The Effects of different agricultural management measures on CH$_4$ emission from paddy fields in southwest Shandong Province

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Abstract: The field experiments were conducted on garlic stubble rice fields in southwestern Shandong Province. The experimental program was designed and the influence of different agricultural management measures on CH$_4$ emission flux and the factors affecting CH$_4$ emission were analyzed. The results show that although temperature affects CH$_4$ emissions from paddy fields, it is not the only influencing factor. Compared with submerged irrigation+no basal fertilizer method, the CH$_4$ emission flux of intermittent irrigation+basal fertilizer method is significantly larger; under the same submerged irrigation method, applying basal fertilizer is beneficial to CH$_4$ emission. In the submerged irrigation+basal fertilizer mode, tillering fertilizer is more conducive to methane emission than panicle fertilizer. The use of intermittent irrigation method to apply appropriate amount of base fertilizer and tiller fertilizer can effectively control the increase of rice yield and the reduction of CH$_4$ emissions in the rice field. The above operations can increase agricultural production and income and reduce greenhouse gas emissions.

1. Introduction

The greenhouse effect potential of methane is second only to carbon dioxide [1]. The sources of methane in farmland ecosystems mainly include two aspects. The first is the acid production pathway. The complex organic matter in the soil is decomposed under the action of microorganisms to produce organic acids with relatively simple structures. These organic acids are further degraded or used by methane bacteria to generate CO$_2$ and H$_2$, and finally methane is generated under the action of methane bacteria. The second is the non-acid production pathway, which refers to the microorganisms directly decomposing complex organic matter into CO$_2$ and H$_2$ and generate methane under the action of methane bacteria[2].

The concentration of methane in the atmosphere has increased at a rate of 0.8% per year in recent years [3-4]. CH$_4$, like CO$_2$, is also a greenhouse gas. The annual increase of CH$_4$ will adversely affect the temporal and spatial distribution and concentration of O$_3$ in the atmosphere. The destruction of the ozone layer may threaten the balance of the entire ecosystem. Therefore, it is imperative to control CH$_4$ emissions. China is a big rice producer. Studies have shown that excessive fertilization and unreasonable irrigation are the direct cause of excessive emissions of greenhouse gases in farmland, especially the large number of paddy crops and unreasonable field management in China, which greatly increase the emissions of agricultural greenhouse gas methane [5-6]. Fertilization is one of the important measures...
in rice production, and different fertilization amounts, fertilization methods and fertilizer types have significant effects on the growth and development and yield of rice at various stages [7-8].

2. Experimental Design
The garlic stubble rice field in southwestern Shandong Province is selected as the research object. The region has a warm temperate monsoon climate, with an average annual temperature of 13.3°C-14.6°C, and an average annual precipitation of about 520-850 mm. Six groups of experimental fields are selected, and the size of each experimental field is 16.0m×4.0m. There are 4 planting areas (size 2.0m×2.0m) in one group.

The planting layout of the six groups of experimental fields is shown in Figure 1.

The rice variety is YH hybrid rice with a growth period of about 126 days. The fertilization interval is the same, once every 20 days. The distance between plant and plant is 10-12 cm.

In Table 1, the base fertilizer used is pig manure, the pH is 8.06, the organic matter content is 26.8%, the total nitrogen content is 1.05%, the total phosphorus (P₂O₅) content is 2.63%, and the total potassium (K₂O) content is 0.34%. Sui Sui Huan (N-P₂O₅-K₂O, 8-4-24) is used as the panicle fertilizer provided by Wuhan Century JinHui Company.

The soil type of the tested paddy field was loamy clay, the pH was 7.2, the organic matter content was 1.58%, the total nitrogen was 0.076%, and the total phosphorus (P₂O₅) content was 0.39%.

From Test group B to test group E uses the submerged irrigation method, and it is synchronized with the irrigation of test group A and test group F. From planting to rice maturity, the rice field has always maintained a water environment. The experiment A and experiment F group kept the water before the rice tillering, and then adopted the intermittent irrigation method. Wait 4-6 days after natural drying before irrigating until the rice matures.
Tab.2. Experimental plots of different agricultural management methods

| Test field name | Base fertilizer/kg/hm² | Tiller fertilizer/kg/hm² | Ear fertilizer/kg/hm² | Irrigation method |
|-----------------|------------------------|--------------------------|-----------------------|------------------|
| Group A         | 0                      | 60                       | 50                    | Intermitten      |
| Group B         | 0                      | 60                       | 50                    | Submerged        |
| Group C         | 4380                   | 61.5                     | 50.5                  | Submerged        |
| Group D         | 6570                   | 75.3                     | 41.8                  | Submerged        |
| Group E         | 4380                   | 93                       | 32.4                  | Submerged        |
| Group F         | 4380                   | 60                       | 50                    | Intermitten      |

3. Sample Collection
The sampling box is made of stainless steel and is divided into upper and lower parts. The size of the sampling box is: 65cm×65cm×40cm. Sampling points must not be destroyed during sampling to prevent the sampling results from being affected.

