Response to Reviewer Jun Shan

Thanks for your comments and suggestions. Please find our detailed answers below. Your comments are repeated in black, and our answers are in blue.

Comments from Reviewer

In this study, the authors claimed that rice straw could be incorporated into paddy soils by optimizing the straw rate and explained why the optimal rate minimized global warming potential mainly from the functional microbial perspective. The topic is interesting and well within the scope of SOIL journal. The MS is generally well-organized and well-written, and the methodology is sound. However, I have several comments to improve the quality of the MS. I recommend **major revision before acceptance**.

General comments

1. The first concern is about the title. The title is overstated. Investigating feasibility can include several aspects such as agronomic measures, soil types, climate regions, and land use, while the authors only focus on the rice straw rate and one paddy soil. I recommend reconsidering the title.

Response: The revised title is: *"Mechanisms of enhancing soil fertility without obviously elevating global warming potential under optimal rice straw incorporation rate in a paddy soil"*.

2. The authors used paddy soils from a long-term field to investigate GHG emission and microbial abundances. I acknowledge that the incubation approach has distinct advantages especially in elucidating the mechanism. The authors should claim more about why they chose to further conduct the microcosm experiment by following the field setting instead of directly sampling from the field.

Response: The reason for us to use microcosm experiment was aiming to precisely measure the dynamics of soil GHG concentration and emission and investigate the mechanisms under controlled environment. Because the conditions in the field (i.e., temperature, rainfall, and field managements) are variable, which can seriously affect the measurements, we could hardly achieve our study aims. So, the soils from the plots of a long-term field experiment with five-year rice straw incorporation were used for the microcosm experiment.

The reason for conducting the microcosm experiment was added (Line 75-77):

"Considering that field experiments can hardly avoid the influences of climate and other factors, and the advantages of microcosm experiment including controlled environment and high operability in frequent gas and soil sampling, …"

3. The authors should explain more about why they only focused on *nirS* and *nosZ*II while excluding their paired genes *nirK* and *nosZ*I. I suggest adding one or two sentences in the Method section to clarify this.

Response: We chose *nirS* and *nosZ*II was because they were reported to be more active than their paired genes of *nirK* and *nosZ*I in nitrite and nitrous oxide reduction processes, respectively, in paddy soils. As another referee suggested, we added the abundance data of *nirK* and *nosZ*I as Fig.S2.

4. The authors revealed that the soil has a holding capacity for CH_4 while not mentioning this for N_2O. From the concentration data, it seems soil did not hold N_2O at least not as long as CH_4. Why? It would be interesting if authors could explain a bit about this since the soil holds CH_4 while not holding N_2O may have implications for GHG mitigation strategy.

Response: Based on our observations, the soil showed a CH_4 holding capacity under anaerobic conditions. It would be related to weak anaerobic CH_4 oxidation activity and soil properties. The mechanisms for this phenomenon require further investigations. However, we did not detect such a result for N_2O. The possible reason would be linked to strong complete denitrification activities under anaerobic conditions, where N_2O reducers could efficiently reduce the produced N_2O. Therefore, N_2O could hardly accumulate and the holding capacity of N_2O was not detected.

5. Besides CH_4 and N_2O, CO_2 is also an important GHG as it contributed up to 45% to the GWP (Table 2). I recommend elaborating more on the mechanisms related to CO_2 in the Discussion part.

Response: The discussion was revised (Line 320-325) as follows:

"*It was detected that the CO_2 fluxes were positively related to the straw incorporation rate, and the higher input induced the higher CO_2 emission. Among straw–amended treatments, ST1 generated the lowest cumulative CO_2 flux, which was about 1.7 times of CK. This would be linked to the small amount of organic substrate for the soil microbial communities and the limited growth of microbial population (Miller et al., 2008; Li et al., 2022). Although the CO_2 emission of ST1 increased significantly compared to CK, its SOC content rose simultaneously, indicating this rate of straw returning was beneficial for the elevation of SOC*".

6. Please improve your English and check the grammar throughout the paper.

Response: We thoroughly checked and polished our grammar, syntax, coherence, and cohesion with the help of native speakers. Please refer to the tracked changes in the revised MS.

Specific comments

Line 55-56. "This study aimed to…, and the related mechanisms". I suggest rephrasing this sentence.

Response: This sentence was refined (Line 80-81): "*This study aimed to reveal the mechanisms of boosting soil fertility without elevating GWP under an optimal rice straw incorporation rate*".

Line 66. Please add the description about water management of the field experiment since water regime could have a legacy impact on GHG emissions. This information would be valuable for potential readers interested in relevant topics.

Response: We added the information about the water management of the field experiment (Line 91-94): "*All treatments were subjected to the same water management. During the rice season, all plots were continuously flooded except for two drying events. The first drying event occurred at the end of the tillering stage and lasted for one to two weeks. The second drying event happened one week before harvest. In the fallow season, all plots remained unirrigated*".

Line 77-83. You sampled the headspace gas in the chamber and then the soil gas in the silicone tube (see Line 96-100). For consistency, I suggest adjusting the order here: For gas flux sampling, … For soil gas sampling, …

Response: Reordered.

Line 84-85. "and each pot contained 1.27 kg (dry weight) of soil to reach about 10 cm in depth". I suggest revising this sentence.

Response: We revised this sentence (Line 116-117): "*Each pot was filled with wet soil to 10 cm in height containing 1.27 kg of dry soil*".

Line 99. What does "at the same time" mean? Did you sample headspace gas and soil gas simultaneously?

Response: This wording is inaccurate. We both sampled headspace gas and soil gas at each sampling time. During each sampling, we followed the order of "headspace gas"-"soil gas". We modified the text (Line 132-133): "*Immediately after collecting all of the headspace gas samples, 1 mL soil gas was taken from each buried silicone tube, followed by an equal volume of helium injected back*".

Line 193-195. The sentence is too long. Please revise it.

Response: The sentence was modified (Line 231-233): "*The dynamics of N_2O emission exhibited two distinct peaks, with one occurring shortly after fertilization and the other during the late drying period (Fig.1c). However, the variation patterns of the two peaks differed markedly both among treatments and between periods*".

Line 249. "similar" should be "similarly".

Response: Revised.

Line 266. It is inappropriate to use “fail to” here. We don’t expect an increase.

Response: The sentence was revised (Line 315-316): “*More importantly, ST1 treatment did not cause a significant increase in GWP compared to CK*”.

Line 291. I suggest deleting “with less than 5 $g \cdot m^{-2}$”. It is meaningless to point out the number here. The GHG cumulative emissions from microcosms are incomparable among studies.

Response: The sentence was revised (Line 348-349): “*Interestingly, the cumulative CH_4 emission from ST1 treatment remained low, whereas ST2 and ST3 sharply elevated the emissions to about 5 and 9 times that of ST1, respectively*”.

Line 293. Change “such a low” to “a much lower”, as the CH_4 cumulative emission should be only compared to the three other treatments in THIS study.

Response: The sentence was deleted following the suggestion from Referee #1.

Line 298-300. Grammatical errors. Please revise the whole sentence.

Response: The sentence was revised (Line 354-355): “*Soil CH_4 consumption would be strongly linked to soil CH_4 holding capacity (Ariani et al., 2022), as the retained CH_4 can be oxidized by methanotrophs*”.

Line 312-314. For now, the outlook could be more comprehensive. Consider revising this if possible.

Response: Here is the revised outlook (Line 369-370): “… *Therefore, the field tests with different soil types are necessary*”.