
Research Article

Methane emission and rice growth on clayey soil under controlled water regime

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Abstract

Conventional lowland rice cultivation involves flooding the paddy from planting to close to harvest, and high N fertilization. This practice leads to large amount of methane emissions. We studied the effect of soil water regime control on methane gas emissions and growth of several rice varieties on clayey soil. The experiment was arranged according to Split Plot Design. The main plot was water regime, i.e. continuous flooding (2-cm inundation), and intermittent flooding (flooded 2 cm then allowed to dry until the soil started to cracks). The sub-plots consisted of 3 rice varieties, i.e. Inpari 32, Mekongga, and Cisadane. Together, there were six treatment combinations, repeated 4 times. We measured methane emission, plant height, number of tillers per clump, number of productive tillers, and root volume. We computed analysis of variance, then performed Duncan Multiple Range Test. We found, at 57 and 73 days after planting, continuous flooding resulted in much (statistically) higher methane gas emissions than intermittent flooding (about 2 times greater for both Inpari and Cisadane, and 5 times greater for Mekongga). The two water regimes examined did not result in differences in plant height, number of tillers, productive tillers and root volume of the three varieties, although the flooded treatment tended to slightly give taller plant, more tillers and productive tillers. In conclusion, intermittent flooding significantly suppresses methane emission compared to continuous flooding. However, certain rice variety produces more methane than others. While intermittent flooding reduced methane emission, it did not statistically affect rice growth compared to continuous flooding.

Introduction

Climate change is a global phenomenon characterized by an increase in weather

variations, such as temperature, rainfall, and wind (Ali and Erenstein, 2017). This phenomenon is expected to worsen in the future and

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have a very large impact in developing countries that are very vulnerable to climate change (Session & Maskrey, 2007). Ali and Erenstein (2017) further explain that the existence of greater temperature fluctuations, changes in precipitation patterns resulting in reduced water availability will affect the amount of agricultural commodity production and income and even lead to poverty.

The influence of climate change in the agricultural sector is very broad, covering various aspects, such as resources, agricultural infrastructure, and agricultural production systems, aspects of food security and self-sufficiency, as well as farmer welfare (Rejeki et al., 2018). Furthermore, it is also explained that the effect of climate change on agriculture is divided into two indicators, namely: 1) vulnerability to climate change, namely the decreased ability of humans, plants and livestock to adapt in carrying out their functions due to the stress of climate change, and 2) the impact of climate change, namely the condition of loss/benefit both physically and socially and economically due to the stress of climate change.

Climate change has proven that its impact is very large on agriculture, but it cannot be denied that agriculture, is also a major contributor to global warming. In 2010 the contribution of non-carbon dioxide (CO₂) greenhouse gases (GHG), such as methane (CH₄) and nitrous oxide (N₂O) was estimated at 5.2-5.8 gigatons of CO₂ equivalent per year (Tubiello et al., 2013). Methane and nitrous oxide are two GHGs that have strong global warming potential, which are 25 and 298 times greater than carbon dioxide on a 100-year mass basis (IPCC, 2013). This GHG emission is estimated to continue to increase if plant cultivation activities are still managed conventionally.

Lipper (2014) describes that GHG emissions from agriculture generally come from agricultural land, namely from the use of synthetic fertilizers, rice cultivation, and mass biomass burning, and these GHG emissions are estimated to continue to increase if agricultural cultivation activities are still managed conventionally. Particularly in Indonesia, in 2010 the agricultural sector took the third position as a GHG contributor with a total of 110.5 Mt (Kartikawati & Sopiawati 2017). One of the

conventional agricultural practices that is suspected as a source of large GHG emissions is the cultivation of rice plants with a water supply system by flooding, starting from planting to approaching harvest age. Rice cultivation with continuous inundation systems will produce high GHG emissions (Linguist et al., 2012).

Several strategies to reduce GHG emissions have been implemented. However, several factors that influence GHG emissions, such as soil type, rice varieties, and their interactions with water regime regulation have not received much attention and information is still very limited. Based on this description, research on "methane gas emissions and the growth of several rice varieties on Alfisol soils through the regulation of the soil water regime" becomes interesting for further study. The aims of this research was to determine the effect of soil water regime regulation on methane gas emissions and the growth of several rice varieties cultivated on Alfisol soils.

