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Biogeosciences
Discussions

Interactive comment on "Pathway of CH_4 production, fraction of CH_4 oxidized, and ^{13}C isotope fractionation in a straw incorporated rice field" *by* G. B. Zhang et al.

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We are grateful for the constructive and detailed expert comments of referee #3, which will help to improve our manuscript. In the following we will consecutively address each point raised and, if appropriate, will make suggestions how to change the manuscript.

Firsly, the referee #3 criticized that the sentences in the original manuscript were too long and redundant, and they were hard to find the logic clearly. So, we asked an expert for a full-scale revision, such as:

1. Sentences "Straw incorporation is regarded as a key practice in management of organic fertilizer in rice cultivation, and proved to be able to gradually improve soil

structure (Wang et al., 2010)..." (Page 14177, Line 8∼11 in the BGD) were changed to "Straw incorporation is regarded as a key practice in management of organic fertilizer in rice cultivation. Moreover, it proves to be able to gradually improve soil structure (Wang et al., 2010)...".

2. Sentences "Organic matter is fermented into acetate, CO2, H2, propionate as well as other fatty acids, while acetate, CO2 and H2 are the main substrates methanogenic bacteria use for production of CH4 (Krüger et al., 2002; Conrad et al., 2010)" (Page 14177, Line 22∼25 in the BGD) were changed to "Organic matter is fermented into acetate, CO2, H2, propionate as well as other fatty acids. However, acetate, CO2 and H2 are the main substrates methanogenic bacteria use for production of CH4 (Krüger et al., 2002; Conrad et al., 2010)"

3. Sentences "On the other hand, rice roots themselves not only excrete organic acid and slough off old or dead tissues as sources of carbon and energy for CH4 production, but also act as an important site in the rhizosphere where CH4 is oxidized by oxygen available from root secretion, which probably stimulates growth and activity of methanotrophs, and consequently increases the potential of CH4 oxidation." (Page 14178, Line 8∼13 in the BGD) were revised to "On the other hand, rice roots themselves not only excrete organic acid and slough off old or dead tissues as sources of carbon and energy for CH4 production, but also act as an important site where CH4 is oxidized by oxygen available from root secretion in the rhizosphere. Therefore, the growth of rice roots may probably stimulate growth and activity of methanotrophs, and consequently increase the potential of CH4 oxidation."

4. Sentences "CH4 produced in paddy soil usually has a high proportion being oxidized in the rhizosphere and at the soil-water interface, and then the remaining CH4 is emitted from the soil to the atmosphere mainly through the aerenchyma of rice plants." (Page 14179, Line 1∼4 in the BGD) were revised to "Usually a high proportion of the CH4 produced in the paddy fields is oxidized in the rhizosphere and at the soil-water interface. The remaining CH4 is emitted from the soil to the atmosphere mainly through

the aerenchyma of rice plants."

5. Sentences "The δ13C-value of CO2 produced in the paddy soil was relatively stable in the two treatments ($\sim$ –18‰ over the four rice growth stages, while the one on rice roots decreased obviously from the tillering and booting stages ($\sim$ –15‰ to the grain filling and ripening stages ($\sim$ –25‰ (Fig. 2c, f)." (Page 14185, Line 8$\sim$12 in the BGD) were changed to "The δ13C-value of CO2 produced in the paddy soil was relatively stable in the two treatments ($\sim$ –18‰ over the four rice growth stages. On rice roots, however, it decreased obviously from the tillering and booting stages ($\sim$ –15‰ to the grain filling and ripening stages ($\sim$ –25‰ (Fig. 2c, f)."

6. Sentences ". . .which probably increased the population and activity of methanogens on the surface of rice roots, thus increasing CH4 production (Fig. 2d)." (Page 14188, Line 11$\sim$12 in the BGD) were changed to ". . .which probably increased the population and activity of methanogens on the surface of rice roots. As a result, CH4 production was increased (Fig. 2d)."

