UNIVERSITI PUTRA MALAYSIA

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By

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Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Agricultural Science in the Faculty of Agriculture Universiti Putra Malaysia

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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Agricultural Science

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October 2000

Chairman : Dr. Rosenani Abu Bakar

Faculty : Agriculture

This study was conducted with the main objective of studying the emission and production potential of methane (CH_4) from different soil types of wetland rice field and determining the controlling soil characteristics affecting methane production. The specific objectives are (i) to determine the best time in the day for manual sampling of CH_4 gas in the field, (ii) to measure CH_4 fluxes and total emission from three rice fields under field conditions, during the wet and dry seasons, and (iii) to determine the ability of some soils in Java to produce methane from its indigenous and added C source.

Two experiments were conducted. The first was a field experiment. Three top soils, classified as brown Regosol, red Latosol and dark brown Alluvial, were placed in a wooden micro-plots lined with plastic sheets and planted with IR 64-rice variety. The soils received continuous irrigation with 5cm ponding above the soil throughout the growing season. A (1m x 1m x 1m) plexi-glass chamber was placed on each of the micro-plots to measure daily CH_4 flux. The experiment was conducted

for two seasons i.e. dry and wet seasons. The Eh and pH changes were recorded regularly every four days.

Results of the experiment show that the emission of methane from the soils reached the highest peak at 40 days after transplanting (primordial stage). The emissions declined after they reached the early flowering stage, and drops to the lowest level until the plots were drained. There were no significant differences in grain yield between the three soils from two seasons of observation. Dark brown Alluvial (156.1 kg CH_4/ha/year) produced the highest emission followed by brown Regosol (142.2 kg CH_4/ha/year) and red Latosol (39.6 kg CH_4/ha/year).

Reducing CH_4 emissions while maintaining or enhancing yield requires information on CH_4 fluxes from a wide range of ecosystems and climatic zones. An optimal less-intensive sampling strategy with the use of manually operated chamber to measure daily CH_4 flux is required. Result from this study suggests that gas sampling using the chamber at 1100 h is the best time to represent the daily flux variation observed throughout the growing season.

The second study involved a laboratory experiment to determine the CH_4 production potential of 11 different rice soils. The soils were incubated in submerged condition for 52 days. Methane gas samples were taken every four days, and pH and Eh of the soils were also recorded. Soil physical and chemical properties were determined before incubation (particle size distribution, organic matter, bulk density, total N, total P, available and exchangeable K, Ca, and Mg, total and available SO_4, total and available Fe_2O_3, total Cu, and total and available MnO_2).

Results from this experiment show that soils categorized as dark-gray Grumosol gave the highest CH_4 production, while brown-grayish Grumosol gave the lowest. One of the soils experienced extreme drops of pH (3.5-4.0) after glucose addition i.e. gray Hydromorph association, which may have inhibited the methanogenic bacteria activities. Statistical analysis shows that the contents of Fe_2O_3>MnO_2 >SO_4 >pH >silt affected methane production.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains Pertanian

PENGARUH SIFAT-SIFAT TANAH KE ATAS POTENSI PENGELUARAN METANA DARI SAWAH PADI TANAH BASAH DI JAWA

Oleh

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Oktober 2000

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Kajian ini telah dilaksanakan dengan objektif utama iaitu mempelajari pancaran dan penghasilan metana (CH_4) daripada berbagai-bagai jenis tanah di kawasan sawah padi dan menentukan ciri-ciri tanah yang mempengaruhi keluaran CH_4. Objektif lebih khusus daripada kajian ini adalah (i) menentukan masa yang paling sesuai untuk persampelan gas secara manual, (ii) mengukur fluks CH_4 dan jumlah pancaran CH_4 daripada 3 tanah sawah padi dalam keadaan medan semasa musim kering dan hujan, dan (iii) menentukan keupayaan beberapa tanah sawah di Jawa untuk menghasilkan CH_4 dari sumber C semula jadi dan sumber tambahan C.

