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Characteristics of Greenhouse Gas Emissions from Alpine Farmland in Qinghai Province

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Abstract: In order to better study the effects of fertilizer application on alpine farmland in Qinghai Province, the effects of fertilizer application on greenhouse gas (CH4, CO2 and N2O) emission fluxes and global warming potential of alpine farmland were studied by static chamber-meteorological chromatography method by static chamber chromatography method, and the trend of greenhouse gas emissions from alpine farmland in Qinghai Province was further analyzed. The results showed that the total CO2 emissions of each treatment increased by 24.75%, 1.5N and M by 24.75% and 74.21% compared with CK. Appropriate application of nitrogen fertilizer reduced N2O emissions, and the total emissions of treated N decreased by 48.59% compared with CK. The overapplication of nitrogen fertilizer promoted N2O emissions, and the total emissions increased by 49.56% compared with CK treatment. The application of organic fertilizer can effectively reduce N2O emissions, and the total emission of M treatment is reduced by 97.41% compared with CK. The application of nitrogen fertilizer and organic fertilizer could promote CH4 emissions, and compared with CK, treatment N increased by 70.25%, treatment 1.5N increased by 143.31%, and treatment M increased by 159.58%. Compared with the treatment of CK, the GWP of treatment N, 1.5N and M increased by 175.46%, 341.59% and 445.36%, respectively. The results showed that the application of nitrogen fertilizer and organic fertilizer could promote greenhouse gas emissions, and the degree of promotion treatment M > 1.5N > N > CK. The global warming potential is mainly due to CO2 and CH4, while the contribution rate of N2O is less than 0.5%.

Keywords: Greenhouse Gases; Nitrogenous Fertilizer; Global Warming Potential

1 INTRODUCTION

China is a big agricultural country, with 1.918 billion mu of cultivated land. Qinghai Province belongs to the plateau continental climate, belongs to the Qinghai-Tibet alpine region, with low temperature, large temperature difference between day and night, less and concentrated rainfall, long sunshine, strong solar radiation, etc., farmland belongs to alpine farmland. Winters are cold and long, and summers are cool and short. Qinghai is located in the middle latitudes, with high solar radiation intensity and long sunshine time, with an annual total radiation of 690.8-753.6 kJ per square centimeter, direct radiation accounting for more than 60% of the radiation, and an annual absolute value of more than 418.68 kJ, second only to Tibet and ranking second in China. Qinghai has about 542,700 hectares of cultivated land, accounting for only 0.75% of the province's land.

Since 1750, the increase in the concentration of greenhouse gases produced by human activities has been the main cause of global warming [1-3]. The greenhouse effect is a key element in maintaining the earth's heat balance and creating livable conditions for organisms, and reducing greenhouse gas emissions is of great significance to control global warming. According to the Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC), excessive emissions of greenhouse gases have seriously harmed the earth's environment, and the global average temperature has risen by 1.1° C and will continue to increase [4].

Carbon dioxide (CO2), nitrous oxide (N2O), and methane (CH4) are the main greenhouse gases in the atmosphere [5]. The continuous increase in greenhouse gas emissions is the main reason for the intensification of global warming [6]. Agriculture accounts for 10%-12% of the world's total anthropogenic greenhouse gas emissions [7]. About one-fifth of the world's greenhouse gases come from agricultural emissions [8], and agriculture, as one of the main sources of global greenhouse gas

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emissions, has a significant impact on global warming [9-10]. As one of the world's largest agricultural countries, 11% of the UK's total greenhouse gas emissions come from agriculture [11], and agricultural carbon emissions continue to grow at an average annual rate of 5% [12]. At present, a large number of studies have been carried out on agricultural greenhouse gas emissions and related issues, including agricultural greenhouse gas emission accounting, emission reduction measures and potentials. Smith et al. [13] showed that the potential for reducing agricultural greenhouse gas emissions will reach 5.5×10^{9}-6.0×10^{9} t • in 2030 a^{-1} CO_2-e.