Materials and methods

The site

The research was carried out at the Gowa Agricultural Development Polytechnic (Polbangtan) glasshouse, while the methane emission analysis was carried out at the Pati Agricultural Environmental Research Institute Laboratory in Central Java, Agricultural Research and Development Agency, Ministry of Agriculture.

Research design

The research was arranged according to a Split Plot Design. The main plot was water regime, namely continuous flooding (2 cm inundation), and intermittent flooding. The subplots consisted of three varieties, namely Inpari 32, Mekongga, and Cisadane. Hence, there were 6 treatment combinations, repeated 4 times (Figure 1).

Preparation of planting media

The soil used was sieved using a sieve with a hole diameter of 1 cm. The soil was put into the pot until planting media reaches a weight of 19 kg pot⁻¹. The soil is mixed with cow bokashi fertilizer at 10 tons ha⁻¹ dosage. The planting medium was then incubated for 1 week.

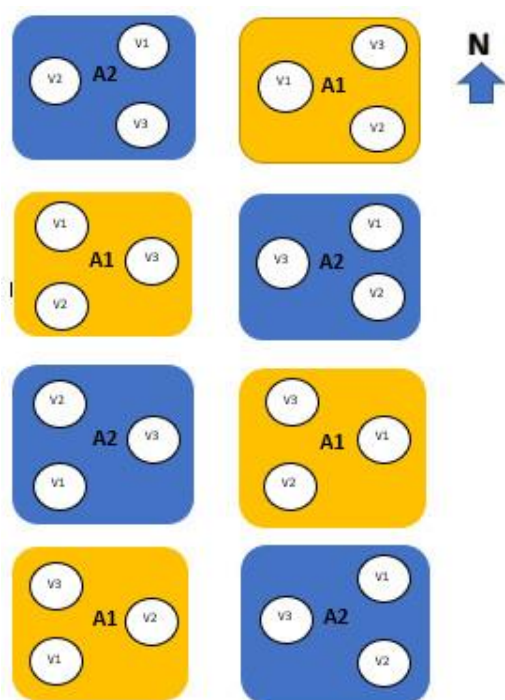


Figure 1. Layout of potted rice plants

Water regime settings

Two water regimes were applied, i.e. continuous flooding (the soil was inundated, 2 cm above the soil surface – the water level was kept constant every day), and intermittent flooding (flooded 2 cm, then left dried out until the soil started to crack, before water was added again to puddle and inundated 2 cm. This water control was carried out repeatedly until the seed filling phase.

Planting

Rice seeds are sown in trays/dapog with planting media of a mixture of soil and manure (1:1), after the seeds are 2 weeks old, the seeds are then planted in prepared pots.

Parameter measurement and data analysis

The parameters were measured include: 1) Emission of methane gas was carried out using a closed chamber, sampling of methane gas in a closed chamber was carried out at 52 days after planting (DAP) and 73 DAP. The GHG flux was calculated using the formula from [Khalil et. al \(1991\)](#):

$$F = \frac{dc}{dt} \times \frac{V_{ch}}{A_{ch}} \times \frac{mW}{mV} \times \frac{273,2}{(273,2 + T)}$$

where :
 F : CH₄ gas flux (mg.m⁻²day⁻¹)
 dc/dt : Difference in CH₄ concentration (ppm min⁻¹)
 V_{ch} : Cover volume (m³)
 A_{ch} : Cover area (m²)
 mW : Molecular weight of CH₄ (g)
 mV : Constant volume of gas molecules (22.41 L)
 T : Average temperature during gas sampling (°C)
 Value 273.2 : Kelvin temperature constant

2) Plant height measured from 1 week after transplanting until the beginning of the generative phase, 3) number of tillers per clump counted from 1 week after transplanting until the beginning of the generative phase, 4) number of productive tillers counted when the plant was 11 weeks old after transplanting at the time of panicle exit, and 5) the volume of roots was measured at harvest by means of the roots in the rice clump being cleaned and then put into a measuring cup with a predetermined volume of water, the increase in the volume of water was the same as the volume of the roots. The data obtained were analyzed using the analysis of variance test, and if there was a significant effect, then continued with the Duncan Multiple Range Test (DMRT).

Plant maintenance

Plant maintenance includes fertilization, pest/disease control, and weed cleaning. For fertilization, the dose used refers to the fertilizer recommendation for Kab. Gowa if there is an addition of 10 tons of organic fertilizer ha⁻¹, namely: Urea 250 kg ha⁻¹, SP 36 50 ha⁻¹, KCl 50 kg ha⁻¹. Meanwhile, pest and disease control is carried out by spraying biopesticides if there are symptoms of pest/disease attacks. While cleaning weeds manually, namely by pulling out the weeds.

