Mitigation of greenhouse gases and rice yields through the addition of urea coated biochar and biocompost in rainfed field

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Abstract. Rice is a strategic commodity, economic, and even political. Rice, as an economic commodity, can be seen from its ability to move the economy through the growth of fertilizer companies (organic and inorganic), seeds, pesticides, and agricultural tools and machinery. The research was carried out in the form of a demonstration in upland in Sidomuki Village, Jaken Subdistrict, Pati Regency, Central Java Province. The study was conducted in the dry season (DS) in 2018, using Ciherang rice varieties with Walik Jerami season in upland. The research consisted of 3 treatments, which were Introductory Technology 1 (T1) in the form of urea coated biochar (UCB), Introductory Technology 2 (T2) in the form of biocompost with balanced fertilization and farmer’s technique (T0). This results in rice ecosystems by means of farmers’ assistance produced higher fluxes than UCB and biocompost settings. Cumulative CH₄ flux in the highest plot of farmer’s technique compared to UCB and biocompost, farmer’s technique produced 1,765.32 mg CH₄ m⁻², biocompost produced 692.04 mg CH₄ m⁻² while the UCB produced 471.67 mg CH₄ m⁻² at the end of observation. Rice ecosystem with UCB produced N₂O flux higher than biocompost and farmer’s technique. And treatment UCB emitted CH₄ 226.13 kg ha⁻¹ season⁻¹, GWP 5.42 t CO₂e ha⁻¹ season⁻¹, and has the lowest emission index value compared to the other treatments is 1.45.

1. Introduction
Rice is a strategic commodity, economic, and even political. Rice, as an economic commodity, can be seen from its ability to move the economy through the growth of fertilizer companies (organic and inorganic), seeds, pesticides, and agricultural tools and machinery. In addition to irrigated rice fields, rainfed lowland rice in Indonesia is relatively wide-reaching 2.08 million hectares or 25.6% of the existing rice field [1]. Rice fields are one of the largest anthropogenic sources of global CH₄ emissions. Decreasing CH₄ rice emissions can contribute significantly to global warming control. Rainfed rice fields are sub-optimal land that needs to be optimized to support national food availability. The limiting factor for rainfed lowland is low soil fertility, vulnerability to drought stress or the effects of climate change, and limited irrigation water sources. Precise and optimal management of rainfed lowland and environmentally friendly land can improve soil and plant productivity as well as mitigated greenhouse gas emissions and reduce contaminants in the soil. Environmentally friendly technological components, the results of superior research from the IAERI, among others are high yielding low-emission varieties such as Ciherang, Situ Bagendit, Inpari 38, 39, 41; Urea Coated Biochar (UCB), that biochar from agricultural waste; compost byproduct biogas and low lignin-based agricultural waste. The provision of compost improves nutrient supply in the soil, and soil structure improves crop productivity and guarantees steady production [2]. Organic fertilizer from straw
compost 2 tonsha\(^{-1}\) contributes potassium nutrients equal to 50 kg KCl ha\(^{-1}\) [3]. The results of the research by Wiharjadi and Wade [4], showed that compost from manure increased the yield of gogorancah rice grain ranging from 0.47-2.20 tons ha\(^{-1}\) and walik straw ranged from 1.01 to 1.29 tonsha\(^{-1}\).

2. Materials and method
The research was carried out in the form of a demonstration in upland in Sidomukti Village, Jaken Subdistrict, Pati Regency, Central Java Province. The study was conducted in the dry season (DS) in 2018, using Ciherang rice varieties with Walik Jerami season in upland.

The research consisted of 3 treatments, which were Introductory Technology 1 (T1) in the form of urea coated biochar (UCB), Introductory Technology 2 (T2) in the form of biocompost with balanced fertilization and farmer’s technique (T0).

The rice varieties used were Ciherang, which is grown with a tile system (15-20) cm x (15-20) cm. Each treatment is cultivated in an area of 0.25 - 0.5 hectares so that for 3 treatments, an area of about 1 hectare is needed.