7. Sentences ". . .and straw incorporation highly increased their CH4 production potentials at those periods, whereas a little was measured at the graining filling and ripening stages (Fig. 2a, d)." (Page 14188, Line 23$\sim$25 in the BGD) were changed to ". . .and straw incorporation highly increased their CH4 production potentials at those periods. However, a little was measured at the graining filling and ripening stages (Fig. 2a, d)."

8. Sentences "Since the temperature of incubation in this study was in the range from 17.6 °C to 29.7 °C and averaged 25.1 °C, αCO2/CH4 = 1.079 was hence considered to be reasonable for calculation of δ13CH4 (H2/CO2), which has been validated in other experiments (Zhang et al., 2011c, 2012)." (Page 14190, Line 21$\sim$24 in the BGD) were changed to "Since the incubation in this study varied in the range from 17.6 °C to 29.7 °C and averaged 25.1 °C in temperature, αCO2/CH4 = 1.079 was hence considered to be reasonable for calculation of δ13CH4 (H2/CO2). Fortunately, it has been validated in the other experiments we conducted (Zhang et al., 2011c, 2012)."

9. Sentences "A similar temporal variation was observed by Krüger et al. (2002) who reported that acetate-dependent methanogenesis was dominant at the end of the season, whereas H2/CO2-dependent methanogenesis was very important at the beginning of the season." (Page 14191, Line 11$\sim$14 in the BGD) were changed to "Similarly, Krüger et al. (2002) also found that acetate-dependent methanogenesis dominated the end of the season, whereas H2/CO2-dependent methanogenesis was very important at the beginning of the season."

10. Sentence ", thus increasing the CH4 oxidation capacity." (Page 14193, Line 5 in the BGD) was deleted .

11. Sentences "The fraction of CH4 oxidized (Fox) was calculated using. . ..., and results of the calculation are shown in Table 7" (Page 14193, Line 25 in the BGD) were changed to "The fraction of CH4 oxidized (Fox) was calculated using. . ..and shown in Table 7."

12. Sentences "Therefore, straw incorporation increases αox, which is probably ascribed to its stimulation of methanotrophic bacteria in the soil by promoting CH4 oxidation in Treatment WS relative to Treatment CK (Fig. 4a)." (Page 14196, Line 20$\sim$23 in the BGD) were revised to "Therefore, straw incorporation increased αox, which is probably ascribed to its promotion of CH4 oxidation by stimulating methanotrophic bacteria in Treatment WS relative to Treatment CK (Fig. 4a)."

Secondly, the referee #3 recommended us to supplement a conclusion in the manuscript. We agreed with the suggestion which was able to better demonstrate our original questions and the important findings. So, a discussion section (5 Conclusions) was added:

5 Conclusions

The study of biogeochemical mechanism of CH4 emission from a Chinese rice field demonstrated that straw incorporation obviously increased CH4 production and oxida-

tion potentials in paddy soil and on rice roots. What is more, the effect of straw incorporation on methanogenic pathways and fraction of CH4 oxidized was quantified by measuring stable carbon isotopic signatures. The results show that straw incorporation increased the contribution of acetate to methanogenesis in paddy soil, but decreased on rice roots, and acetoclastic methanogenesis was more important in the former than in the latter. Furthermore, the fraction of CH4 oxidized was significantly decreased by straw incorporation, which is likely ascribed to the fact that CH4 production potential was increased to a larger extent than CH4 oxidation potential was. This indicates that the production of CH4 increased directly by straw incorporation will indirectly reduce the fraction of CH4 oxidized, thus significantly decreasing CH4 emission from the rice fields. Although it may be difficult to estimate its exact effects on CH4 production and oxidation on a regional or a global scale, the variation pattern of methanogenesis being increased while the fraction of CH4 oxidized being reduced by straw incorporation is probably not changed. Certainly, more relevant investigations in different conditions should be done in the future.

