COMPARISON OF METHANE EMISSION FROM CONVENTIONAL AND AGROECOLOGICAL RICE APPROACH IN KELANTAN MALAYSIA

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ABSTRACT

Methane (CH4) is a potent greenhouse gas that contributes to climate change, and its emission from agricultural activities is a significant source of concern, particularly in rice cultivation in Malaysia, where rice is a staple crop. Numerous studies have shown that conventional rice cultivation methods produce higher methane emissions than agroecological approaches. Thus, a study was conducted with the objective estimating methane emissions from two different locations at Bachok and Kadok, Kelantan during the main and off-season from July 2018 until Jun 2019. Treatments comprising two methods of crop establishment viz., conventional (CM) and system of rice intensification (SRI) as the agroecological approach (AE) was laid out in randomized complete block design with four replications and plot size of 5 x 5 m. MARDI fragrant rice (Oryza sativa L) variety 'MRQ 76' seeds were directly seeded in the conventional treatment plots with flooded conditions while in SRI, 12-day-old seedlings were transplanted in the SRI treatment plots with saturated conditions were maintained. Methane gasses were sampled during 40, 70, and 100 days after sowing. Results of the study indicated that among the methods of crop establishment, the C method had the maximum cumulative CH4 emission followed by SRI. Methane emission using the SRI method in Bachok was 64% lower with an average value of 3.06 mg/m2/hr compared to the conventional technique with 8.47 mg/m2/hr. The SRI method also showed a 63% lower value in Kadok with 2.90 mg/m2/hr compared to the conventional with 7.90 mg /m2/hr. Emission of CH4 was higher in the early stage of the crop at 40 days after sowing and declined at 100 days after sowing in all two methods.

Keywords: *Agroecological Approach, Conventional, Methane, Rice, Kelantan*

INTRODUCTION

Rice (Oryza sativa L.) is a staple food, particularly in Asia which is grown on more than 150 million hectares, with an estimated 600 million tonnes of rice produced worldwide each year (Sohrabi, Rafii, Hanafi, Siti Nor Akmar, & Latif, 2012). Rice is Malaysia's third largest crop after rubber and palm oil covering an area of 647,860 ha with a total production of 2,428,900 metric tonnes in 2021 (MAFI, 2021). Malaysia reportedly remains a net importer of rice with SSL ranging between 60 and 70 percent (Rashid et al., 2020), and imports almost 30% of the rice from neighboring countries such as Vietnam and Thailand (Othman et al., 2020).

Compared to most methods used for other crops, traditional irrigation for rice uses a continuous flooding method that requires a lot of water. In general, during the growing season, rice crops require 1100–1500 mm of water (De Barreda et al., 2021; Zampieri et al., 2019), which is higher than other grain crops. Approximately 93 million hectares, or 75% of the world's rice crop, are produced mostly in irrigated lowland rice systems (Dorairaj & Govender, 2023). Agriculture activities in Asia use more than 80% of the world's freshwater resources, with rice cultivation consuming half of this total (Mostafazadeh-Fard, Jafari, Mousavi, & Yazdani, 2010) due to puddling and flooding during field preparation and crop production. In Malaysia, rice is commonly cultivated by continuous flood irrigation, which consumes a lot of freshwaters. However, previous studies have shown that flooded rice paddy fields were among the largest methane (CH_4) emissions during the rice growing period (Cai, Tsuruta, & Minami, 2000). About 18% of the radiative forcing caused by humans is caused by CH_4, the second-most significant greenhouse gas after carbon dioxide (CO_2). Small changes in the amount of CH_4 in the atmosphere have a big effect on global warming since it has 25 times the global warming potential of the CO_2 molecule (Bridgham, Cadillo-Quiroz, Keller, & Zhuang, 2013). The concentration of CH_4 in the atmosphere has grown dramatically from 700 to 1803 parts per billion during the pre-Industrial period (IPCC, 2021).

Long-term waterlogging creates an anoxic environment that is favorable for anaerobic microorganisms such as fermentative bacteria and methanogenic archaea, which predominate in the microbial community and release CH_4 during the anaerobic breakdown of organic matter (Liesack, Schnell, & Revsbech, 2000; Ly, Jensen, Bruun, & de Neergaard, 2013). Thus, methane emissions from rice fields can be decreased by modifying the variables that control these emissions, including water and fertiliser management, cultural techniques, and crop cultivar selection. Due to the fact that conventional rice paddy management relies heavily on water, the growing concerns about climate change will necessitate climate smart management and greater awareness of resource utilisation (Tian et al., 2021).

