Greenhouse gas emissions and rice yield from different rice varieties using Gora Systems and Walik Jerami Systems in Rainfed Lands

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Abstract. The rapid development has resulted in the shrinkage of relatively fertile irrigated rice fields. To increase the yields, various rice varieties are recommended but their GHG emissions remain largely unknown if planted in two different system (e.g. gogorancah and walikjerami). This study aims to determine GHG emissions and rice yields from various varieties in rainfed lowland areas. The research was conducted at experimental station of Indonesian Agricultural Environmental Research Institute, Pati Central Java during the 2015/2016 high season. Eight high yielding rice varieties (Ciherang, Mekongga, Inpari 18, IPB 3S, Inpari 13, Inpari 31, Inpari 32 and Inpari 33) were planted in boxes measuring 1 m² on a 5 x 6 m² plot. The experiment was designed in a randomized block design with three replications. CH₄ and N₂O samples were taken using manual GHG gauges. The results showed that the CH₄ emissions released from the eight varieties were significantly different at the level of P <0.05. The highest CH₄ emission in the gora system was in the IPB 3S variety of 532.89 kg CH₄/ha/season while the highest CH₄ emission in the wajer system was shown by the Inpari 32 variety of 482.35 kg CH₄/ha/season. The highest N₂O emission in the gora system was in the Ciherang variety of 0.75 kg N₂O/ha/season, while the highest N₂O emission in the wajer system was shown by the Inpari 32 variety of 0.57 kg N₂O/ha/season. The highest average rice yield was shown by the Inpari 32 variety which was 7.78 t/ha higher in the gora system than the wajer system.

1. Introduction
The rapid development has resulted in the shrinkage of relatively fertile irrigated rice fields or the conversion of land to residential, industrial and other physical facilities. This requires an effort to optimize other sources of efficient food crops, such as rainfed rice fields.

Flooded soil conditions such as rice fields and tidal land affect soil characteristics, biological activities, and the environment. Changes in soil characteristics due to the oxidation-reduction process result in variations in greenhouse gas fluxes. Therefore, rice farming technology can be pursued to increase the efficiency of using agricultural chemicals, conserve natural resources, and reduce greenhouse gas emissions.

N₂O gas is produced from microbiological nitrification and denitrification processes. Management of agricultural land through fertilization and water management are the two most important factors of several factors that directly affect the process of nitrification and denitrification of agricultural land that produce emissions in the form of N₂O and NO. However, the effect of the combination of fertilization and water management has not been widely evaluated. The different distribution and amount of water
applied to the regulated irrigation system should result in better conditions for the denitrification process [1].

$\text{N}_2\text{O}$ emissions from agricultural land are mainly obtained from the biological processes, namely the nitrification and denitrification processes in the soil. The biggest controlling factor of $\text{N}_2\text{O}$ production is temperature, and the amount of NH$_4^+$ -N, water, organic matter in the soil. Research results indicate the addition of N will increase $\text{N}_2\text{O}$ emissions [2]. The aim of this research was to determine GHG emissions and rice yields of various varieties using the gogorancah (gora) and walik jerami (wajer) system in rainfed lowland.

2. Material and Method

2.1 Site description and experimental design

The research was conducted from December 2015 to June 2016 during two seasons, namely season I and season II in experimental station of Indonesian Agricultural Environmental Research Institute, PatiCentral Java. This research used randomized block design (RBD) with three replications and eight treatments of rice varieties: (1) Ciherang, (2) Mekongga, (3) Inpari 18, (4) IPB 3S, (5) Inpari 13, (6) Inpari 31, (7) Inpari 32 and (8) Inpari 33.

Rice plants 1-3 seeds per hole with the gora system were carried out by table (direct planting) on season I with a spacing of 20 cm x 20 cm planted on a plot with a size of 5 m x 6 m while for season II it was done with a wajer system by transplanting. The water level is maintained daily at 5 cm from the start of plant growth until 1 week before harvest. Rice plants were fertilized with a dose of urea 120 kg N/ha which was given three times at a dose of 939.13 grams at 29, 42 and 55 days after planting (DAP). SP-36 fertilizer with a dose of 60 kg P2O5/ha, was given fully three days before planting, KCl with a dose of 90 kg K2O/ha, given three times the same as urea fertilizer at a dose of 540 grams.