This study also contributes another important question related to carbon isotope fractionation during the processes of CH4 oxidation and transport. Although it is very limited, to our knowledge so far, in paddy soil, the fractionation factor αox varied in the range of 1.025–1.038, which was well in agreement with previous reports on different soils. What is more, it was increased by straw incorporation, which probably resulted from the effects of straw incorporation stimulating methanotrophs and hence promoting CH4 oxidation in the soil. Difference between δ13C-values of the emitted and aerenchymatic CH4 indicates a fractionation factor εtransport of –12.0‰ to –8.0‰ which was to some extent controlled by straw incorporation. The reason is likely that the diffusion process in transport is affected by growth of rice plants and pressure in the rhizosphere, though the processes to cause the difference are not clearly known. As a traditional practice in the rice cultivation in China, straw incorporation is very important to the global carbon cycles involved in source and sink of the greenhouse gas CH4. Therefore, it is essential to contribute more efforts to the study on methanogenic and

methanotrophic microbial communities, and fractionation factors αox and εtransport to better elucidate the processes of CH4 emission from rice fields as affected by straw incorporation.

Thirdly, in order to more desirable to express the variables like soil Eh and isotopic composition, the referee #3 recommended us to change the modes of Fig. 1b, Fig. 2b-c-e-f, and Fig. 3b-d. Thanks very much! They were revised carefully, and we hoped that they could meet the requirement. Please see the attached files below.

Interactive comment on Biogeosciences Discuss., 9, 14175, 2012.

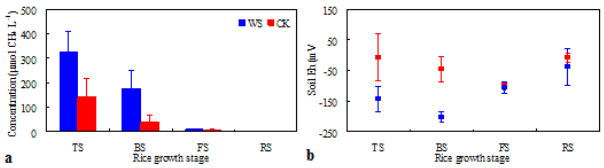
WS
CK
Concentration (nmol) CH4 L-1
Soil Eh (mV
TS
BS
FS
RS
Rice growth stage
a
b

Fig. 1.

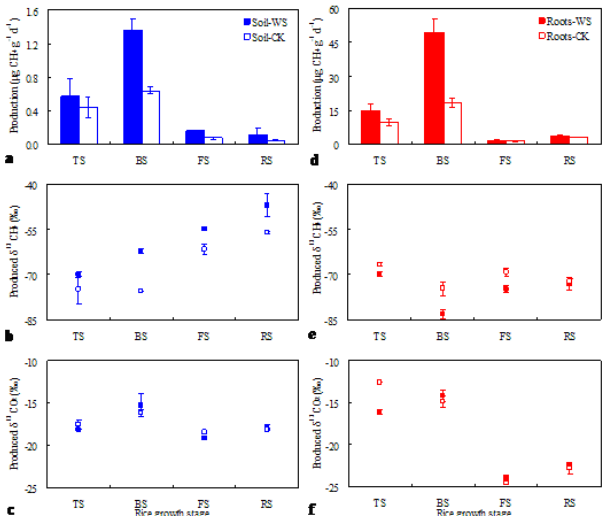
Soil-WS
Soil-CK
Roots-WS
Roots-CK
Production (μg CH4 g-1 d-1)
Produced δ13 CH4 (‰)
Produced δ13 CO2 (‰)
TS
BS
FS
RS
a
b
c
d
e
f

Fig. 2.

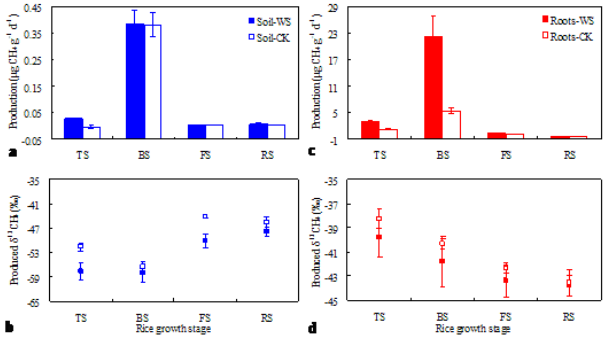
Soil-WS
Soil-CK
Roots-WS
Roots-CK
Production (μg CH4 g-1 d-1)
Produced δ13CH4 (‰)
TS
BS
FS
RS
Rice growth stage
a
b
c
d

Fig. 3.