Cultivation components which include tillage, planting, plant maintenance, harvesting, and processing results are carried out according to the standard. Fertilizing urea coated biochar (UCB) and KCl in the T1 treatment was carried out at the age of 21 days after planting (DAT) with a dose of 225 kg urea CB ha\(^{-1}\) and 34-45 kg KCl ha\(^{-1}\) while phonska fertilization with a dose of 267 kg ha\(^{-1}\) is done simultaneously planting. At T2, phonska and biocompost treatments were given at planting with doses of 5 t biocompost ha\(^{-1}\) and 267 kg Phonska ha\(^{-1}\) while fertilizing urea and KCl at a dose of 178 kg urea ha\(^{-1}\) and 34-45 kg KCl ha\(^{-1}\) was given twice, which were at age 21 and 42 DAT. Farmer technique (T3) is a comparison that generally uses 300 kg Phonska ha\(^{-1}\) fertilizer and 250 kg urea ha\(^{-1}\), which was applied according to the habits of local farmers.

The parameters observed included environmental parameters (greenhouse gas emissions) and agronomic parameters (grain yield and weight of biomass).

3. Result and discussion

3.1. Plant parameters
Plant height from 31, 37, 49, 57 and 82 DAT all treatments increased, while for the number of tillers varied from 31 DAT to 37 DAT for UCB and biocompost treatment increased, when the plant was aged 49, 57 and 82 DAT decreased while the farmers’ technique from 31, 37, 49, 57 and 82 DAT decreased (number of tillers). Growth in plant height and number of tillers can be seen in Table 1.

| Treatment          | 31 DAT | 37 DAT | 49 DAT | 57 DAT | 82 DAT |
|--------------------|--------|--------|--------|--------|--------|
| Plant Height (cm)  |        |        |        |        |        |
| Biocompost         | 56.7   | 56.8   | 75.3   | 86.6   | 101.2  |
| UCB                | 55.2   | 58.5   | 78.5   | 95.7   | 103.8  |
| Farmer’s technique | 53.2   | 58.9   | 84.5   | 87.9   | 106.7  |

| Number of tillers (tiller) | Biocompost | UCB | Farmer’s technique |
|----------------------------|------------|-----|-------------------|
| 31 DAT                     | 15.4       | 16.7| 18.4              |
| 37 DAT                     | 17.1       | 18.7| 16.4              |
| 49 DAT                     | 12.3       | 15.5| 12.7              |
| 57 DAT                     | 10.1       | 12.8| 11.2              |
| 82 DAT                     | 9.9        | 12.0| 10.9              |

The yield of rice for biocompost showed the highest yield of 4,592 tons ha\(^{-1}\) Harvested Dry Grain (HDG) (3,265 kg ha\(^{-1}\) Milled Dry Grain (MDG)) followed by UCB 3,739 tons ha\(^{-1}\) HDG (2,766 kg ha\(^{-1}\) MDG), farmer technique 3,382 tons ha\(^{-1}\) (2,423 tons/ha MDG). The biocompost can increase the
yield by 34.75% compared to the farmers’ technique, while the UCB can increase yield by 14.17% from the farmer method (Table 2).

| Treatment                  | Large Land (m²) | Weight of harvested grain (kg) | Average Moisture Content at harvest (%) | Yield HDG ha⁻¹ (kg) | Yield MDG/KA14% (kg) | The difference in yields with farmers (kg ha⁻¹) | Increased yield compared to farmers (%) |
|----------------------------|-----------------|-------------------------------|---------------------------------------|---------------------|----------------------|-----------------------------------------------|---------------------------------------|
| Biocompost                 | 3,241           | 1,488.5                       | 19.69                                 | 4,592.72            | 3,265.52             | 842.18                                        | 34.75                                 |
| UCB                       | 2,292           | 857                           | 18.92                                 | 3,739.09            | 2,766.77             | 343.43                                        | 14.17                                 |
| Farmer’s technique         | 4,732           | 1,600.5                       | 19.54                                 | 3,382.29            | 2,423.34             |                                               |                                       |

Rice plant growth experiences various obstacles such as pests and diseases, early growth of age 10 DAT there has been a blast attack until the age of 45 DAT, it is very disturbing plant growth so it must be sprayed with chemical pesticides, with the attack of stem borers and crop diseases decreases besides that the production costs also increase.

3.2. Greenhouse gases on rice
Rice ecosystems by means of farmers’ assistance produced higher fluxes than UCB, and biocompost settings (Figure 1), daily CH₄ fluxes in the plot manage biocompost at 13.61 - 750.54 mgCH₄m⁻²day⁻¹, urea use plots 4.6 - 493.38 mgCH₄m⁻²day⁻¹ while the plot of farmer’s technique is 200.65 - 827.19 mgCH₄m⁻²day⁻¹.