2.2 $\text{CH}_4$, $\text{CO}_2$ and $\text{N}_2\text{O}$ measurements

We measured $\text{CH}_4$, $\text{CO}_2$, and $\text{N}_2\text{O}$ gas fluxes once a week during the rice-growing season using the closed chamber method. Sample for $\text{CH}_4$ gas was collected in a 50 cm x 50 cm x 100 cm acrylic chambers in a pot equipped with a battery to operate the fan inside, which was turned on during gas sampling only to homogenize the headspace air [3]. We covered four plants per pot. The $\text{N}_2\text{O}$ and $\text{CO}_2$ gas samples were collected using an acrylic chamber measuring 40 cm x 20 cm x 20 cm in the space between plants. The gas samples were taken from the chamber headspace using a tight syringe inserted through a fixed rubber septum. GHGs concentrations were analyzed by gas chromatography equipped Flame Ionization Detector (FID) for $\text{CH}_4$, Thermal Chapter Detector (TCD) for $\text{CO}_2$ and Electron Capture Detector (ECD) for $\text{N}_2\text{O}$ (HGG 450 Varian type). Gas sampling was carried out consistently between 06:00 and 08:00 A.M. to minimize the effect of diurnal variations. Gas samples (10 ml) were taken at 5, 10, 15, 20 and 25th minutes during plant cages and analyzed for $\text{CH}_4$. For $\text{N}_2\text{O}$ and $\text{CO}_2$, gas samples (20 ml) were taken at 10, 20, 30, 40 and 50th minutes. GHG emissions were calculated as described by [4]:

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

where E is the gas emission (mg/m²/day), dc/dt is difference in concentrations per times (ppm/minute), Vch is box volume (m³), Ach is box width (m³), mW is molecule weight (g), mV is molecule volume (22.41 l) and T is the mean air temperature inside the chamber during sampling ($°C$).

2.3 Data analysis

The data in the tables and figures are presented as mean values of the standard deviations. The SAS 9.1.3 portable analytical software package was used for all statistical analyses. Statistical analysis was performed by standard analysis of variance (ANOVA) and differences between treatments determined using Tukey’s test were used where significant differences occurred.
3. Result and Discussion

3.1 Number of tillers and plant height

Number of tillers and plant height were observed at 27, 44, 55, 66, 80 and 97 DAP (Day After Planting) for the gora system (season I) while for the wajer system at 14, 28, 47, 57 and 71 DAT (Day After Transplanting). From the two cropping systems, the number of tillers and plant height varied. In the gora system at the beginning of the observation, the number of tillers was significant (P <0.05), this is different from the results of the first observations on the wajer system which showed no significant difference. The number of tillers showed significantly different values until the end of the observation. The plant height was significantly different during the observation in the two growing seasons.

