</td>
<td></td>
<td>4.32</td>
</tr>
<tr>
<td></td>
<td>KCl</td>
<td>KCl 1 M extract (1:5) analyze with pH meter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where, $E$ is flux of greenhouse gas emission (mg/m/hour for CO$_2$ and CH$_4$, μg/m/hour for N$_2$O). $\delta c / \delta t$ is the change of gas concentration (ppm); h is effective high of closed chamber head space (m); mW is molecule weigh of CO$_2$ (44 gram/mol), CH$_4$ (16 gram/mol), and N$_2$O (44 gram/mol); 273°C is Standard temperature; mV is volume of molecule ($22.41 \times 10^{-3}$ m$^3$); and $T$ is temperature in close chamber (°C).

Applied fertilizer in sugarcane plantation were 600 kg ZA, 200 kg SP36 and 200 kg KCl per ha. The first fertilization was applied as base fertilizer (1/3 dose of ZA, all of SP36 and KCl). The 2/3 dose of ZA was applied in second fertilization when the sugarcane 1.5 month, in the early of rainy season.
Application of fertilizer was conducted by

RESULT AND DISCUSSION

The result of N<sub>2</sub>O observation in sugarcane plantation before and after fertilization in 2014 is showed by Figure 3.

![Figure 3. N<sub>2</sub>O fluxes before and after fertilizer application](image)

N<sub>2</sub>O fluxes were varies during observation. According to Danevic et al. (2009), it due to many factors influence to N<sub>2</sub>O emission such as temperature, soil pH, availability of organic matter, aeration and fertilizer use. Elder & Lal (2008) was also find that N<sub>2</sub>O fluxes positively correlated with soil temperature in several depth, air temperature and CO<sub>2</sub> fluxes and one of N loses from plantation is N<sub>2</sub>O emission. Denmead et al. (2010) mentioned that covering by canopy and high frequency of rainfall lead high humidity of soil that induce high production of N<sub>2</sub>O through nitrification and denitrification process. In this study showed that N<sub>2</sub>O fluxes increase after fertilizer application (in observation date of March 28 and April 10). Daily average of N<sub>2</sub>O fluxes before and after fertilizer application were 2,015 ± 236 and 2,858 ± 690 µg m<sup>-2</sup> day<sup>-1</sup>. Total N<sub>2</sub>O emission during observation in rainfed sugarcane plantation was 4.21 ± 2.53 kg N<sub>2</sub>O ha<sup>-1</sup> year<sup>-1</sup>. While the Global Warming Potential (GWP) was 1.31 ton CO<sub>2</sub>-e.

Several studies found that large variation of N<sub>2</sub>O emission occur, particularly in spreading in the edge of plant. Application of N fertilizer either through chemical or organic fertilizer (Dalal et al. 2003; Jantalia et al. 2008; Signor 2010 cit Oliveira et al. 2013). Jantalia et al. (2008) recorded that N<sub>2</sub>O fluxes varies from 0 to 183 mg N<sub>2</sub>O-N m<sup>-2</sup> day<sup>-1</sup>, while Signor (2010) observed N<sub>2</sub>O fluxes from -10 to 2520 mg N<sub>2</sub>O-N m<sup>-2</sup> day<sup>-1</sup> followed amount of different N fertilizer applied in sugarcane plantation. They showed that variation in N<sub>2</sub>O fluxes depend on application of N fertilizer, method of application, soil type, and soil water content.

<table>
<thead>
<tr>
<th>Time application</th>
<th>N&lt;sub&gt;2&lt;/sub&gt;O Fluxes (µg N&lt;sub&gt;2&lt;/sub&gt;O m&lt;sup&gt;-2&lt;/sup&gt; day&lt;sup&gt;-1&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before fertilizer</td>
<td>Maximum: 4.011  Minimum: 223  Average: 2.015 ± 236</td>
</tr>
<tr>
<td>After fertilizer</td>
<td>Maximum: 6.408  Minimum: 25  Average: 2.858 ± 690</td>
</tr>
</tbody>
</table>

Increasing of N availability in soil could enhance N<sub>2</sub>O gas, however it depend on interaction between soil type, climate and cultivation technique. The important factors for forming and releasing N<sub>2</sub>O gas are ammonia content and nitrate in soil, aeration status of soil and soil water content, easily degraded of organic matter, soil pH and temperature (Bauwman 1994 cit. Orbanus-Naharia 2002). According to Verge et al. (2007), application of organic and chemical fertilizer tend to increase N<sub>2</sub>O emission in soil, N<sub>2</sub>O emission from soil increase 16% between 1999 and 2000 and N fertilizer contribute around 4%. Machefert et al. (2002) stated that the highest N<sub>2</sub>O emission produced by agriculture followed by forest and grassland and the main factor which affect are availability of N mineral, soil temperature, water soil content and organic matter.

CONCLUSIONS

Maximum flux in the sugarcane plantation before fertilization as 4.011 µg N<sub>2</sub>O
m−2 day−1 and minimum flux as 223 μg N₂O m−2 day−1. Meanwhile the maximum and minimum flux after fertilization as 6.408 and 25 μg N₂O m−2 day−1, respectively. N₂O emission from sugarcane plantation was recorded as 4.21 ± 2.53 kg N₂O ha−1 year−1 with the GWP as 1.31 t CO₂-e.

**ACKNOWLEDGEMENT**

Thank you very much Titi Sophiawati, Jumari, Susanto, Rakhmah Setianingrum, Sri Wahyuni, and Hilda Amelia Rakhmawati and technicians in research group of Emission and Absorption of GHG in Indonesian Agricultural Environment Research Institute for helping us in this study.

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