Results and discussion

Methane gas emissions

The results of measurement and the DMRT test for rice methane gas emissions at the age of

52 and 73 DAP are presented in Figures 2 and 3. In general, the flooding (A1) treatment gave higher emission values than the intermittent water supply (A2) treatment at both 52 and 73 DAP. At 52 DAP Mekongga gave the smallest emission value and was significantly different from other varieties, and at 73 DAP Cisadane gave the smallest emission value and was significantly different from other varieties.

The ability to release methane gas from each variety varies greatly, depending on the nature, age and activity of plant roots. This is in accordance with Xu et. al (2015) that the amount of CH₄ gas emitted into the atmosphere from irrigated rice fields is influenced by plant age, water management during planting, input of organic and inorganic materials, soil type, temperature and variety.

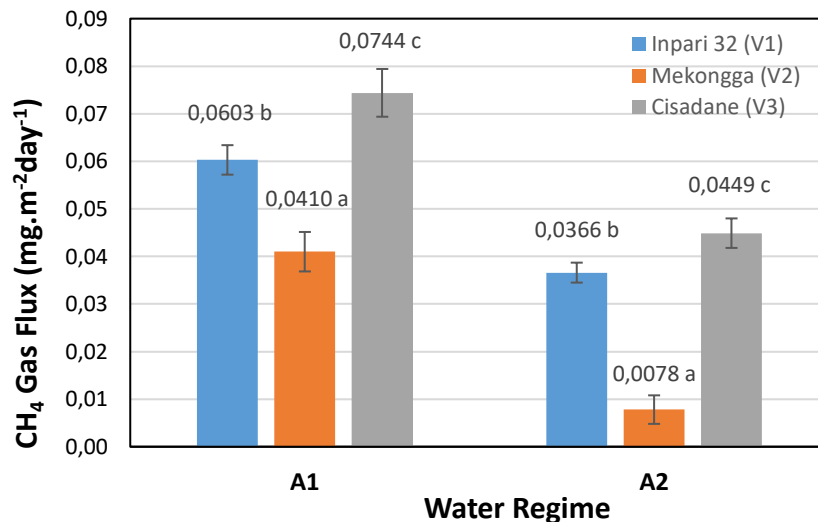


Figure 2. Average methane emission of several rice varieties at the age of 52 DAP in water regimes with flooding (A1) and intermittent water supply (A2)

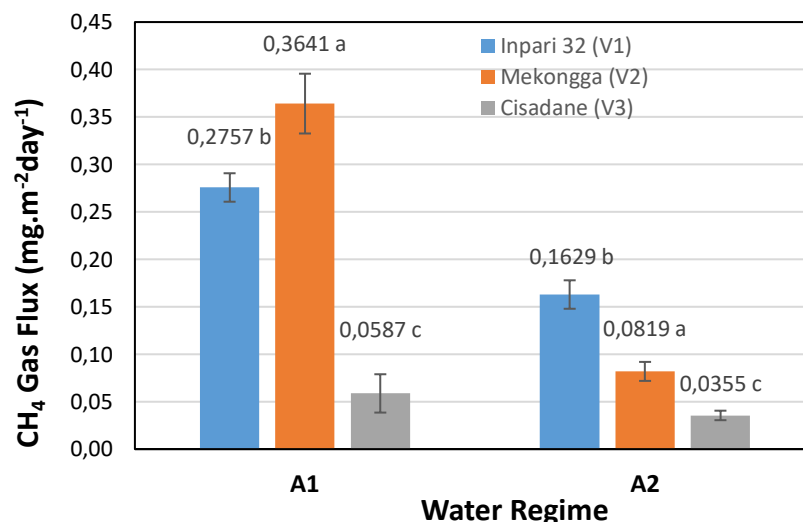


Figure 3. Average methane emission of several rice varieties at the age of 73 DAP in water regimes with flooding (A1) and intermittent water supply (A2)

Kartikawati et al. (2011) stated that the use of new varieties with early maturity are able to reduce methane gas emissions. Setyanto et al.

