A strategy for reducing methane emission using hybrid rice variety

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Abstract. Hybrid rice varieties are widely cultivated in the farmer because of high yield production compared to inbred variety. However, the agronomic traits supported to the high yield are expected to release GHG emission. Therefore, a study to investigate the effect of hybrid rice varieties on reducing methane emission in flooded rice filed was conducted at Indonesia Agriculture Environment Research Institute. Eight commercial hybrid rice varieties, namely Mapan 05, Arize Gold, Intani, Sembada 168, Sembada 868, Hipa 8, Hipa 18 and Hipa 19 and one inbred rice variety (Ciherang) were used for this study during the dry season of 2018. All rice varieties were cultivated by transplanting system on 21 days old seedling with 20 cm x 20 cm plant spacing, fertilizer doses are 120 kg ha\(^{-1}\) N, 45 kg ha\(^{-1}\) P\(_2\)O\(_5\) and 60 kg ha\(^{-1}\) K\(_2\)O. The water level was maintained on 5 cm above the soil layer. Methane gas was capture using a closed chamber method and analyzed using Gas Chromatography (GC). The study showed that seven of hybrid rice varieties produced higher methane emission than inbred rice variety. The highest methane emission was produced by Arize Gold (660 kg CH\(_4\) ha\(^{-1}\) season\(^{-1}\)) followed by Mapan 05, Hipa 19, Sembada 168 and Sembada 989. While the inbred rice variety (Ciherang) produced 370 kg CH\(_4\) ha\(^{-1}\) season\(^{-1}\). One of hybrid rice variety (Sembada 168) has the opportunity to be improved as low methane emission hybrid rice variety indicated from the low index of CH\(_4\) emission to yield.

1. Introduction

Some countries have been trying to increase their rice production to meet the food demand through the development of hybrid rice variety [1-3]. Chamling and Basu [4] stated that hybrid technology could produce rice yield about 15-20% more than the best-improved varieties. Khushik et al. [5] also mentioned that hybrid rice has advantages over inbred varieties such as higher rice yielding, more responsive to fertilizer and adapt to the varying environment. Development of hybrid rice has been conducting using morphological improvement and heterosis or hybrid vigor.

In Indonesia, research collaboration on hybrid rice initiated by the Indonesian Agency for Agricultural Research and Development (IAARD), IRRI and FAO since 2001. Then IAARD by Indonesian Center for Rice in 2004 and 2006 successfully produced four hybrid rice varieties, namely Hipa 3, Hipa 4, Aromatic Hipa 5 Ceva and Hipa 6 Jete [6]. Now hybrid rice varieties are widely cultivated in the farmer because of high yield production compared to inbred varieties. However, the agronomic traits supported to the high yield are expected to contribute to GHG emission. Concrad [7] found that methane production is determined by substrate availability which was increased by the high-yielding varieties indicated by both higher root biomass and dissolved organic carbon.
While sustainable rice cropping requires not only increase yield but also reducing methane emission. Therefore, a study was conducted to investigate the effect of hybrid rice varieties on reducing methane emission in the flooded rice field.

2. Materials
The field experiment was conducted in the Research Station of Indonesian Agricultural Environment Research Institute (IAERI) located at Sidomukti, Subdistrict of Jaken, district of Pati, Central Java Province. The location lies between 111°10' E longitude and 6°45' S latitude. Rice fields are dominated by rainfed rice area, with an average of rainfall, maximum and minimum of temperature, daily temperature, and solar radiation during the experiment was 303 mm, 42 °C, 23.0 °C, 37.3 °C, and 62970 Cal cm⁻², respectively. The soil experiment was sandy loam and low organic matter.

