Geoderma Regional 7 (2016) 223–229

Contents lists available at ScienceDirect

Geoderma Regional

journal homepage: www.elsevier.com/locate/geodrs

Factors affecting methane emissions from rice production in the Lower Mississippi river valley, USA

Kristofor R. Brye [a,*], L. Lanier Nalley [b], Jesse B. Tack [c], Bruce L. Dixon [b], Andrew P. Barkley [d], Christopher W. Rogers [e], Alden D. Smartt [a], Richard J. Norman [a], Krishna S.V. Jagadish [f]

[a] Department of Crop, Soil, and Environmental Sciences, University of Arkansas, Fayetteville, AR, USA
[b] Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville, AR, USA
[c] Department of Agricultural Economics, Mississippi State University, Starkville, MS, USA
[d] Department of Agricultural Economics, Kansas State University, Manhattan, KS, USA
[e] Department of Plant, Soil and Entomological Sciences, University of Idaho, Aberdeen, ID, USA
[f] Department of Agronomy, Throckmorton Plant Sciences Center, Kansas State University, Manhattan, KS, USA

ARTICLE INFO

Article history:
Received 11 February 2016
Received in revised form 25 April 2016
Accepted 26 April 2016
Available online 28 April 2016

Keywords:
Rice production
Greenhouse gas emissions
Albaqualfs
Epiaquerts

ABSTRACT

Rice (*Oryza sativa* L.) plays a key role in sustaining global food security; however, rice production also accounts for a significant proportion of global methane (CH_4) emissions, a major greenhouse gas involved in altering global climate. Many previous studies have quantified the proportion of CH_4 emissions by independently evaluating factors such as soil texture and cultivars – an approach that has led to potentially biased estimates of their actual contribution to total emissions. Most of these studies have not considered the influence of the preceding crop or growing-season weather that could lead to a significant variation in carbon budgets. The main objective of this study was to identify the key edaphic, cultivar, and environmental factors and determine their proportional contributions towards CH_4 emissions in direct-seeded, rice-based cropping systems. A multiple regression model was developed to quantify CH_4 emissions as a function of temperature (both day and night independently and in combination) and other weather variables, soil (silt-loam-surface-textured Albaqualf and clay-surface-textured Epiaquert), cultivar (conventional and hybrid), and cropping system (rice-rice and soybean [*Glycine max* L.]-rice). Results showed that (i) the Albaqualf emitted 211% more CH_4-C than the Epiaquert ($P < 0.01$; (ii) inbred cultivars accounted for 55 to 70% more CH_4-C emissions than hybrid cultivars ($P < 0.01$); (iii) soybean-rice rotations produced 58% less CH_4-C emissions than rice-rice rotations ($P < 0.01$); and (iv) future warming scenarios increased CH_4-C emissions by up to 53%. To mitigate CH_4 emissions, future research and crop production strategies that prioritize rice production on clay-surface-textured soils and use alternatives to a rice-rice rotation are recommended.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Anthropogenic activities have resulted in an increase in atmospheric methane (CH_4) from 714 parts per billion (ppb) during the pre-industrial era to 1770 ppb at present (Philippot and Hallin, 2011). Though rice (*Oryza sativa* L.) plays a major role in sustaining global food security, rice production also accounts for a significant proportion of global CH_4 emissions, a major greenhouse gas involved in changing global climate. It has been reported that flooded-rice ecosystems account for approximately 20% of the total global CH_4 budget (Scheehle and Kruger, 2006; Philippot and Hallin, 2011). Methane emissions from flooded-rice cultivation have been shown to be affected by numerous soil and plant properties, particularly soil texture, soil management practices (Sass et al., 1994; Sass and Fisher, 1997; Brye et al., 2013), previous crop (Rogers et al., 2013, 2014), and cultivars selected (i.e., conventional versus hybrid; Lindau et al., 1995; Huang et al., 1997; Sigren et al., 1997; Ma et al., 2010; Rogers et al., 2014), among other factors, across a variety of production systems (USEPA, 2014). A diel (day and night) CH_4 emissions pattern has also been identified along with soil texture, air and water temperature, soil organic carbon, and cultivar contributing to overall CH_4 emissions from rice production (Aulakh et al., 2001; Zhan et al., 2011; Zhang et al., 2012; Yun et al., 2013).