| Table 1. Number of tillers and plant height of eight varieties of rice gora system (season I) |
|-----------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Variety            | 27  | 44  | 55  | 66  | 80  | 97  |
| Ciherang           | 14  | a   | 16  | abc | 19  | a   | 15  | ab  | 13  | bcd | 14  | ab  |
| Mekongga           | 13  | a   | 16  | abc | 19  | a   | 14  | ab  | 14  | abc | 14  | ab  |
| Inpari 18          | 10  | a   | 14  | bc  | 14  | bc  | 13  | bc  | 12  | cd  | 12  | bc  |
| IPB 3s             | 10  | a   | 12  | e   | 13  | c   | 11  | e   | 11  | d   | 10  | c   |
| Inpari 13          | 10  | a   | 15  | abc | 18  | ab  | 13  | bc  | 13  | bcd | 13  | bc  |
| Inpari 31          | 13  | a   | 19  | abc | 21  | a   | 15  | ab  | 15  | ab  | 15  | ab  |
| Inpari 32          | 12  | a   | 18  | ab  | 21  | a   | 15  | ab  | 14  | abc | 14  | ab  |
| Inpari 33          | 14  | a   | 17  | abc | 21  | a   | 16  | a   | 16  | a   | 16  | a   |
| Plant height (cm)  |     |     |     |     |     |     |     |     |     |     |     |     |
| Ciherang           | 42  | abc | 70  | b   | 82  | b   | 90  | bc  | 113 | bc  | 116 | bc  |
| Mekongga           | 40  | abc | 69  | b   | 82  | b   | 86  | bc  | 110 | bc  | 113 | bcd |
| Inpari 18          | 44  | ab  | 73  | b   | 88  | ab  | 98  | ab  | 106 | c   | 107 | d   |
| IPB 3s             | 46  | a   | 84  | a   | 99  | a   | 112 | a   | 134 | a   | 135 | a   |
| Inpari 31          | 37  | bc  | 68  | b   | 79  | b   | 94  | bc  | 113 | bc  | 115 | bcd |
| Inpari 32          | 35  | c   | 65  | b   | 78  | b   | 81  | c   | 108 | c   | 111 | bcd |
| Inpari 33          | 40  | abc | 69  | b   | 81  | b   | 87  | bc  | 107 | c   | 108 | cd  |

Remark: Values in column followed by the same letters is not significantly different (P<0.05)

| Table 2. Number of tillers and plant height of eight varieties of rice wajer system (season II) |
|-----------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Variety            | 14  | 28  | 47  | 57  | 71  |
| Ciherang           | 5   | abc | 9   | abc | 10  | abc |
| Mekongga           | 6   | a   | 11  | ab  | 11  | a   |
| Inpari 18          | 4   | c   | 8   | c   | 7   | c   |
| IPB 3s             | 5   | bc  | 8   | bc  | 8   | bc  |
| Inpari 13          | 6   | ab  | 10  | abc | 9   | abc |
| Inpari 31          | 5   | abc | 10  | abc | 10  | ab  |
| Inpari 32          | 6   | ab  | 12  | a   | 11  | a   |
| Inpari 33          | 5   | bc  | 10  | abc | 9   | abc |
| Plant height (cm)  |     |     |     |     |     |     |
| Ciherang           | 36  | bc  | 56  | c   | 71  | de  |

Remark: Values in column followed by the same letters is not significantly different (P<0.05)
Table 3. Yield components in the gora system (season I) and the wajer system (season II)

| Variety   | weight of 1000 grains (g) | Grain content (grain) | Empty grain (g) | number of productive tillers | Rice yield (t/ha) | Straw weight (t/ha) |
|-----------|--------------------------|-----------------------|-----------------|------------------------------|-------------------|---------------------|
|           |                          |                       |                 |                              |                   |                     |
| Season I  |                          |                       |                 |                              |                   |                     |
| Ciherrang | 27.9 a                   | 1091 ab               | 290 b           | 14 ab                        | 5.98 bc           | 6.9 a               |
| Mekongga  | 27.6 a                   | 1173 a                | 228 b           | 14 ab                        | 6.51 bc           | 6.8 a               |
| Inpari 18 | 27.5 a                   | 822 b                 | 329 ab          | 12 bc                        | 6.09 bc           | 7.2 a               |
| IPB 3S    | 28.0 a                   | 974 ab                | 471 ab          | 10 c                         | 5.69 c            | 8.0 a               |
| Inpari 13 | 26.4 a                   | 808 b                 | 498 ab          | 13 bc                        | 5.82 c            | 7.2 a               |
| Inpari 31 | 27.1 a                   | 1016 ab               | 605 a           | 15 ab                        | 7.12 ab           | 6.4 a               |
| Inpari 32 | 28.3 a                   | 1040 ab               | 328 b           | 14 ab                        | 7.78 a            | 6.7 a               |
| Inpari 33 | 28.2 a                   | 937 ab                | 282 b           | 16 a                         | 5.86 c            | 6.1 a               |
| Season II |                          |                       |                 |                              |                   |                     |
| Ciherrang | 26.4 c                   | 462 a                 | 344 b           | 8 abc                        | 3.55 b            | 4.3 ab              |
| Mekongga  | 25.9 c                   | 642 a                 | 339 b           | 9 a                          | 3.71 b            | 4.4 ab              |
| Inpari 18 | 30.0 a                   | 533 a                 | 237 b           | 7 bc                         | 3.84 b            | 4.0 ab              |
| IPB 3S    | 28.5 ab                  | 617 a                 | 262 b           | 7 c                          | 3.72 b            | 4.6 ab              |
| Inpari 13 | 26.4 c                   | 590 a                 | 264 b           | 8 ab                         | 3.67 b            | 4.1 ab              |
| Inpari 31 | 26.0 c                   | 489 a                 | 512 a           | 9 a                          | 3.56 b            | 4.5 ab              |
| Inpari 32 | 28.6 ab                  | 627 a                 | 306 b           | 9 a                          | 4.71 a            | 5.5 a               |
| Inpari 33 | 28.2 b                   | 466 a                 | 203 b           | 8 a                          | 3.48 b            | 3.7 b               |