Eight commercial hybrid rice varieties Mapan 05, Arize Gold, Intani, Sembada 168, Sembada 868, Hipa 8, Hipa 18 and Hipa 19 and one inbred rice variety (Ciherang) were planted by transplanting in plots of 6 m x 6 m with three replication in a randomized block design (RBD). Chemical fertilizers were applied at 120:45:60 kg N: P₂O₅: K₂O ha⁻¹. One-third dose of urea, half dose K₂O and a full dose of P₂O₅ were applied at the active tillering growth stage. The other one-third doses of urea and half dose of K₂O were applied at maximum tillering or panicle initiation stages. The water was maintained 5 cm above soil surface during plant growing and dried before harvesting.

3. Methods
Methane fluxes were determined from 33 until 83 days after transplanting (DAT). Gas samples were measured using the closed chamber method. Chamber of 50 cm length, 50 cm width and 103 cm height made of acrylic transparent sheets were used. Gases were taken using the syringe on interval time of 4, 8, 12 and 16 minutes after closing chamber. Methane concentration in the gas samples was estimated using a Gas Chromatography (GC Shimadzu 14A) equipped by Flame Ionization Detector (FID). The methane flux was calculated using the following equation:

\[ E = \frac{dc}{dt} \times \frac{Vch}{Ach} \times \frac{mW}{mV} \times \frac{273.2}{(273.2+T)} \]

where \( E \) is the flux of CH₄ (mg m⁻² day⁻¹), \( dc/dt \) is the difference of gases concentration per time (ppm minute⁻¹), \( Vch \) is the volume of chamber (m³), \( Ach \) is large of chamber (m²), the size of the chamber was 50 cm x 50 cm x 103 cm, \( mW \) is the weight of gases molecule (g), \( mV \) is volume of gases molecule (22.41 l) and \( T \) is the average of temperature during gases sampling (°C).

The number of tillers and plant height were recorded at different plant phase (active tiller, maximum tiller, heading, milky and maturity), while grain yield and rice straw were recorded at the time of harvest. The Minitab 16.0 version was used to calculate the means for methane emissions and plant parameters. Tukey’s (p<0.05) was done to find out the differences between the recorded parameters.

4. Results and Discussion
Methane fluxes among the high yielding rice varieties were around 72-1400 mg m⁻² day⁻¹ (Fig. 1). In the early measurement (33 DAT), an average of methane flux was 343 mg m⁻² day⁻¹ and increase gradually on 39-53 DAT. Methane fluxes decrease in reproductive and ripening phase by 350 and 180 mg m⁻² day⁻¹, respectively. In this study, we found that the methane flux pattern of hybrid rice varieties was similar, particularly in rice variety of Arize Gold, Mapan, Intani, Hipa 8, Hipa 18 and Hipa 19. While rice variety of Ciherang produced lower methane flux during plant growth. Rice varieties of Sembada 168 and Sembada 989 showed the different pattern and lower methane flux compared to other hybrid rice variety.
We found that the average methane flux was significantly different between rice varieties during planting season. The highest methane flux was showed by rice variety of Arize Gold (452 mg m$^{-2}$ day$^{-1}$), followed by Mapan and Intani. While the lowest of methane flux was produced by Sembada 989 (305 mg m$^{-2}$ day$^{-1}$), followed by Cihong (355 mg m$^{-2}$ day$^{-1}$). Almost of hybrid rice variety showed higher methane fluxes than inbred variety (Cihong) and the highest methane flux produced by Ariza Gold.

Jiang et al (2017) stated that high yielding rice varieties could induce methane production and emission by increasing carbon substrate, particularly in low soil C content but greatly reduce methane emissions in high C soil.

Each of the rice varieties shows different growing period. Hybrid rice of Mapan and Arize accomplished of the growing period during 106 days, while Intani, Hipa 8, Hipa 18, Hipa 19 and Cihong was 104 days. Sembada 168 and Sembada 989 showed a shorter period by 88 and 95 days, respectively. The period of plant growth could also contribute to methane emission, particularly in the flooded rice field.