(2017) explains that each rice variety produces different methane emissions, so the use of the right variety, besides being adaptive to the

environment, is also low in GHG emissions as a climate change mitigation measure. He further stated that in the future, rice varieties are needed that are low in GHG emissions, but still produce high production, and are in accordance with ecosystem conditions, resistant to pests and diseases and extreme conditions (Setyanto et al., 2017).

Plants in their growth need sufficient and available water in the soil. The intermittent irrigation system in this study provides lower methane emissions. This is in accordance with Xu et al. (2015) that intermittent irrigation can reduce up to 60% CH₄. This is in line with Haque et al. (2016) that intermittent irrigation in mid-season also significantly reduces global warming potential 46-56% compared to conventional inundation, reduces 50-53% CH₄ flux without any difference in production.

Plant height

The results of measurement and the DMRT test for rice plant height at the age of 1-8 week after planting are presented in Table 1. Based on Table 1 it can be described that at weeks 1-8 there was no effect of setting the water regime on plant height in each variety, while the difference in plant height for each variety in each water regime began to be seen from the 3rd to the 8th week. In flooding (A1), the Cisadane variety gave the highest value and only have significant different from Inpari 32 at the 3rd and 4th week. While intermittent irrigation (A2), at weeks 3, 4, and 5 Cisadane have significant different from other varieties, and at weeks 6, 7, and 8, Cisadane have not significant different from Inpari 32.

Table 1. The results of the DMRT test for rice plants height at the age of 1-8 WAP in the water regime with flooding (A1) and intermittent water supply(A2)

Variety	1 st week		2 nd week		3 rd week		4 th week	
	A1	A2	A1	A2	A1	A2	A1	A2
Inpari 32 (V1)	26.13	25.38	37.88	36.75	47.50 a	46.25 a	59.50 a	61.25 a
Mekongga (V2)	24.00	22.25	36.50	34.63	51.00 ab	45.00 a	63.00 ab	57.00 a
Cisadane (V3)	28.25	30.00	42.75	40.75	58.00 b	57.25 b	74.25 b	72.50 b
CV (%)	9,96		10,67		9,53		9,41	

Variety	5 th week		6 th week		7 th week		8 th week	
	A1	A2	A1	A2	A1	A2	A1	A2
Inpari 32 (V1)	76.50 a	76.00 a	87.25 a	86.00 b	98.50 a	96.25 b	105.25 a	103.00 b
Mekongga (V2)	77.00 a	69.50 a	87.00 a	78.00 a	89.50 a	84.75 a	96.75 a	87.25 a
Cisadane (V3)	87.00 a	85.75 b	97.00 a	91.00 b	103.00 a	97.50 b	107.00 a	102.00 b
CV (%)	7,43		6,35		7,17		9,80	

Note: the numbers in the same column, followed by different letters mean that they are have significant different in DMRT α 0.05

There is a difference or diversity between varieties starting from the 3rd week to the 8th week, because the plants are in a state of vegetative growth, according to the character of each variety, where each variety has different genetic potentials in responding to its growing environment. The ability of a plant or variety to adapt to its environment can be seen from the rate of plant growth, if a variety is more adaptive it will provide better growth. This is in

accordance with the opinion of Utama et al. (2009) which states that plants that are tolerant of environmental stresses have the ability to adapt morphologically and physiologically.

Number of tillers

The results of measurement and the DMRT test for the number of rice tillers at the age of 1-8 WAP are presented in Table 2. Based on Table 2 it can be described that at weeks 1-8 there is

no effect of setting the water regime on the number of tillers in each variety, while the difference in the number of tillers of each variety in each water regime began to be seen from the 3rd to the 8th week. In flooding (A1), in general, from the 1st to the 8th week, the Mekongga variety gave the highest value, and only

significantly different from other treatments at the 3rd week. While intermittent water supply (A2), at weeks 3, 4, 5, and 6 Mekongga have not significant different from Cisadane, and at weeks 7, and 8, Mekongga have significant different from Cisadane and Inpari 32.