Figure 1. CH₄ flux in a rainfed field with various treatments.
Cumulative CH₄ flux in the highest plot of farmer’s technique compared to UCB and biocompost, farmer’s technique produced 1,765.32 mgCH₄ m⁻², biocompost produced 692.04 mgCH₄ m⁻² while the BCU produced 471.67 mgCH₄ m⁻² at the end of observation (Figure 2).

Based on research by Chirinda et al. [5], long-term use of organic fertilizers can increase soil carbon uptake, soil respiration, mineralized nitrogen potential, and ammonium oxidation potential. According to Aguilera et al. [6] the use of organic fertilizers is one of the ways to mitigate climate change through the absorption or sequestration of carbon and to reduce the problem of waste management and provision of soil nutrients.

While the use of inorganic fertilizers can accelerate the decomposition of organic residues and potentially reduce aggregate stability [5]. In previous studies, the effect of inorganic fertilizers on CH₄ emissions still produced inconsistent data. Mentions CH₄ emissions decreased with the addition of inorganic fertilizers, while other studies show an increased or no change Ma et al., and Banger et al., report that CH₄ emissions decrease by adding nitrogen fertilizer was caused by stimulation of methanotroph in intermittently in lowland [7], [8].

**Figure 2.** Cumulative CH₄ flux in a rainfed field with various treatments.
Figure 3. N\textsubscript{2}O flux in a rainfed field with various treatments.

Rice ecosystem with UCB produced N\textsubscript{2}O flux higher than biocompost and farmer's technique (Figure 3). Daily N\textsubscript{2}O flux in biocompost plots ranged from 108.01 to 972.73 µgN\textsubscript{2}O\textsubscript{m}^{-2}\textsubscript{day}^{-1}, UCB plots ranged from between 152.94 to 1,825.29 µgN\textsubscript{2}O\textsubscript{m}^{-2}\textsubscript{day}^{-1}while the plot of farmers technique was 37.70 to 1,954.15 µgN\textsubscript{2}O\textsubscript{m}^{-2}\textsubscript{day}^{-1}.

Figure 4. Cumulative N\textsubscript{2}O flux in a rainfed field with various treatments.
Based on Figure 4 the cumulative N$_2$O flux on the highest UCB plot than the biocompost plot and the farmer’s technique, UCB produced 2,499.32 µgN$_2$O·m$^{-2}$·s while the farmer’s technique produced 2,743.67 µgN$_2$O·m$^{-2}$·s in ends of observed.

In almost all observed, N$_2$O emissions increased in line with the age of rice plants, Lu et al. (2000) [10] reported that dissolved C organics in the rhizosphere of rice plants were influenced by root exudates, which increased with plant growth. In addition, the increase in plant residues also causes an increase in levels of dissolved organic C, which is followed by an increased in N$_2$O emissions (Luo et al., 2004 cit, Gogoi, and Baruah, 2012) [9].

In contrast to previous studies, Chirinda et al. (2010) and Aguilera et al. (2013) examined N$_2$O flux on agricultural soil by treating organic and inorganic fertilizers and produced higher cumulative values of N$_2$O flux in soil with inorganic fertilizer compared to organic fertilizer [5], [6]. But according to Aguilera et al. (2013), the use of organic fertilizers in the long term can increase N$_2$O emissions due to increased concentrations of soil organic matter and increased soil nitrogen levels due to the slow release of nitrogen minerals in organic fertilizers [6].

Table 3. Emission, GWP, yield and emission index MK I in 2018

| Treatment     | Emission (kg ha$^{-1}$ season$^{-1}$) | GWP (tCO$_2$·ha$^{-1}$·season$^{-1}$) | Yield MDG (t·ha$^{-1}$) | Emission Index |
|---------------|--------------------------------------|--------------------------------------|-------------------------|----------------|
|               | CH$_4$                              | N$_2$O                               |                         |                |
| Biocompost    | 317.77±161.74                       | 0.49±0.12                            | 8.12 ± 4.04             | 4.59           | 1.77           |
| UCB           | 226.13±155.55                       | 0.62±0.16                            | 5.42 ±3.28              | 3.74           | 1.45           |
| Farmer technique | 651.75±85.51                     | 0.49±0.20                            | 13.19 ± 6.82            | 3.38           | 3.90           |

Table 3 showed UCB emitted CH$_4$, GWP, and has the lowest emission index value compared to the other treatments. In addition to reducing emissions and increasing the binding capacity of greenhouse gases, the application of biochar can also improve soil fertility, thereby increasing crop production [10]. The application of biochar to the soil increases the availability of major cations and phosphorus, total nitrogen, and soil cation exchange capacity. Adequate nutrient availability for plants is the effect of increasing nutrients directly from biochar and increasing nutrient retention, in addition to changes in soil microbial dynamics.