Remark: Values in column followed by the same letters is not significantly different (P<0.05)

3.2 Yield Component

The highest average rice yield was produced by Inpari 32, which was 7.78 t/ha in the gora system and 4.71 t/ha in the wajer system. Rice yields of Inpari 32 variety were 65.18% higher in the gora system (season I) than the wajer system (season II). The grain yield is influenced by the number of filled grains and the weight of 1000 grains (Table 3). According to [5] the amount of grain and the number of filled grains determine the level of yields. This is because the yield components greatly affect the yield based on the characters of each rice variety. The diversity of rice plant characters varies due to the genetic material characteristic of each rice variety.

3.3 CH₄ emission

CH₄ emissions in the gora system in eight rice varieties ranged from 157.13 to 827.68 kg CH₄/ha/season while in the wajer system ranged from 245.47-616.17 kg CH₄/ha/season. The highest CH₄ emission in
the gora system was shown by the IPB 3S variety of 532.89 kg CH$_4$/ha/season (Figure 1) and the lowest was shown by the Inpari 32 variety of 203.83 kg CH$_4$/ha/season while for the wajer system the highest CH$_4$ emissions indicated by Inpari 32 variety of 482.35 kg CH$_4$/ha/season and the lowest CH$_4$ emission was shown by Inpari 31 variety at 374.8 kg CH$_4$/ha/season. CH$_4$ production is influenced by several soil parameters such as availability of inorganic elements, methanogens population, groundwater, aeration, temperature, soil Eh, pH, and salt [6].

![Graph showing CH$_4$ emissions from eight rice varieties](image)

**Figure 1.** CH$_4$ emissions from eight rice varieties.

The difference in CH$_4$ emissions is due to the different characteristics of each variety, including the number of tillers and plant age [7]. The level of CH$_4$ gas emission varies due to the influence of the morphological and physiological diversity of rice plant varieties (Wihar djaka and Sarwoto, 2015). Based on the research results of [9], rice varieties that have a low number of tillers are able to suppress the formation and breaching of CH$_4$ from paddy fields.

Other factors that influence CH$_4$ emissions are the number of aerenchyma cavities, plant root patterns, and metabolic activity [10]. The ability of plants to produce root exudate as organic matter can also affect CH$_4$ gas production in plant root areas [9].

### 3.4 N$_2$O emission

Figure 2 showed that the average N$_2$O emission in rice planted soil during one season field study ranged from 182.8 to 1637.6 µgN$_2$O/m$^2$/day. N$_2$O emission in the early observations showed the highest rates in the treatment of straw.
Figure 2. N₂O emission from eight rice varieties