Table 2. The results of the DMRT test for the number of rice tillers at the age of 1-8 WAP in the water regime with flooding (A1) and intermittent water supply (A2)

Variety	1 st week		2 nd week		3 rd week		4 th week	
	A1	A2	A1	A2	A1	A2	A1	A2
Inpari 32 (V1)	3.25	3.50	3.25	3.75	3.50 a	4.50 a	3.50 a	4.50 a
Mekongga (V2)	3.75	3.75	4.25	4.25	4.75 b	4.75 a	4.75 b	4.75 a
Cisadane (V3)	3.75	3.00	3.75	4.50	3.50 a	4.00 a	4.75 b	4.50 a
CV (%)	13,88		14,88		14,97		17,93	
Variety	5 th week		6 th week		7 th week		8 th week	
	A1	A2	A1	A2	A1	A2	A1	A2
Inpari32 (V1)	3.75 a	4.50 a	4.50 a	4.75 a	5.25 a	5.00 a	5.25 a	5.00 a
Mekongga (V2)	6.75 b	6.00 b	6.75 a	6.50 b	8.00 b	7.25 b	8.00 b	7.25 b
Cisadane (V3)	6.00 b	5.75 b	6.75 a	6.00 b	6.75 b	6.00 a	6.75 b	6.00 a
CV (%)	12,21		16,67		11,70		11,70	

Note: the numbers in the same column, followed by different letters mean that they are have significant different in DMRT α 0.05

Based on the research results obtained, the water regime treatments have not significant effect on the number of tillers in each variety. The difference in the number of plant tillers is basically more influenced by genetic traits. This is in accordance with [Husna and Ardian \(2010\)](#) that the number of tillers will be maximized if the plant has good genetic characteristics coupled with favorable environmental conditions or in accordance with plant growth and development. The intermittent water supply (A2) is still an ideal environment for the growth of rice plants, so that rice plants are still able to provide the maximum number of tillers, and have not significant different with the flooding (A1).

The development of the number of rice tillers is not only affected by genetic factors, but also by unfavorable environmental conditions, as described by [Ikhwan et al. \(2013\)](#). They noticed that the closer the spacing or the more plant population per unit area, the greater the competition between rice clumps in capturing solar radiation, absorption of nutrients and

water. As a result, plant growth is inhibited, the number of tillers is reduced and the yield of rice plants is decreased.

Number of productive tillers

The results of measurement and the DMRT test for the number of productive tillers of rice at the age of 11 WAP are presented in Figure 4. In general, the number of productive tillers of the Mekongga (V2) variety was higher and have significant different from Cisadane and Inpari 32 in all water regime treatments. From Figure 1 it can also be seen that the water regime A1 (flooding) gave higher tiller yields than intermittent water supply (A2), especially for the Mekongga and Cisadane varieties. In A1 Mekongga gave the highest value of 14.50 tillers and have significant different from other varieties, the same thing happened in A2, where Mekongga gave the highest yield of 12 productive tillers and also have significant different from other varieties.

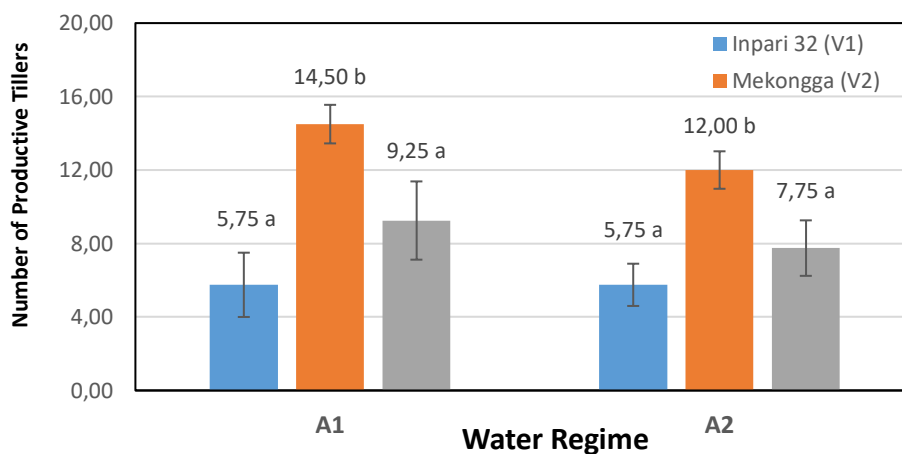


Figure 4. Average number of productive tillers of several rice varieties at the age of 11 WAP in water regimes with flooding (A1) and intermittent water supply (A2)

As with the number of tillers, the number of productive tillers is affected by genetic factors. [Husna and Ardian \(2010\)](#) explain that the maximum number of tillers will be achieved if the plant has good genetic characteristics, with favorable environmental conditions or in accordance with plant growth and development. The water regime with flooding (A1) and intermittent water supply (A2) is still a suitable environment for the growth of rice plants, so that rice plants are still able to provide the maximum number of productive tillers. The increase in the number of productive rice tillers is directly proportional to the increase in the total number of tillers. [Riyani et al. \(2013\)](#) stated that the formation of the number of productive tillers is closely related to the total

number of tillers, where the greater the total number of tillers, the greater the number of productive tillers.