Agroecological activities contribute to agroecosystem sustainability by improving various ecological processes and ecosystem services such as nutrient cycling, biological N fixation, natural pest management, biodiversity protection, carbon sequestration, and soil and water conservation (Wezel et al., 2014). The system of rice intensification, known as SRI, which was created in Madagascar with the assistance of Malagasy farmers, calls for alternate wet and dry irrigation (AWDI) adoption as part of a novel method of rice intensification, or the practise of producing rice under mostly aerobic soil conditions. The SRI method provides several adjustments to rice farming management practices not only to improve the conditions for rice growth (Chapagain, Riseman, & Yamaji, 2011) but also to offer an alternate approach of aerating the soil to reduce methane emissions from paddy soil.

As of right now, it is evident that various management techniques, including cultivation methods, have a significant influence on the oxidation and generation of CH_4 in the soil, which in turn influences the emissions of CH_4 from paddy fields. Nevertheless, only a small number of studies have provided a thorough analysis of the impacts of cultivation methods on CH_4 emissions from paddy soils. Here, we collected data on the effects of different cultivation methods on soil CH_4 emissions in paddy fields at three different plant ages which are 40, 70 and 100 days after sowing (DAS). The objectives of this study were to (1) quantify the effects of different cultivation techniques between agroecological approach and conventional methods on CH_4 emissions from paddy fields, and (2) determine the CH_4 emissions at three different plant ages (40, 70 and 100 DAS).

MATERIALS AND METHODS

The field experiment was conducted at a farmer's field in Bachok, Kelantan (6.061416, 102.384542) during the main season from July to November 2018 and in Kadok, Kelantan (6.005827, 102.252605) during the off season from February to June 2019. The location in Kelantan were chosen due to Kelantan is the second largest producer of rice after Kedah with 207,853 million metric tons in 2018, 305,676 million metric tons in 2019, and 342,914 million metric tons in 2020 (Zakaria & Nik Abdul Ghani, 2022). The rice seeds of variety MRQ 76 were obtained from the Malaysian Agricultural Research and Development Institute (MARDI) Seberang Perai, Pulau Pinang. The study was conducted using a randomised complete block design with the size of the experimental plots 5 m x 5 m (25 m^2), with two treatments namely the Agroecological approach (AE) and conventional method (CM). Each treatment was replicated three times.

The seedling used for transplanting of the Agroecological approach (AE) is 12 days old after seeding on the tray of the nursery bed. The transplanting of a single plant was done quickly after the seedlings were removed from the nursery bed, and carefully putting the seedling in very shallow (1-2 cm) soil in a square pattern with spacing at 30 x 30 cm distances between rows and hills. Commercial organic SRI fertilizer formulated by local SRI farmers was used in the AE plots and was applied every 10 days until 80 DAT. In the AE, plots were kept moist with a water level of about 1-2 cm at the vegetative phase until the ripening phase and drained 20 days before harvest. In the conventional method (CM) plots, the pre-germinated seeds of rice are directly broadcasted at the plots of direct seeded at a rate of 140kg/ha based on a regular practice by the conventional farmers. Flooded water was supplied continuously with a water level of about 5 - 10 cm until 14 days before harvest in the CM method. The CM plots received inorganic NPK fertilizer at rates 15:15:15 at 21 and 34 DAS and 12:12:17 at 49 DAS.

Gas sampling and analysis of methane emission in this study using the Closed Chamber Method as suggested by (Minamikawa, Tokida, Sudo, Padre, & Yagi, 2015) (2015). The chamber is made of perspex material measuring 35 cm x 35 cm x 100 cm (length x width x height) and is divided into 2 parts, the upper and lower parts as shown in Figure 1. The gas sampling process in the field as in Figure 2 was done from 10 am to 12 pm. A total of 20 ml of gas from inside the chamber was extracted and immediately transferred into a gas storage tube that has been vacuumed beforehand in the laboratory. Gas samples were collected at 10-minute intervals, namely 0, 10, 20 and 30 minutes after the upper chamber was closed. Gas sampling was conducted and measured according to the growth stage of the rice at 40, 70 and 100 days after planting. The top of the chambers was let open during fertilizing and weeding activities.

