学 位 論 文 要 旨

Influence of gypsum application on methane production and emission from saline paddy soils in relation to growth and root exudation of rice plants
石膏施用した塩類水田土壌におけるイネの生育と根浸出物がメタンの生成および放出におよぼす影響

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Paddy rice fields are identified as one of the major sources of global warming methane (CH_4) gas. However, the extent of CH_4 emission is largely influenced by the soil condition to which rice is planted and management practices associated with rice cultivation. Among the world total rice areas, about 30% contains too high levels of salts for normal rice growth. In general, soil salinity is caused by occasional or periodic intrusion of sea water, or by surface evaporation of soil water initially high in salt content. Thus, CH_4 emission from rice cultivation was evaluated under irrigation water salinity and saline soil. To improve the rice growth in Na^+ saturated soil or water, gypsum fertilizer application is one of the common practices. Therefore, the effect of gypsum fertilizer addition to saline condition on CH_4 emission was also studied in relation to rice growth.

In chapter (2), CH_4 production potential of soil was evaluated under five different irrigation water salinity levels; 0, 10, 30, 60 and 90 mmol L^{-1}NaCl for 3 weeks. The addition of NaCl up to 30 mmol L^{-1} increased in CH_4 production. At salinity levels such as 60 and 90 mmol L^{-1}NaCl, CH_4 production was 19 to 33% lower compared to control. The salinity levels such as 30 and 90 mmol L^{-1}NaCl which showed maximum and minimum CH_4 production were selected and studied in rice cultivation with or without gypsum fertilizer addition. It was conducted as pot experiment. The continuous application of saline water significantly suppressed the rice growth at both salinity levels. The rice plants in salinity 90 mmol L^{-1} could survive until 7 weeks after transplanting. The higher total numbers of dead leaves were observed in saline condition with or without gypsum fertilizer addition. The CH_4 emission in salinity level 30 mmol L^{-1}NaCl without gypsum fertilizer (296 kg CH_4 ha^{-1}) was not significant different with that of control (316.2 kg CH_4 ha^{-1}). The lowest CH_4 emission was observed in salinity 90 mmo L^{-1}NaCl (44.2-55.5 kg CH_4 ha^{-1}). Gypsum fertilizer addition reduced CH_4 emission either in saline or non-saline condition. The reduction rate due to gypsum fertilizer addition was about 53-83% in saline condition and about 56% in non-saline condition.Thus, the effect of different rates of gypsum fertilizer addition in to rice cultivation on CH_4 emission was evaluated in chapter (3) with pot experiment. The gypsum application rates were 0, 1, 2.5 and 5 ton ha^{-1} and irrigation water salinity levels were 0 and 25 mmol L^{-1}NaCl. The results showed that the irrigation of water with salinity level 25 mmol L^{-1}NaCl could not suppress CH_4 emission. Higher application of gypsum resulted in higher reduction in CH_4 emission. However, the reduction of CH_4 emission due to gypsum fertilizer addition was higher in non-saline condition than saline condition.

As saline soil is composed of a range of dissolved salts such as NaCl, Na_2SO_4, $MgSO_4$, $CaSO_4$, $MgCl_2$, KCl, and Na_2CO_3, CH_4 emission was also studied in coastal saline soil in chapter (4). The coastal saline soil was collected from the tsunami flooded paddy field in Sendai city, Tokyo, Japan. Three different rates of gypsum fertilizer such as gypsum 0.5, 1 and 2 ton ha^{-1} were applied to the coastal saline soil to provide the appropriate Na/Ca ratios in the soil. Methane emission was evaluated during vegetative stage for 30 days. Gypsum fertilizer addition significantly reduced the soil pH and increased the soil EC. However, the increase in K^+ concentration of plants and decrease in Na^+ concentration of plants were observed in gypsum 0.5 and 1 ton ha^{-1}. The total organic carbon concentration in gypsum 0.5 ton ha^{-1} was the highest among the treatments at 30 days after transplanting. There was no significant difference in the shoot dry weight except gypsum 2 ton ha^{-1}. The significant highest CH_4 emission was observed in gypsum 0.5 ton ha^{-1} and the lowest CH_4 emission was observed in gypsum 2 ton ha^{-1}.

As organic acids in root exudation of rice plants are one of the carbon sources for CH_4 emission, organic acids concentration in root exudates were analyzed in chapter (5). Six organic acids species such as Citric, Tartaric, Malic, Lactic, Formic and Acetic acids were observed in the root exudates of control, gypsum 0.5, and 1 ton ha^{-1}. Only four organic acids species, Citric, Tartaric, Malic, and Lactic acids were observed in gypsum 2 ton ha^{-1}. Among the 6 organic acid species, Lactic acid exudation was the highest and the range of lactic acid exudation was observed as 3.9 to 7.9 µmol ml^{-1} root $tip^{-1}day^{-1}$. The minimum amount of exudation was observed in Acetic acid and the range of its exudation was found as 0.08 to 0.4 µmol ml^{-1} root $tip^{-1}day^{-1}$. Furthermore, the higher values of organic acid exudation potential were observed in gypsum fertilizer treatments over that control.