Dua percubaan telah dijalankan untuk kajian ini. Pertama adalah percubaan di ladang. Tiga jenis tanah iaitu Regosol coklat, Latosol merah dan Alluvium coklat tua, telah ditempatkan dalam plot kayu mikro yang lapik dengan lembaran plastik dan ditanami dengan padi variety IR 64. Tanah menerima pengairan berterusan dengan ketinggian air 5 cm semasa musim pertumbuhan. Kebuk "plexi-glass" berukuran 1m x 1m x 1m telah diletakkan pada setiap plot mikro bagi mengukur fluks harian CH_4. Perubahan Eh dan pH telah direkodkan setiap 4 hari sekali.

Hasil kajian ladang menunjukkan bahawa pancaran metana daripada tanah mencapai puncaknya pada masa 40 hari sesudah menanam. Pancaran metana berkurangan setelah mencapai tahap pembungaan awal, dan menurun kepada kadar paling rendah sehingga plot dikeringkan. Tiada perbezaan ketara hasil padi diantara ketiga-tiga jenis tanah dalam kedua-dua musim penyelidikan. Aluvium coklat tua (156.1 kg CH_4/ha/tahun) menunjukkan pancaran metana tertinggi diikuti Regosol coklat (142.2 kg CH_4/ha/tahun) and Latosol merah (39.6 kg CH_4/ha/tahun).

Strategi untuk mengurangi pancaran metana ketika mempertahankan atau mempertingkatkan hasil memerlukan maklumat mengenai fluks metana daripada ekosistem dan zon iklim. Sistem kebuk otomatik sangat mahal bagi tujuan mengukur fluks metana. Oleh itu, strategi persampelan dengan menggunakan kebuk yang dioperasikan secara manual masih lagi diperlukan. Hasil daripada kajian ini menunjukkan bahawa persampelan gas pada pukul 11.00 adalah terbaik dan tepat sekali bagi pengiraan fluks metana harian (mg CH_4 m^{-2} $hari^{-1}$)

Kajian kedua adalah kajian makmal, iaitu untuk menentukan potensi keluaran metana dari 11 jenis tanah. Tanah diinkubasi dalam keadaan terendam selama 52 hari, persampelan gas diambil setiap 4 hari sekali dan pada masa tersebut perubahan pH dan Eh tanah direkodkan juga. Tanah dianalisa secara fizik dan kimia sebelum diinkubasi (tekstur, bahan organik, ketumpatan pukal, N dan P total, K, Ca dan Mg tukar ganti, SO_4 total dan tersedia, Fe_2O_3 total dan tersedia, Cu total, dan MnO_2 total dan tersedia).

Hasil kajian menunjukkan bahawa tanah yang dikategorikan sebagai Grumosol kelabu tua menghasilkan metana paling tinggi, sedangkan Grumosol coklat kelabu adalah yang paling rendah. Ada tanah yang mengalami penurunan pH mengejut (3.5-4.0) setelah pemberian glukosa seperti pada Hydromorph kelabu. Keadaan ini dapat menghindar aktiviti bakteria metanogenik. Analisis statistik menunjukkan bahawa ciri-ciri tanah yang sangat mempengaruhi penghasilan metana secara turutan ialah Fe_2O_3>MnO_2,>SO_4>pH> kandungan kelodak.

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CHAPTER I

GENERAL INTRODUCTION

Methane is one of the main greenhouse gases that contribute to global warming. The atmospheric concentration of methane (CH_4), is increasing at the rate of 1% per year, which is more than doubled over the last two centuries. Prior to this, the atmospheric concentration of methane remained fairly constant, at least for the past 160,000 years (Schutz et al. 1989a).

The warming efficiency of methane is 20 to 60 times more effective in trapping heat in the Earth's atmosphere than carbon dioxide (Dickenson and Cicerone, 1986). An increase of 12 ppbv requires an excess of sources over sinks of 36 Tg/yr. Approximately 70% of the total global emission of atmospheric methane (500 $\pm$ 100 Tg/yr) comes from anthropogenic sources, mainly from anaerobic decay of organic matter in rice fields and enteric fermentation in ruminants, and about 30% comes from natural sources, i.e. the natural wetlands. As part of wetlands, rice fields are considered as one of the most important sources of methane emissions to the atmosphere. Estimates of methane emission from this source showed a wide range of 30-100 Tg/yr with an average of about 60 Tg/yr or around 18% of the total global emission.