Figure 1: Part of gas sampling chamber

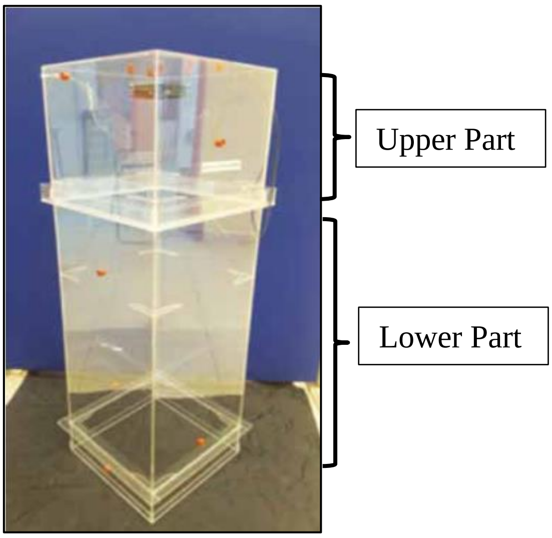


Figure 2: Gas sampling process at the field

The concentration of methane gas (CH_4) was analyzed using Gas Chromatography (Model-SRI 8610C, USA) equipped with a Flame Ionization Detector (FID). All gas results (ppm) obtained from the GC are adjusted according to the method specified in (IAEA, 1992) and presented as a flux (mg /m^2/hr) calculated based on the equation below:

$$Fluks = \frac{dc}{dt} \times \frac{Vc}{Ac} \times \cdot\, \text{ƥ} \times \frac{273}{273+T}$$

Where dc/dt = rate of increase of CH_4 concentration with time, Vc = chamber volume (m^3), Ac = Ground area covered by the chamber (m2), ƥ = gas density (0.717 kg m–3 for CH_4) and T = average temperature in a closed room (°C).

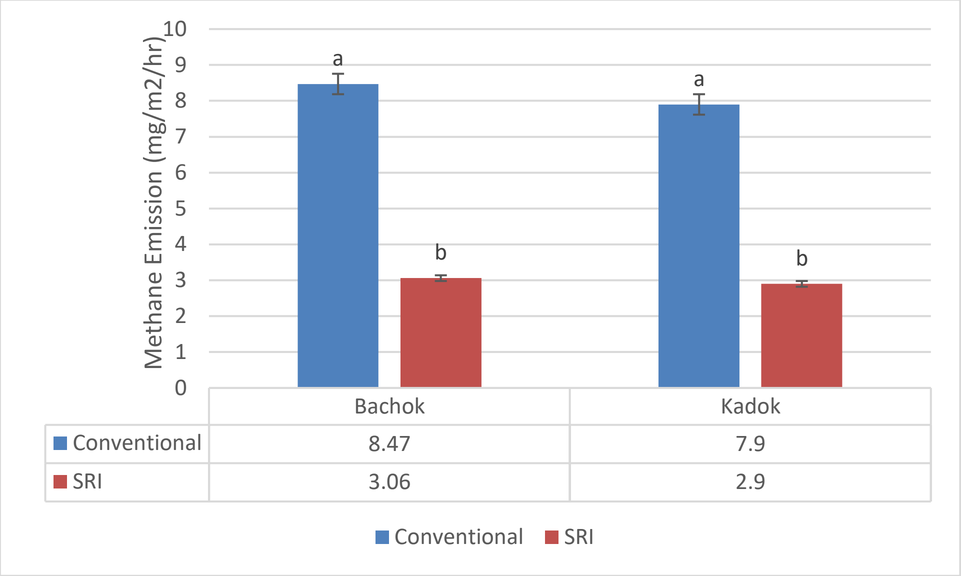
One-way analysis of variance (ANOVA) methods were used to analyse all the data statistically using Statistical Analysis System (SAS) software version 9.3. Mean separation was carried out for significantly different parameters using the Least Significant Difference (LSD) test at $p<0.05$.

