CHARACTERISTIC OF RICE VARIETY FOR LOW GREENHOUSE GASES (GHGS) EMISSION IN FACING THE CHALLENGES OF CLIMATE CHANGE AND NATIONAL FOOD SECURITY

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ABSTRACT

Rice varieties show large variation in their ability to emit GHGs emission. It indicates that possibility of selecting rice varieties for lower GHGs emission is based on the characteristic of rice variety. The objective of this study was to observe characteristic of rice varieties for low GHGs emission to cope with climate change and food security. The study was conducted in Indonesia Agricultural Environment Research Institute (IAERI). The treatment was consisted of seven rice varieties released by Indonesian Agency for Agricultural Research and Development, IAARD (Ciherang, Mekongga, Inpari 13, Inpari 18, Inpari 31, Inpari 32 and Inpari 33) and 1 rice variety released by Bogor Agricultural University (IPB 3S) which replicated three times. Rice paddies were cultivated on November 2015-March 2016 by applying direct seeded system. Measurement of greenhouse gases fluxes were carried out using automatically close chamber installed permanently in the field. Observation of plant characteristic covered tiller number, panicle number, plant height, grain yield, weight of root per hill and length of root. The study showed that GHGs emissions significantly positive correlated with tiller number, panicle number, grain yield and weight of root, however, negative correlated significantly with plant height ($p < 0.05$). Variety of Inpari 13 produced the lowest of GWP (10.3 t CO2-e ha^{-1} yr^{-1}) and possibility to be improved as plant material to create low GHGs emission variety based on the lowest index of GWP and high grain yield.

Keywords: GWP, index emission, plant characteristics, rice variety

INTRODUCTION

Agriculture sector is a significant contributor for greenhouse gases emission, particularly CH_4 and N_2O. Methane and nitrous oxide (N_2O) are two important gases with the Global Warming Potential (GWP) of 28 and 296 times higher than carbon dioxide (CO_2), respectively (IPCC, 2013). Smith *et al*. (2007) mentioned around 50% of CH_4 emission and 60% of N_2O emission released from agriculture. Win *et al*. (2011) stated that methane emissions from rice field were promoted by activity of metanogenic bacteria in anaerobic condition and affected by several factors (Bodelier *et al*. 2000) such as application of chemical and organic fertilizer, water management practices, soil properties, soil and air temperatures, and characteristics of rice cultivars. The recent of methane emissions from rice paddies ranges between 493 – 723 Mt $CO_2e\ yr^{-1}$ (IPCC, 2014). Zou *et al.* (2007) expected that rice paddies were not only as contributor of methane emission but also N_2O emission which related to fertilizer management.

Rice varieties show large variation to emit GHGs emission on study which conducted in China, Japan, India, Italy and USA. It indicates that reduction of GHGs emission could be conducted by selecting rice varieties for lower GHGs emission base on its characteristic. Study by Gogoi *et al.* (2008) showed that traditional rice cultivars with longer vegetative growth produced higher methane fluxes compared with high yielding varieties. Baruah *et al.* (2010) also showed that high yielding rice variety emitted less CH_4 and N_2O compared to traditional varieties. The GHGs emissions correlate positive significantly with leaf area, leaf number, tiller number and root dry weight.

Indonesian Agency for Agricultural Research and Development (IAARD) has released several high yielding rice varieties every year. In facing the challenges of climate change, rice varieties take an important role both on reducing GHGs emission and stabilizing food security. Observation of rice variety's characteristic on high yield rice varities which low GHGs emission should be conducted. Because of those information was scanty in Indonesia, therefore we conducted a study to observe characteristic of rice varieties for low GHGs emission to cope with climate change and food security. Information from the study could be used for plant breeding program to create low GHGs and high yield rice varieties in the future.