Fig.2 Diagram of the device for collecting methane gas

After the sampling box is placed in the frame slot for a certain period of time, the gas in the first box is collected with a glass syringe, and the sampling time lasts for 30 minutes. A group has four sampling points, each sampling point is collected 12 times from 6:00-18:00 every day, and once every 0.5 hour; the average value of these four sampling points represents the CH₄ emission flux of the test field on that day. Therefore, one group collects 48 test numbers a day, a total of one hundred and six days, a group of 5088 data, and six groups a total of 30528 test numbers. According to the collection time and gas concentration of 48 samples, draw the linear regression method to obtain the linear slope dC/dt according to the following formula to obtain the methane emission flux.

\[ F = \frac{M \times P}{R \times T \times H} \times \frac{dC}{dt} \]

In the formula: M represents the molecular weight of CH₄. P stands for atmospheric pressure. T stands for absolute temperature. R represents the gas constant. H represents the effective height of the box.

4. Test items and Methods
Methane gas detection: The imported Shimadzu GC-2010PLUS chromatograph is used to detect methane gas. The chromatographic column is Rtx-5 0.32mm (ID), the carrier gas is argon, the carrier gas flow rate is 20ml/min, the column temperature is 40°C, the detector FID temperature is 180°C, and the sampler temperature is 100°C. Total nitrogen: determined by concentrated sulfuric acid digestion-Kjeldahl method. Total phosphorus: concentrated sulfuric acid digestion-ammonium vanadyl molybdate colorimetric method. Total potassium: concentrated sulfuric acid digestion-flame photometer determination. Organic matter: potassium dichromate volumetric method. Stem thickness: use vernier
calipers to measure.
    Plant height: Take the distance from the base of the rice to the top of the highest ear; measure it with
    a meter ruler. pH: Measured with DDSJ-3F pH meter, the water-soil ratio is 2.5:1.

5. Results and Discussion

5.1. The impact of different agricultural management methods on rice yield

| Test group | Stem thickness /mm | Plant height /cm | Soil pH (when transplanting seedlings) | Soil pH (when mature) | Rice yield/kg/hm² |
|------------|--------------------|------------------|---------------------------------------|----------------------|-------------------|
| Test A     | 4.02               | 82.3             | 6.52                                  | 7.53                 | 5236              |
| Test B     | 3.64               | 79.4             | 6.60                                  | 7.66                 | 4673              |
| Test C     | 4.20               | 86.9             | 6.83                                  | 7.63                 | 5567              |
| Test D     | 4.80               | 95.6             | 6.79                                  | 7.55                 | 6082              |
| Test E     | 4.62               | 84.7             | 6.72                                  | 7.49                 | 5763              |
| Test F     | 5.20               | 89.5             | 6.85                                  | 7.64                 | 6350              |

From the data in Table 3, we can see that different agricultural management methods have a certain
impact on rice yield. Experiment F group has the highest rice yield, 6350kg/hm², and stem thickness is
5.2mm. Experiment B group has the lowest rice yield, 4673kg/hm², stem thickness is 3.6mm. At
the same time, it also reflects that the application of basal fertilizer and the use of intermittent irrigation are
beneficial to the growth of rice [9], which is consistent with literature reports. The plants in the test D
group were higher than those in the test F group. This shows that the influencing factors of rice growth
speed are not single, and soil acidity and alkalinity have an impact on rice.

5.2. The impact of different agricultural management methods on methane emissions

From the comparison of methane emissions from experimental group A to experimental group F, it can
be seen that the use of submerged irrigation and additional organic fertilizers can promote methane
emissions to a certain extent. Because the intermittent irrigation method will make the soil have the
opportunity to contact the air, this method can promote the oxidation and reduction of the soil, thereby
destroying the life of the methane bacteria, and suppressing the methane emission in the rice. From
the rice output data, under the same basic fertilizer, the intermittent irrigation method has higher yield than
the submerged irrigation method. It can also be seen from Figure 8 and Figure 4 that the average CH₄
emission flux of the experimental group F reached 38.3mg/m²/h, the average CH₄ emission flux of test
group B only reached 15.6mg/m²/h. Therefore, adopting intermittent irrigation and applying basal
fertilizer to reduce CH₄ emissions has a certain effect on increasing agricultural income and production.