RESULTS AND DISCUSSION

Comparison of Methane Emission by Different Cultivation Systems

Results from the factorial analysis between cultivation systems indicated that the CH_4 emission is affected by the different rice cultivation systems in both locations in Bachok and Kadok. The SRI rice cultivation technique was found to produce 64% lower CH_4 emission with an average value of 3.06 mg/m^2/hr compared to the conventional method with an emission of 8.47 mg/m^2/hr in Bachok, while the SRI technique in Kadok recorded 63% lower with a value of 2.90 mg/m^2/hr compared to conventional techniques that emit more CH_4 with a value of 7.90 mg/m^2/hr (Figure 3). This proves that the practice of SRI rice cultivation is a method that contributes less to the emission of CH_4 gas into the atmosphere which can cause global warming. Similar results were also found by Jain et al., (2014), SRI rice crops recorded a 61.1% reduction in CH_4 gas emissions compared to conventional rice cultivation using the local rice variety Pusa 44 in India while in Korea, GHG emissions from SRI plots reduced by 71.8% compared to that from the continuous flooding plot (Kim, Lee, Lee, Choi, & Ryu, 2012). The SRI rice cultivation technique approach involves the "Alternate Wetting and Drying" (AWD) irrigation system in paddy fields (Omwenga, Mati, & Home, 2014) which is considered an effective water-saving technology that is carried out in rice paddy conditions using limited water resources. Thus, SRI rice cultivation techniques are reported to be able to reduce the emission of methane gas which is a contributor to global warming.

Figure 3: Methane emission as affected by conventional and SRI Methods



Comparison of Methane Emission by rice plant age

This study also shows that the emission of CH_4 is also affected by the age of the plant without taking into account the differences in rice cultivation systems in Kadok. Rice plants aged 70 days after sowing (DAS) that emitted CH_4 gas amounting to 6.51 mg/m^2/hr recorded the emission of methane was higher than 100 DAS with a value of 4.56 mg/m^2/hr but did not show a significant difference from rice plants at the age of 40 DAS (5.14 mg/ m^2/hr). The same trend was also observed in the Bachok plot although the analysis showed no significant difference.

The same results were also recorded in a study by Baruah, Gogoi, & Gogoi, (2010) where the results showed that the highest CH_4 emission was recorded during the active vegetative growth phase and reproductive stage. The high emission of CH_4 at the reproductive stage is due to the higher availability of decomposed carbon resulting from decaying tissue which acts as an important carbon source for CH_4 production by supplying energy for microbial activity (Baruah et al., 2010). Holzapfel-Pschorn, Conrad, & Seiler, (1986) stated that about 90% of the total CH_4 emission from the entire growing season is reported to be produced during the flowering (reproductive) stage because the biomass of rice increases gradually and reaches a maximum during the rice flowering stage. This is related to this study where the results (Table 1) show that the highest CH_4 emission is at the reproduction stage, which is during the flowering phase. The breeding stage for rice plants which starts with the formation of stalks (panicles) until flowering is for 30 days which is 65 days after the formation of stalks until flowering 95 days after seed sowing or planting (Bhakta Shrestha, Sawano, Ohara, Yamazaki, & Tokunaga, 2019) where the rice variety MRQ76 flowers at 70 days after planting.

Table 1: Main and interaction effects of different cultivation methods on methane emission

Factor	**Emission of CH_4 (mg/m^2/hr)**	
	Bachok	**Kadok**
40 DAS	6.76 a^z	5.14 ab
70 DAS	6.60 a	6.51 a
100 DAS	3.94 b	4.56 b
Significant level	ns	*
CV (%)	42.26	27.35

**Significant at 5% probability level, ns: Not significant. ^{z}Means in each column with the different letters within each factor indicate significant differences at $P \leq 0.05$ level according to LSD (Mean ± S.E; n=3). DAS: Day after sowing.*

CONCLUSION

This study showed that methane emission was found to be affected by different cultivation systems or methods. The study revealed that the SRI method is efficient in reducing GHG emissions while also saving irrigation water from rice fields without affecting production. The agroecological approach or SRI technique recorded lower methane emission than the conventional method with 64% in Bachok and 63% in Kadok. The CH_4 emission peaks were found during the flowering phase and vegetative stage while the lowest was recorded during 100 DAS before the rice harvest. Therefore, the Agroecological approach or SRI technique could be a potential mitigation option for reducing greenhouse gases in the Malaysian rice cultivation system in the future. Farmers may be able to earn carbon credits through GHG mitigation using SRI agroecological method. Furthermore, reductions like those of the GHG emissions from the SRI plot in the current study could greatly aid in the government's goal of reducing national GHG emissions and mitigating global warming in the future. To fully examine the potential benefits of SRI in Malaysia, it is advised that thorough SRI research be conducted in the future.

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