MATERIALS AND METHODS

Study was conducted in The Research Station of Indonesian Agricultural Environment Research Institute, located at Sidomukti, subdistrict of Jaken, district of Pati, Central Java Province. The location lies between 111°10′ E longitude and 6°45′ S latitute. Rice fields are dominated by rainfed rice area, with average of rainfall, maximum and minimum of temperature and daily temperature during the experiment was 675 mm, 40 °C, 23.9 °C and 37.3 °C, respectively. The soil chemical properties in the experimental site were pH (H_2O) 5.13, 29.26% sand, 58.77% silt,11.97% clay, 0.32% C-organic content, 0.06% total N and cation exchange capacity (CEC) of 9.16 $cmol^{(+)}\ kg^{-1}$.

Eight of high yielding rice varieties, namely Ciherang, Mekongga, Inpari 13, Inpari 18, Inpari 31, Inpari 32, Inpari 33 and IPB 3S were used in the experiment. The field experiment was arranged using randomized block design with three replicates. All of rice varieties were cultivated on November 2015 using direct seeded system. The size of experimental plot was 5 m x 6 m. Chemical fertilizers were applied at 120:45:60 kg $N:P_2O_5:K_2O\ ha^{-1}$. One-third dose of urea, half dose K_2O and full dose of P_2O_5 were applied at active tillering growth stage. The other one-third doses of urea and half dose of K_2O were applied at maximum tillering or panicle initiation stages. Plant growth parameters such as tiller number, panicle number, plant height, rice yield, root weight per hill and root lenght were measured bi-weekly interval.

Greenhouse gases emission (CH_4 and N_2O) were measured using close chamber method, operated automatically during rice growing season. Gases were taken on interval time of 4, 8, 12 and 16 munite after chamber closing. Analysis of sampling gases was carried out using Gas Chromatography (GC) equipped by Flame Ionization Detector (FID) and Electron Capture Detector (ECD) which specifically to detect CH_4 and N_2O, respectively. Flux of CH_4 and N_2O was calculated using the folloeing equation:

$$E = \frac{dc}{dt} x \frac{Vch}{Ach} x \frac{mW}{mV} x \frac{273.2}{(273.2 + T)}$$

Where E is flux of CH_4 and N_2O (mg m^{-2} day^{-1}), dc/dt is difference of gases concentration per time (ppm $minute^{-1}$), Vch is volume of chamber (m^{-3}), Ach is large of chamber (m^{-2}), The size of chamber was 1 m x 1 m x 1.25 m mW is weight of gases molecule (g), mV is volume of gases molecule (22.41 l) and T is average of temperature during gases sampling (^oC)

The Minitab 16.0 version was used to calculated the correlation coefficient of plant parameters with mean CH_4 and N_2O emission from different rice varieties. Tukey's ($p<0.05$) was done to find out the differences between the recorded parametes.

RESULTS AND DISCUSSION

The GHGs emission (CH_4 and N_2O) were significant different amongs all the rice varieties (Table 1). The lowest CH_4 and N_2O emission were produced by variety of Inpari 13 as much as 168 and 4.81 kg ha^{-1} yr^{-1}, respectively. This result was similar with Baruah *et al.* (2010) that found significant different on CH_4 and N_2O emission amongs ten rice varieties. Related to Global Warming Potential (GWP), the highest GHGs emission was contributed by variety of Inpari 32, followed by Inpari 31 and Inpari 18. Whereas, the lowest GHGs emission was emitted by variety of Inpari 13 (10.3 t CO_2-eq ha^{-1} yr^{-1}).

Table 1. GHGs emissions, GWP and yield of some rice varieties

Varieties	Emission (kg ha^{-1} $season^{-1}$)		GWP (ton CO_2-eq ha^{-1} $season^{-1}$)	Yield (ton ha^{-1})	Emission index (ton CO_2-e t^{-1} grains
	CH_4	N_2O			
Ciherang	229 bc	9.52 a	14.9b	5.98 bc	2.5
Mekongga	202 cd	8.29 ab	12.8c	6.51 bc	2.0
IPB 3S	240 b	7.64 ab	15.2b	5.69 c	2.5
Inpari 13	168 d	4.81 b	10.3d	5.82 c	1.8
Inpari 18	249 ab	8.81 a	15.8b	6.09 bc	2.7
Inpari 31	277 a	8.82 a	17.5a	7.12 ab	2.5
Inpari 32	285 a	9.77 a	18.2a	7.78 a	2.3
Inpari 33	235 bc	7.24 b	14.1bc	5.86 c	2.4