In flooded-rice cultivation, up to 90% of the produced CH_4 is emitted into the atmosphere, with aerenchyma tissue acting as the flow path for emissions (Philippot and Hallin, 2011). The remaining CH_4 in the soil is often re-oxidized, defined as methanotrophy, into carbon dioxide (CO_2)

---

* Corresponding author at: Department of Crop, Soil, and Environmental Sciences, 115 Plant Sciences Building, University of Arkansas, Fayetteville, AR 72701, USA.
E-mail addresses: kbrye@uark.edu (K.R. Brye), llnalley@uark.edu (L.L. Nalley), jbtack@gmail.com (J.B. Tack), bdixon@uark.edu (B.L. Dixon), barkley@ksu.edu (A.P. Barkley), cwrogers@uidaho.edu (C.W. Rogers), adsmartt@uark.edu (A.D. Smartt), rnorman@uark.edu (R.J. Norman), kjagadish@ksu.edu (K.S.V. Jagadish).

http://dx.doi.org/10.1016/j.geodrs.2016.04.005
2352-0094/© 2016 Elsevier B.V. All rights reserved.

and released into the atmosphere (Philippot and Hallin, 2011). Methane emissions are differentially regulated by rice growth stage, with tillering generally associated with a greater proportion of CH_4 emissions (Satpathy et al., 1997; Jia et al., 2002). Methane emissions vary widely among rice cultivars such as hybrids, inbred lines, and conventional varieties (Aulakh et al., 2001; Jia et al., 2002). This variability is a result of physiological differences among cultivars in the transport capacity of CH_4 and in the methanogenic (i.e., production of CH_4) and methanotrophic activity in the rhizosphere (Aulakh et al., 2001; Jia et al., 2002). Using a multiple regression approach, previous research reported a strong, positive relationship between CH_4 production and rice-plant-mediated transport efficiency, as well as an inverse relationship with CH_4 oxidation in the rhizosphere (Jia et al., 2002).

Research on spatiotemporal (1990 to 2010) differences in CH_4 emissions from rice paddies in northeast China revealed that soils with a sandy-loam texture produce significantly greater CH_4 emissions relative to finer-textured soils due to greater soil porosity (Zhang et al., 2012). Researchers have documented that CH_4 emissions are lower in clay as compared to silt-loam soils in the United States (Brye et al., 2013). In addition to the required soil redox potential, methanogens, the facultative anaerobic microorganisms responsible for CH_4 production, also require a source of reducible C as substrate to drive CH_4 production during organic matter decomposition. Denier van der Gon and Neue (1995) reported that seasonal CH_4 emissions were positively correlated with added organic matter. Hence, the amount of added organic material or biomass (i.e., residue) returned to the soil from the previous crop grown in rotation with rice is an additional factor partially contributing to the control of CH_4 emissions. In the US, cultivated rice is most often grown in rotation with another crop, typically soybean (*Glycine max* L.), with or without a winter crop such as wheat (*Triticum aestivum* L.). In 2012, over 70% of the total rice production in Arkansas was in rotation with soybean, while the majority of the remaining rice was grown in a rice-rice rotation (Hardke and Wilson, 2013), while its soybean alone or in rotation with soybean and crawfish (*Procambarus clarkia*) in Louisiana (Street and Bollich, 2003) and rice-fallow or rice-rice rotation in California (Hill et al., 1992).

Methane emissions can also be influenced by changes in air, soil and/or water temperature (Satpathy et al., 1997; Zhan et al., 2011), with increasing soil temperatures increasing organic matter decomposition rates (Conant et al., 2011) and methanogenic microbial activity (Fey and Conrad, 2003). Air temperatures between 32 and 35 °C have been reported as optimal for maximum CH_4 emissions (Gaihre et al., 2013). In contrast, a two-fold increase in CH_4 emissions at temperatures beyond 35 °C has also been reported (Allen et al., 2003), indicating a lack of consistency in the literature regarding the effects of air temperature on CH_4 emissions. Furthermore, the diel pattern of CH_4 emissions and the rice plant's response to soil redox potential indicate a potentially strong relationship between CH_4 emissions and changes in atmospheric temperature and solar radiation. Emissions recorded on an hourly basis over a 24-h time period showed that maximum emissions occurred from 1400 to 1500 h, with minimum emissions occurring at midnight (Yun et al., 2013).