For this study, we have categorized the rice varieties into three groups, namely high methane emission which showed by Arize Gold (622 kg m$^{-2}$ season$^{-1}$), Mapan (555 kg m$^{-2}$ season$^{-1}$) and Intani (510 kg m$^{-2}$ season$^{-1}$); moderate methane emission by Sembada 168 (460 kg m$^{-2}$ season$^{-1}$), Hipa 8 (450 kg m$^{-2}$ season$^{-1}$), Hipa 19 (430 kg m$^{-2}$ season$^{-1}$) and Hipa 18 (420 kg m$^{-2}$ season$^{-1}$); and low methane emission by Cihong (355 kg m$^{-2}$ season$^{-1}$), Sembada 989 (305 kg m$^{-2}$ season$^{-1}$). In this study, we also observed the weigh of rice straw and root per hill. It showed that high methane categorized tend to produce higher weigh of rice straw and root (Table 1). According to Huang et al (1997), higher root productivity could increase the availability of substrate for methane production through root exudates. An interesting case occurred on rice variety of Sembada 168 which produced low weight both on rice straw and root but produced moderate methane production. Methane fluxes increased sharply on 39 DAT (active tillering phase) which contribute to higher methane emission on Sembada 168.

Rice yield was not significantly different among rice varieties, but we could state that the highest yield produced by Arize Gold and the lowest showed by Sembada 989. Our study showed that almost of hybrid rice variety produced higher both methane emission and rice yield than inbred variety. Index methane emission to yield showed that rice varieties of Cihong, Sembada 168 and Sembada 989 produced the lower index, but Arize Gold showed the highest index (Table 2). For rice, sustainability requires not only increasing yield but also reducing methane emission. Therefore, improvement of hybrid rice of Sembada 168 could be a win-win strategy as it simultaneously decreases methane emission and increases rice yield.
Table 1. Weight of rice straw and root per hill among rice varieties

| Varieties     | Weigh of rice straw per hill (g) | Weigh of rice root per hill (g) |
|---------------|----------------------------------|---------------------------------|
| Ciherang      | 27.58 ab                         | 5.20 a                          |
| Mapan 05      | 35.67 a                          | 3.37 ab                         |
| Arize gold    | 32.12 ab                         | 4.57 a                          |
| Intani        | 30.93 ab                         | 5.27 a                          |
| Sembada 168   | 21.73 b                          | 1.17 b                          |
| Hipa 8        | 26.97 ab                         | 5.43 a                          |
| Hipa 18       | 31.97 ab                         | 4.15 ab                         |
| Hipa 19       | 31.35 ab                         | 3.72 ab                         |
| Sembada 989   | 30.52 ab                         | 2.38 ab                         |

Remark: The value in a column followed by the same letters are not significantly different from each other at the 5% level of significance, according to the Tukey test.

Table 2. Index of methane emission to yield among rice varieties

| Rice variety     | Yield (t ha\(^{-1}\)) | Methane emission (kg ha\(^{-1}\) season\(^{-1}\)) | Index of methane to yield |
|------------------|-----------------------|-----------------------------------------------|---------------------------|
| Ciherang         | 5.48 a                | 370 ab                                        | 0.07                      |
| Mapan 05         | 5.97 a                | 589 ab                                        | 0.10                      |
| Arize gold       | 6.21 a                | 660 a                                         | 0.11                      |
| Intani           | 5.68 a                | 531 ab                                        | 0.09                      |
| Sembada 168      | 5.30 a                | 405 ab                                        | 0.08                      |
| Hipa 8           | 5.17 a                | 532 ab                                        | 0.10                      |
| Hipa 18          | 5.23 a                | 446 ab                                        | 0.09                      |
| Hipa 19          | 5.00 a                | 457 ab                                        | 0.09                      |
| Sembada 989      | 4.80 a                | 318 b                                         | 0.07                      |

Remark: The value in a column followed by the same letters are not significantly different from each other at the 5% level of significance, according to the Tukey test.

5. Conclusion
One of hybrid rice variety (Sembada 168) has the opportunity to be improved as low methane emission hybrid rice variety indicated from the low index of CH\(_4\) emission to yield.

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