5.3. The impact of fertilizers on methane emissions

Test B group did not apply basal fertilizer, test C group applied basal fertilizer, test D group applied
basal fertilizer 1.5 times that of C group, test E group and C group applied the same basal fertilizer.
Comparison of methane emissions: Group D> Group E> Group C> Group B. It shows that applying
basal fertilizer can promote methane emission in rice fields; it also shows that under the same basal
fertilizer, tillering fertilizer is more conducive to methane emission than panicle fertilizer. The reason is
that in the presence of basal fertilizer, the activity of CH₄ bacteria increases and the release of methane
increases; ear fertilizer is beneficial to soil redox and inhibits the production of more CH₄ by methane
bacteria under anaerobic conditions.

5.4. The influence of temperature on methane emissions

It can be seen from Figure 3 to Figure 8 that the curve is a double peak. The height of these two peaks
is closely related to the growth and temperature of rice. The highest daily average temperature of the
The first peak was 28.6°C, and the lowest daily average temperature was 20.3°C. In such an environment, and the rice has just been transplanted, the soil contains a lot of organic matter during this period, and the rice grows rapidly, then the CH$_4$ anaerobic bacteria will quickly decompose the organic matter and produce a large amount of CH$_4$.

The second peak appears when the highest daily average temperature is 24.7°C and the lowest daily average temperature is 17.3°C. In such a low temperature environment, the activity of CH$_4$ bacteria is restricted. Rice is in the late stage of growth, and the organic quality is gradually reduced. CH$_4$ bacteria can only be decomposed by partially decomposed plant structure. At this time, the rate of decomposing plant structure is greater than that of decomposing organic matter, so the first peak is higher than the second peak. Different from literature reports, this may be because methane emissions are also related to rice types, soil types, water quality, regions, fertilizer types, and other conditions.

![Fig.3 Methane emission flux of test group A](image1)

![Fig.4 Methane emission flux of test group B](image2)

![Fig.5 Methane emission flux of test group C](image3)

![Fig.6 Methane emission flux of test group D](image4)
6. Conclusion

(1) Different agricultural management methods have a great impact on crop rice output. Compared with the submerged irrigation method, the intermittent irrigation method is more conducive to the growth of rice, so as to achieve the purpose of increasing production and income. This has certain practical guiding significance for agricultural management in the southwest of Shandong Province.

(2) Different agricultural management methods have a certain impact on methane emissions from rice fields. Compared with submerged irrigation, intermittent irrigation is beneficial to methane emissions from paddy fields. At the same time, applying basal fertilizer can also promote methane emissions.

(3) The comparison test B/C/D/E group shows that the application of basal fertilizer can promote methane emission in rice fields. Under the same base fertilizer, tillering fertilizer is more conducive to methane emission than panicle fertilizer.

(4) Temperature is one of the factors affecting methane gas emissions from paddy fields. Within a certain temperature range, the higher the temperature, the activity of CH$_4$ bacteria and the emission of methane are promoted. The lower the temperature, the activity of CH$_4$ bacteria will be restricted and methane emissions will be reduced. At the same time, the amount of methane emission is also related to the amount of organic matter in the soil and soil pH.

References

[1] Wang Mingxing, Zhang Renjian, Zheng Xunhua. Sources and sinks of greenhouse gases[J]. Climatic and Environmental Research, 2000, 5(1): 75-79.

[2] Li C S. Modeling trace gas emissions from agricultural ecosystems[J]. Nutrient Cycling in Agroecosystems, 2000(58): 259-276.

[3] Steinkamp R, Butterbach-Bahl K, Papen H. Methane oxidation by soils of an N limited and N fertilized spruce forest in the Black Forest, Germany[J]. Soil Biology and Biochemistry, 2001(33): 145-153.

[4] IPCC. Climate change 2007-impact, adaptation and vulnerability[M]. Cambridge, UK and New York, USA: Cambridge University Press, 2007, 750-752.

[5] Cheng Yanmei. Discussion on farmers' income increase and agricultural management in rural economy[J]. Southern Agriculture, 2018, 12(24): 95-97.

[6] Ding Yuding. Discussion on the issue of farmers' income increase in rural economy and agricultural management research[J]. Nongjiashui Consultant, 2017(8): 147-150.

[7] Chen Qingchun, Li Ming, Zhu Qiuming, et al. Effects of combined application of organic fertilizer and inorganic fertilizer in different proportions on rice growth and yield. China Rice, 2018, 24(05): 105-109.

[8] Li Kaixu, Lu Jianwei, Lu Mingxing, etc. The effect of different special formula fertilizers on rice
yield, nutrient absorption and economic benefits. China Agricultural Science and Technology Review, 2017, 19(01): 100-107.

[9] Li Bo, Wei Yafeng, Xue Yaguang, et al. The effect of basal application of organic fertilizer instead of inorganic nitrogen tiller fertilizer on rice yield and growth. Chinese Agricultural Science Bulletin, 2018, 34(04): 21-26.