As emphasized above, the contribution of cultivar, soil characteristics, available organic substrate, and high temperature have been studied independently and identified as major determinants of CH_4 emissions from rice production. However, no study has systematically quantified the complexity involved in crop rotation and CH_4 emissions. Furthermore, most previous studies have reported actual CH_4 emissions rather than CH_4 emissions per unit of biomass or grain yield produced, which is a more indicative measure of ecosystem efficiency. To address the aforementioned knowledge gaps, and to quantify the determinants of CH_4 emissions, field data were compiled over the course of two years from a cropping system in eastern Arkansas containing both a legume (soybean)-cereal (rice) and a cereal (rice)-cereal (rice) rotation. Therefore, the main objective of this study was to identify the key edaphic, cultivar, and environmental factors and determine their proportional contribution towards CH_4 emission in direct-seeded, rice-based cropping systems. Additionally, a multiple regression model was developed to quantify CH_4 emissions as a function of temperature (both day and night independently and in combination) and other weather variables, soil (Albaqualf with a silt-loam surface texture and Epiaquert with a clay surface texture), cultivar (conventional and hybrid), and cropping system (rice-rice and soybean-rice).

2. Materials and methods

2.1. Field site description

Field research was conducted in 2012 and 2013 at the Rice Research and Extension Center (RREC) near Stuttgart, AR (34° 28′ N, 91° 25′ W) on a DeWitt silt loam (fine, smectitic, thermic, Typic Albaqualfs; NRCS, 2014) and at the Northeast Research and Extension Center (NEREC) at Keiser, AR (35° 40′ N, 90° 5′ W) on a Sharkey clay (very-fine, smectitic, thermic Chromic Epiaquerts; NRCS, 2014). The Albaqualf had 0.21 $g\ g^{-1}$ clay (Rogers et al., 2013) and the Epiaquert had 0.50 $g\ g^{-1}$ clay (Smartt et al., 2016) in the top 10 cm. At both locations, the study areas had previously been managed in a rice-soybean rotation for at least the past 15 years. The crop residues were typically disked into the soil to a depth of at least 7.5 cm, followed by land planning in the fall to achieve a flat seedbed to facilitate planting during the subsequent spring.

2.2. Plot establishment and treatments

Following procedures described by Rogers et al. (2013), replicated small plots 1.6 m wide by 5.0 m long were established to accommodate experimental treatments each year at each location. Each plot consisted of nine rice rows planted with a row spacing of 18 cm (Rogers et al., 2013). In 2012 and 2013 at the RREC, four replications of the standard-stature, pure-line cultivar 'Taggart', the semi-dwarf, pure-line cultivar 'Cheniere', and the hybrid cultivar 'CLXL745' (Rice Tec, Inc., Alvin, TX) were sown in adjacent bays following rice and soybean as the previous crop. In 2012 at the NEREC, four replications of 'Taggart' were sown following soybean as the previous crop, while in 2013, four replications of 'Taggart', 'Cheniere', and 'CLXL745' were sown into adjacent bays following soybean and rice as the previous crop.

Pure-line cultivars were seeded at a rate of 112 $kg\ ha^{-1}$ (Hardke and Wilson, 2013) and were fertilized in a split application of 118 (RREC, Albaqualf) or 152 (NEREC, Epiaquert) $kg\ N\ ha^{-1}$ with urea (46% N) onto dry soil at the four- to five-leaf growth stage. This fertilizer application was conducted 1 d prior to flood establishment, followed by the application of 50 $kg\ N\ ha^{-1}$ into the floodwater at panicle differentiation (Roberts and Wilson, 2012). Hybrid cultivars were seeded at a rate of 30 $kg\ ha^{-1}$ (Roberts and Wilson, 2012) and were fertilized in a split application of 134 (RREC, Albaqualf) or 168 (NEREC, Epiaquert) $kg\ N\ ha^{-1}$ with urea at the same time and in the same manner as the pure-line cultivars. This initial fertilizer application was followed by the application of 34 $kg\ N\ ha^{-1}$ into the floodwater at booting for both locations (Roberts and Wilson, 2012).

2.3. Methane measurements

Each year at each location, plots were outfitted with a 30-cm diameter, enclosed-headspace gas sampling chamber assemblage constructed out of 0.6-cm thick, schedule 40 PVC to facilitate gas sampling (Parkin and Venterea, 2010; Rogers et al., 2014). Each chamber assemblage consisted of i) a 30-cm long base collar, beveled at the bottom and pounded into the soil approximately 10 cm, with small holes drilled around the perimeter at 12 cm from the bottom to allow water flow in and out, ii) extensions of varying length depending on the height of the rice plants, and iii) a 10-cm tall, vented cap with a gray butyl-rubber septa (Voigt Global, part # 73828A-RB, Lawrence, KS) to

Download English Version:

https://daneshyari.com/en/article/4480774

Download Persian Version:

https://daneshyari.com/article/4480774

Daneshyari.com