In agricultural production, nitrogen fertilizer application is the main source of soil nitrogen in farmland in China [14]. In recent years, the amount of chemical fertilizer input in China's agricultural production has increased rapidly, and the high-intensity application of chemical fertilizer has brought significant negative impacts on the ecology and environment. The nitrogen and phosphorus in farmland enter the receiving water body with surface runoff or infiltrate into the soil with groundwater, causing agricultural non-point eutrophication and serious soil pollution and non-point source pollution [15]. Nitrogen fertilizer has a significant effect on increasing yield, but it also affects greenhouse gas emissions from farmland such as CH_4, CO_2 and N_2O. CH_4, CO_2, and N_2O are the three main greenhouse gases that cause global warming, and dryland farmland soil is the main source of CO_2 and N_2O emissions, and its greenhouse effect cannot be ignored [16]. A large number of field experiments have shown that increasing the amount of nitrogen fertilizer can improve crop yields, but the application of chemical fertilizers in large quantities will produce too many greenhouse gases [17]. High nitrogen fertilizer application can enhance plant photosynthesis, stimulate root microorganisms, and enhance soil respiration, resulting in higher CO_2 emissions [18]. These results indicate that rational nitrogen application is of great significance to greenhouse gas emissions and crop yields [17].

According to the statistics of the Food and Agriculture Organization of the United Nations, the average amount of nitrogen fertilizer in China is 12.0% higher than that of the European Union, and the amount of phosphate fertilizer and potassium fertilizer is also 2.7 times and 1.0 times higher than that of the European Union, respectively. Although the amount of chemical fertilizer used in China is several times higher than that of the European Union, the yield of wheat in China is (5.2 $t\cdot hm^{-2}$) and the average EU production level (5.8 $t\cdot hm^{-2}$) compared with no significant increase. Excessive application of nitrogen, phosphorus, potassium and other chemical fertilizers is the main reason for the low fertilizer utilization rate, which will not only cause environmental pollution and resource waste in farmland, but also increase the cost of agricultural production [19].

On March 29, 2019, Qinghai Province determined the implementation of the "Overall Idea of the Provincial Implementation of Chemical Fertilizer and Pesticide Reduction and Efficiency Enhancement Action and the 2019 Pilot Program", promoted the application of organic fertilizer instead of fertilizer, and in order to better study the impact of fertilizer application on alpine farmland in Qinghai Province, taking spring wheat as the research object, the impact of fertilizer application on greenhouse gas (CH_4, CO_2 and N_2O) emission fluxes and global warming potential of alpine farmland was studied through field positioning experiments, and the trend of nitrogen and alpine greenhouse gas emissions in Qinghai Province was further analyzed It provides a theoretical basis for fertilizer reduction in alpine farmland in Qinghai Province.

2 MATERIALS AND METHODS

2.1 OVERVIEW OF THE STUDY AREA

The experimental site is located in the experimental site of Qinghai Academy of Agriculture and Forestry Sciences (36056'N, 101074'E, 2290 m above sea level) in Chengbei District, Qinghai Province, which belongs to the continental arid climate, with the average annual temperature, precipitation and evaporation of 5.9 ° C, 367.5 mm and 1180.9 mm, respectively, and the annual average sunshine hours, sunshine rate and total photosynthetic radiation are 2748 h, 62.8% and 612.5 $J\cdot cm^{-2}$, the soil is chestnut limestone.

2.2 EXPERIMENTAL DESIGN

Three nitrogen fertilizer application levels and one organic fertilizer application level were set in the experiment, as shown in Table 1, which were (1) blank control (CK), (2) nitrogen fertilizer alone (N), (3) high nitrogen fertilizer (1.5N), and (4) organic fertilizer application alone, and 4 replicates were set for each treatment level, with a total of 16 treatments. The test site is located in the experimental site of Qinghai University Academy of Agriculture and Forestry Sciences, Chengbei District, Qinghai Province, and the test wheat variety is Qingchun 38, and the planting mode is spring wheat continuous cropping. The wheat was sown on March 27, the basal fertilizer was sprinkled and pressed before the wheat was sown, and the top dressing was applied with irrigation at the wheat tillering stage.

TABLE 1 FERTILIZER APPLICATION IN THE EXPERIMENTAL PLOT

Treatment	N/	Organic fertilizer (kg·acre-1)	Ground fertilizer (g·27.5m-2)			Additional fertilizer
	(kg·acre-1)		Urea	Calcium superphosphate	Organic fertilizer (kg)	Urea
CK	0	0	0	0	0	0

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N	8	0	50 0	0	0	0
1.5N	12	0	31 0	0	0	770
M	0	2000	0	0	80	0

2.3 INDICATOR MEASUREMENT

2.3.1 GAS SAMPLE COLLECTION AND ANALYSIS

The gas sample was collected by using a fully automatic gas collector to sample four times after the static chamber was sealed, the air in the chamber was mixed for 10 s before each sampling, the gas was extracted for 10 s, and the next sampling was carried out after an interval of 480 s. The sampling times were 10 s, 510 s, 1010 s, and 1510 s, respectively. Immediately after sampling, they are brought back to the laboratory and the concentration of N2O, CO2, and CH4 in the collected gas samples is measured using a gas chromatograph.