Root volume

The results of measurement and the DMRT test for rice root volume at the age of 105 DAP are presented in Figure 5. In general, the root volume of the Cisadane (V3) variety was higher in all water regimes and gave significant different from Mekongga and Inpari 32 in the intermittent water supply (A2). In Flooding (A1) Cisadane gave the highest value is 105 cm³ and only have significant different to Inpari 32 variety, while in the A2, Cisadane gave the highest yield of 112 mL which have significant different from other varieties.

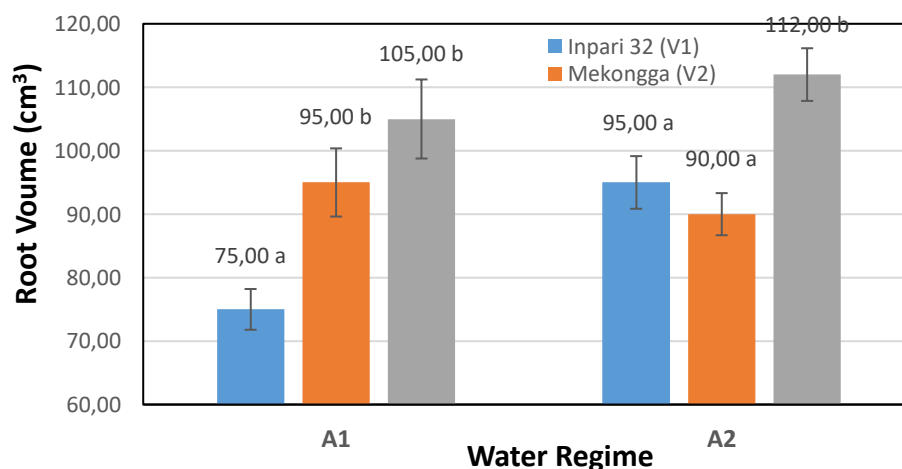


Figure 5. Average root volume of several rice varieties at the age of 105 DAP in water regimes with flooding (A1) and intermittent water supply (A2)

Measurement of the root volume of rice plants is very important in relation to rice plant methane gas emissions. Roots have an important role in the release of methane gas into the atmosphere, because it can increase the methanogenesis process through the release of root exudates which are rich in available carbon sources. With increasing oxygen concentration, the methane production process can be reduced because methane is oxidized biologically by methanotropic bacteria (Setyanto et al., 2017). The roots of rice plants are able to exchange oxygen, so they can form a thermodynamic balance in which about 60-90% of methane is produced in the rhizosphere layer through the aerenchyma vessels of rice plants. This is supported by Nisha & Arief (2018) that during vegetative growth, plants produce a lot of aerenchyma tissue.

Methane gas emissions in various varieties of rice plants are determined by differences in their physiological and morphological properties. The ability of varieties to emit methane depends on the aerenchyma cavity, number of tillers, biomass, root pattern and metabolic activity (Setyanto, 2017).

Conclusion

Intermittent flooding suppresses methane emission compared to continuous flooding. Continuously flooded soil yielded methane emission two to five times greater than intermittent flooded soil. However, the amount of methane emitted depends on rice variety; certain variety produces greater methane than others. No statistically difference in rice growth between the two water regimes examined. Intermittent flooding can be used a means of reducing methane emission from paddy field, while not affecting rice growth. Further studies on the effect of such water regime on rice production in the field is necessary.

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Author's declaration

Authors declare that there is no conflict of interest. All authors read and approved the final version of the manuscript.