Indonesian wetland rice fields cover an area of 8.5 million ha (irrigated and rainfed), or about 6.8% of the total world's wetland rice fields. The harvested area of rice in Indonesia in 1993 was 9.81 million ha of which 54% were located in Java

Island. Different estimations of total methane emission from Indonesian rice fields have been reported i.e. 5.8-9.8 Tg/yr by the Japan Environmental Agency and Ministry of Population and Environment of Indonesia (1992), 3.7-4.8 Tg/yr by Bachelet and Neue (1992), 2.9-3.7 Tg/yr by Mathews et al. (1991) as cited by Bachelet and Neue (1992), 3.2-5.8 Tg/yr by Taylor et al. (1991) as cited by Bachelet and Neue (1992) and 6.2 Tg/yr by Shearer and Khalil (1993). These wide ranges of methane emissions were based on extrapolations of methane flux data from other countries (temperate regions) or by an assumption that a fraction of net primary production (NPP) of rice plant is converted to methane. Accurate estimates of methane emissions from rice fields are difficult to calculate due to the lack of experimental data on methane fluxes. In all cases published figures were based on fluxes that were measured from rice fields in specific areas such as in temperate regions and then extrapolated to global environment. This extrapolation, in fact, could give an overestimate or probably an under-estimate of potential methane emission.

Since 1993 research work had been conducted by Indonesian scientists to predict the total emission per annum from Indonesian rice fields (Nugroho et al. 1996; Netera et al. 1995; Lumbanraja et al. 1996; Setyanto and Makarim, 1994; Makarim et al. 1996). Studies were done in-situ and the data obtained were used to extrapolate to a wide range of rice areas using models or mathematical approaches. Yet there were still differences between the estimates of actual emission rates from Indonesian rice fields. These observed variations are due to contribution of many variables such as soil properties, temperature, agricultural practices, types and rates of fertiliser (mineral and organic) application and water management.

Since the first measurements of methane emission from a Californian rice field (Cicerone and Shetter, 1981), numerous studies have been made and they showed that methane emissions from rice fields are influenced by climate, organic amendments, water regime, rice variety, fertiliser application and soil characteristics. To develop a more accurate estimation of methane emission, the uncertainty of the factors that affect the formation of methane from rice fields needs to be narrowed to have a reliable global methane budget. Soils, as part of the uncertainties, need to be highlighted, because it is one of the key factors, which play an important role in methane production and emission. However data on methane emission from different soil types are lacking when compared to data on agronomic practices.

1.1 Objectives

Improving rice cultivation system in Indonesia is essential in order to increase rice production and maintain national rice self-sufficiency. Environmental, issues related to global warming such as methane emission from rice fields should also be given serious attention. In order to achieve this, intensive study on methane emission, the process of its production and options of mitigation must be conducted.

This study was carried out with the main objectives of studying the emission and the production potential of methane from different soil types of wetland rice fields and to determine the controlling factors affecting the methane production.

CHAPTER II

LITERATURE REVIEW

2.1 The Greenhouse Effect

The fundamental process driving the climate system is (1) heating by incoming short wave solar radiation, and (2) cooling by long wave infrared radiation into space (Figure 2.1). The average global temperature is determined by the equilibrium between incoming energy from the sun and outgoing energy as heat from the earth. Part of the outgoing infrared radiation is trapped by radiactively active gases, the so-called greenhouse gases, in the lower atmosphere and then re-emitted. This process, generally referred to as the greenhouse effect, adds to the net energy input of the lower atmosphere and thus leads to an increased global temperature. The absorption of radiation emitted from the earth's surface by greenhouse gasses has been demonstrated with satellite measurements. In fact, the greenhouse effect is highly appreciated since the mean global temperature of the earth would be -18°C without the greenhouse effect, making life virtually impossible. The concentrations of greenhouse gases are increasing since pre-industrial times due to human activities. This is likely to cause an enhanced greenhouse effect (Denier van der Gon, 1996).