The emission factor (EF) was reduced from 0.0042 kgN$_2$O·N·kg$^{-1}$ of N fertilizer without biochar to 0.0013 kgN$_2$O·N·kg$^{-1}$ of N fertilizer with biochar at 40 t·ha$^{-1}$. The results of the study by Zhang et al. (2010) show that biochar significantly increases rice yield and reduces N$_2$O emissions, but increases total CH$_4$ emissions [11]. CH$_4$ emissions will depend on the type of soil, the chemical nature of biochar, and on fertilization and water management regimes [12].

The addition of biochar to agricultural land can slow the release of carbon and nitrogen, which is associated with high organic carbon content in biochar and changes in soil properties that affect microbial activity [13]. The addition of previous biochar has been shown to increase plant productivity by increasing the physical and biochemical properties of the soil [14], with further crop response variations depending on the chemical and physical properties of biochar, soil conditions, and plant species [12], [15].

The reduction in net emissions of CH$_4$ and N$_2$O from some very acidic and limited nutrient soils following amendments to biochar has been well documented by Rondon et al. [16, 17] in both pot and field experiments. Knoblauch et al. [18] argue that organic labile biochar C ponds can decompose and become the main source of methanogenic substrates, thus promoting CH$_4$ production, especially in the early stages of rice. This partly explains the decrease in CH$_4$ emissions in the following year in 2008 according to the lower content of the HWEC group in the second cycle (Table 3).

At present, in soils with moderate soil fertility, the study of rice, soil pH, soil organic carbon, total nitrogen, and rice yields has increased, but increasing soil volumes have increased consistently in the
two cycles of rice planting assisted by biochar amendments. However, N\textsubscript{2}O emissions decreased very significantly, and CO\textsubscript{2} emissions did not change for two rounds, while the biochar effect on CH\textsubscript{4} emissions was seen to decline in the second cycle. Overall, biochemical amendments \textbf{C}The intensity of rice production in paddy is replaced. Improve the effect of biochar can increase SOC (increase by 30%), increase SOC, and increase plant productivity (up to 20-30%) from increase and pH of soil bulk (\textasciitilde 10%) years after amendments [19].

Clough et al. [20] attributed higher N\textsubscript{2}O emissions from biochar amended soil concentrates to larger nitrite (NO\textsubscript{2}) about with nitrification inhibitors on biochar, which added nitrate (NO\textsubscript{3}) was formed. The study of Feng et al. [21] resulted in the addition of biochar can (1) significantly increase the abundance of methanotrophic proteobacteria, and (2) reduce the methanogenic ratio to very methanotrophic abundance. This shows that conversion to biochar can not only reduce CH\textsubscript{4} emissions and maintain more carbon in rice soils, but also stimulate soil microbes, increase soil productivity, and increase grain yield. These results provide insight into the mechanisms underlying how biochar reduces CH\textsubscript{4} emissions of rice. This knowledge can be applied to develop a more effective greenhouse gas mitigation process for rice fields. The addition of biochar significantly reduced the cumulative CH\textsubscript{4} emissions of rice on Ultisol soil. Decreasing CH\textsubscript{4} emissions with the addition of biochar is associated with inhibition of methanogenic growth. In line with the results of research by Liu et al. [22] found a decrease in 51.1-91.2% of CH\textsubscript{4} emissions in plants with the addition of biochar. As a result, biochar applications can reduce and even reduce global warming [23].

The addition of biochar increases soil aeration, thus making soil conditions better for methanotrophs and increasing oxidation of CH\textsubscript{4} [12]. Because methanotrophs are anaerobic group, gram-negative bacteria, their growth can be stimulated by an increase in oxygen supply with the addition of biochar. As a result, the oxidizing activity of CH\textsubscript{4} from methanotrophs is greatly enhanced.

4. Conclusions
1. The yield of rice for biocompost the higher compared to the other treatments.
2. Rice ecosystems, by means of farmers' assistance, produced higher fluxes than UCB and biocompost settings.
3. Treatment BCU emitted CH\textsubscript{4}, GWP, and has the lowest emission index value compared to the other treatments.

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