References

- Ali, A., and O. Erenstein. (2017). Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Climate Risk Management*, 16, 183–194. [CrossRef](#)
- Haque, Md M., G. W. Kim, P. J. Kim, and S. Y. Kim. (2016). Comparison of net global warming potential between continuous flooding and midseason drainage in monsoon region paddy during rice cropping. *Field Crops Research*, 193, 133–142. [CrossRef](#)
- Husna, Y. dan Ardian. (2010). Pengaruh penggunaan jarak tanam terhadap pertumbuhan dan produksi padi sawah (*Oryza sativa* L.) varietas IR 42 dengan metode SRI (*System of Rice Intensification*). *Jurnal Sagu*, 9(1), 21–27. [Direct Link](#).
- Ikhwan, Pratiwi, Paturrahman, dan Makarim. (2013). Peningkatan produktivitas padi melalui penerapan jarak tanam jajar legowo. *Jurnal Iptek Tanaman Pangan*, 8(2), 72–79. [Direct Link](#).
- IPCC. (2013). *Climate change 2013 the physical science basis, working group I contribution to the fifth assessment report of the intergovernmental panel on climate change*. London, UK: Cambridge University Press [Direct Link](#).
- Kartikawati, R., H.L. Susilawati, A. Miranti, and P. Setyanto. (2011). Teknologi mitigasi gas rumah kaca (GRK) dari lahan sawah. *Agroinovasi*, XLII(3423), 7–12. [Direct Link](#).
- Kartikawati R. and T. Sopiawati. (2017). *Pengukuran gas rumah kaca dengan teknik sungkup tertutup otomatis (automatically closed chamber)*. Badan Litbang Pertanian, Pati, Jawa Tengah.
- Khalil, M. A. K., R. A. Rasmussen, M. X. Wang, and L. Ren. (1991). Methane emissions from rice fields in China. *Environmental Science and Technology*, 25(5), 979–81. [CrossRef](#)
- Linquist, B.A., M.A. Adviento-Borbe, C.M. Pittelkow, C. van Kessel, and K.J. van Groenigen. (2012). Fertilizer management practices and greenhouse gas emissions from rice systems: A quantitative review and analysis. *Field Crops Research*, 135, 10–21. [CrossRef](#)

- Lipper, L. (2014). Climate-smart agriculture for food security. *Nature Climate Change* 4, 1068–72. [CrossRef](#)
- Nisha, F.N dan C. Arief. (2019). Pengembangan model denitrification decomposition (DNDC) untuk pendugaan emisi gas metana (CH₄) dari lahan padi sawah. *Jurnal Teknik Sipil dan Lingkungan*, 4(1), 1–12. [CrossRef](#)
- Riyani, R., Radian, dan S. Budi. (2013). Pengaruh berbagai pupuk organik terhadap pertumbuhan dan hasil padi di Lahan pasang surut. *Jurnal Sains Pertanian Equator*, 2(2), 1–11. [Direct Link](#).
- Rejekiningrum, P., I. Las, I. Amien, N. Pujilestari, W. Estiningtyas, E. Surmaini, Suciandini, Y. Sarvina, A. Pramudia, B. Kartiwa, S. Muharsini, Sudarmaji, Hardiyanto, C. Hermanto, G.A. Putranto, O. Marbun. (2011). *Adaptasi perubahan iklim sektor pertanian* 2018. Badan Litbang Pertanian, Pati, Jawa Tengah.
- Session, F., and A. Maskrey. (2007). *Disaster risk reduction 2007 global review*. June, 5–7. [Direct Link](#).
- Setyanto, P, A. Pramono, T.A. Adriany, H,L, Susilawati, T. Tokida, A.T.Padre & K. Minamikawa. (2017). Alternate wetting and drying reduces methane emission from a rice paddy in Central Java, Indonesia without yield loss. *Soil Science and Plant Nutrition* 64(1), 23-30, [CrossRef](#)
- Tubiello, FN., M. Salvatore, S. Rossi, A. Ferrara, N. Fitton, and P. Smith. (2013). The FAOSTAT database of greenhouse gas emissions from agriculture. *Environmental Research Letters*, 8, 1–11. [CrossRef](#)
- Utama, M.Z.H., W. Haryoko, R. Munir, Sunadi. (2009). Penapisan varietas padi toleran salinitas pada lahan rawa di Kabupaten Pesisir Selatan. *Jurnal Agronomi Indonesia*, 37(2), 101–106.
- Wahyuni, S. (2008). Hasil padi gogo dari dua sumber benih yang berbeda. *Penelitian Pertanian Tanaman Pangan*, 27(3), 135–140. [Direct Link](#).
- Xu, Y., J. Ge, S. Tian, S. Li, A.L. Nguy-Robertson, M. Zhan, and C. Cao. (2015). Effects of water-saving irrigation practices and drought resistant rice variety on greenhouse gas emissions from a no-till paddy in the central lowlands of China. *Science of the Total Environment* 505, 1043–52. [CrossRef](#)