The N₂O emission in the gora system in eight rice varieties ranged from 0.3-1.03 kg N₂O/ha/season while in the wajer system ranged from 0.1-0.72 kg N₂O/ha/season. The highest N₂O emission in the gora system was shown by the Ciherang variety of 0.75 kg N₂O/ha/season (Figure 2) and the lowest was shown by the Inpari 33 variety of 0.41 kg N₂O/ha/season while for the wajer system the highest N₂O emission was shown the Inpari 32 variety was 0.57 kg N₂O/ha/season and the lowest N₂O emission was shown by the Mekongga variety at 0.16 kg N₂O/ha/season. The N₂O emission during the planting season of wajer was 80.76% higher than the N₂O emission during the gora growing season. N₂O emissions in the agricultural sector increase with the application of nitrogen fertilizers. NH₄⁺ from fertilizers that are not absorbed by plants can be converted into N₂O through a nitrification process under aerobic conditions and denitrification in anaerobic conditions by microorganisms [11]. Anaerobic conditions in the agricultural sector are mostly found in rice fields.

4. Conclusion
The highest CH₄ emission in the gora system was in the IPB 3S variety of 532.89 kg CH₄/ha/season, while the highest CH₄ emission in the wajer was shown in the Inpari 32 variety of 482.35 kg CH₄/ha/season. The highest N₂O emission in the gora system was in the Ciherang variety of 0.75 kg N₂O/ha/season, while the highest N₂O emission in wajer system was shown by the Inpari 32 variety of 0.57 kg N₂O/ha/season. The highest average rice yield was shown by the Inpari 32 variety which was 7.78 t/ha higher in the gora system than the wajer system.

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References

[1] Martin, L.S., A, Meijide, L, Garcia-Torres, and A, Vallejo 2010, Combination of drip irrigation and organic fertilizer for mitigating emissions of nitrogen oxides in semi-arid climate, Agriculture, Ecosystem and Environment 137: 99-107

[2] Meng, L., W, Ding, & Z, Cai 2005, Long-term application of organic manure and nitrogen fertilizer on N2O emissions, soil quality and crop production in sandy loam soil, Soil Biology and Biochemistry 37: 2037-2045

[3] Anonim, 2007, Petunjuk Teknis Pengambilan dan Analisis Sampel Gas CH₄, Balai Penelitian Lingkungan Pertanian. Departemen Pertanian. 10

[4] IAEA (International Atomic Energy Agency) 1993. Manual on Measurement of Methane and Nitrous Oxide Emission from agricultural Vienna.

[5] Dahlan, D., Yunus M., dan Muhammad I. A 2012. Pertumbuhan dan Produksi Dua Varietas Padi Sawah pada Berbagai Perlakuan Rekomendasi Pemupukan. Jurnal Agrivivor. 11 2 : 262-274.

[6] Mitra, S., P. Patra, S. Chandra and P. Pramanik 2012. Efficacy of highly water-dispersed fabricated nano ZnO against clinically isolated bacterial strains. Applied Nanosciene 2, 231-238.

[7] Kartikawati, R., Hesti Y., A. Wihardjaka and Prihasto S 2016. Upaya Adaptasi terhadap Perubahan Iklim pada Lahan Tadah Hujan melalui Budidaya Padi Rendah Emisi Metana. Disampaikan pada Seminar Nasional BB Padi tanggal 30 Agustus 2016.

[8] Wihardjaka, A., dan Sarwoto 2015 Emisi gas rumahkaca dan hasil gabah dari beberapa varietas padi unggul tipe baru di lahan sawah tadah hujan di Jawa Tengah. Ecolab. 9 1 : 1-46.

[9] Aulakh, M.S., J. Bodenbender, R. Wassmann, and H. Rennnenberg 2000 Methane transport capacity of rice plant. I. Influence of methane concentration and growth stage analyzed with automate measuring. Nut Cycl in Agroecosyst. 58:357-366

[10] Surmaini E, E. Runtunuwu and I. Las 2011Upaya Sektor Pertanian dalam Menghadapi Perubahan Iklim. Jurnal Litbang Pertanian 30 1:1-7.

[11] Smart K.M., C. Blake, A. Staines and C. Doody 2011 The Discriminative Validity of "Nociceptive," “Peripheral Neuropathic,” and "Central Sensitization" as Mechanisms-based Classifications of Musculoskeletal Pain. Clinical Journal of Pain 27 8:655-63. DOI: 10.1097/AJP.0b013e318215f16a