Values in same column followed by same letter do not differ significantly according to Tukey test at 5% level

The highest and lowest rice yield were produced by Inpari 32 and IPB 3S, respectively (Table 1). GHGs emission index showed that Inpari 13 contributed less GHG emission per ton harvested grain. The highest GHGs emission index was contributed by variety of Inpari 18 which produced 2.7 t CO_2-e per 1 ton of rice grain.

Methane emission has strongly positive correlation with N_2O emission ($p < 0.05$) (Table 2). It also showed a significant positive correlation with tiller number, particularly with N_2O emission. This might be associated with availability of substrate to produce CH_4 and N_2O. According to Steinbach and Alvarez (2006), increase in nitrification and denitrification processes was stimulated by availability of nitrogen substrate for nitrifying and denitrifying microorganism in soil which contributed to N_2O production. Yang and Cai (2005) also mentioned that N_2O production was induced by senescence of older leaves and decomposition of crop roots.

Table 2. Matric correlation between GHGs emission (CH_4 and N_2O) with plant variables

Traits	N_2O flux	CH_4 flux	Tiller number	Plant height	Panicle number	Grain yield
CH_4 flux	0.512* (0.011)					
Tiller number	0.402 (0.052)	0.338 (0.106)				
Plant height	-0.517* (0.010)	-0.464* (0.023)	-0.432* (0.035)			
Panicle number	0.417* (0.043)	0.272 (0.199)	0.973** (0.000)	-0.400 (0.053)		
Grain yield	0.256 (0.228)	0.607** (0.002)	0.400 (0.053)	-0.157 (0.463)	0.343 (0.101)	
Root weight per hill	0.172 (0.422)	0.526** (0.008)	0.096 (0.655)	-0.281 (0.183)	-0.018 (0.933)	0.372 (0.074)
Root lenght	-0.193 (0.365)	0.250 (0.239)	0.190 (0.373)	-0.041 (0.849)	0.187 (0.383)	0.431* (0.035)

Values in brackets indicate the probability of the correlation coefficient on it, * correlated significantly at α 0.05, ** correlated significantly at α 0.01

For CH_4 emission, organic materials could generally promote CH_4 production by increasing carbon supply to methanogenic bacteria (Wassman *et al.*, 2000). Root exudates also contribute to CH_4 emission. Our study showed a significantly positive correlation between root weight and CH_4 emission ($p < 0.05$). Lu *et al.* (1999) stated the increase of root biomass could attribute to large quantity of organic carbon as a substrate of methanogenic bacteria. Baruah *et al.* (2010) revealed that root biomass contribute to higher CH_4 and N_2O emission because of more surface area for gases diffusion into roots. Our study also found that rice yield has significantly positive correlation with CH_4 emission which might be supported by root weight and root lenght.

Panicle number of rice varieties showed positive correlation with GHGs emission (strongly with N_2O emission). The panicle development was related to vegetative phase, particularly tiller number. In photosynthesis proccess, the photosynthates are translocated towards vegetative phase to develop root and shoot growth and support reproductive phase. According to Jimenez and Lal (2006), photosynthate was stored in different parts of plant which associated to availability of substrate for methanogenic bacteria. Study by Baruah *et al.* (2010) showed that excessive of vegetative growth and high stored photosynthate on roots and root exudation could provide more substarte for methanogenesis.

CONCLUSION

GHGs emission significantly positive correlation with tiller number, panicle number, gain yield and weight of root but significantly negative correlation with plant height ($p < 0.05$). Variety of Inpari 13 produced the lowest of GWP (10.3 t CO_2-e ha^{-1} $season^{-1}$) and possibility to be improved as plant material to create low GHGs emission variety based on the lowest index of GWP and high grain yield.

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