The static chamber used in field trials consists of a stainless-steel base, a middle box and a top box. The base holds the bottom of the sampling chamber at a depth of 15 cm in the soil before planting, maintaining equilibrium with the soil surface and holding it in place throughout the growing season. The middle box is closed on all sides, the top box is closed on all sides and the top, the top box is equipped with a collection tube, and the base and the middle top box have a sealed water tank. The box is made of stainless-steel plate, in order to prevent the influence of the outside temperature on the temperature inside the box, the outer layer of the box is covered with foam board insulation and then wrapped with tin foil. Keep the three rows of wheat sampling boxes inside while installing the base. During the sampling process, the appropriate box combination was selected according to the growth height of the wheat.

GHG gas samples are expected to be collected 1-2 times before planting; Collected every 5-7 days after sowing; Collect 1 time after harvesting. Each sample collection was divided into four gas collections, each with an interval of 500 s. During the whole experimental sampling process, the sampling time was 9:00-11:00 (Beijing time) to reduce the diurnal variation of N2O, CO2, and CH4 emissions. Immediately after each sampling, the sampling box is removed from the base to reduce disturbance to the soil and crops.

Soil temperature and humidity were determined using TDR300 and recorded when the sample collection period was fixed for 9 min.

2.3.2 GREENHOUSE GAS EMISSION FLUXES AND TOTALS

Greenhouse Gas Emission Flux (GF) is calculated by the following formula:

$$\mathrm{GF} = \frac{\mathrm{dc}}{\mathrm{dt}} \times \frac{273}{\mathrm{T} + 273} \times \rho \times \mathrm{H}$$

GF – Greenhouse Gas Emission Flux (mg·m-2·s-1,μg·m-2·s-1）;

$\mathrm{dc}/_{\mathrm{dt}}$ ——The rate of change of greenhouse gas concentration in the static chamber per unit time (mg·m-3·s-1,μg·m-3·s-1）;

T - the temperature in the chamber (° C) at the time of sampling;

ρ ——Standard gas density (kg·m-3), CO2, N2O, and CH4 were 1.997, 1.34, and 0.716, respectively

H - the height of the sampling box (m), the value is 0.5 or 1 according to the actual situation;

Total Greenhouse Gas Emissions (TG) is calculated using the following formula:

$$\mathrm{TG} = \sum \left[\frac{(\mathrm{GF}_{\mathrm{i+1}} + \mathrm{GF}_{\mathrm{i}})}{2} \times (\mathrm{D}_{\mathrm{i+1}} - \mathrm{D}_{\mathrm{i}}) \right] \times \mathrm{k}$$

TG - Total greenhouse gas emissions (mg·m2) ;

GFi+1, GFi—GFi+1 and GFi were the greenhouse gas emission fluxes (mg •) at the ith and i+1 samples, respectivelym-2·s-1, μg·m-2·s-1）;

Di+1, Di-Di, and Di+1 are the times of i and i+1 samples, respectively.

k - unit conversion constant, CO2, N2O, CH4 values are 86400;

2.3.3 GLOBAL WARMING POTENTIAL OF GREENHOUSE GASES

Global Greenhouse Gas Warming Potential (GWP):

$$\mathrm{GWP} = \mathrm{TG} \times \frac{\mathrm{M}_0}{28} \times \mathrm{G}_{100} \times \mathrm{k}$$

GWP – global warming potential of greenhouse gases;

M0 - the molar mass of greenhouse gases, CO2, N2O, and CH4 are 44, 44, and 16, respectively;

G100 - the 100-year warming potential of greenhouse gases, CO2, N2O, and CH4 are 1, 256, and 28, respectively;

K - unit conversion constant, CO2, N2O, CH4 are 1, 0.001, 1 respectively;

The flux and total amount of greenhouse gas emissions were measured by static chamber-gas chromatography, and short-term and multiple measurements were carried out before and after fertilization, sowing and harvesting to analyze the changes of greenhouse gases.

2.4 DATA PROCESSING

Data processing, graph production, and statistical analysis were performed using Excel 2010, Origin 2017, and SPSS Statistics 23, respectively. All data are averages of independent measurements. Data were compared between groups using one-way and two-way ANOVA followed by LSD test. Compared with the control, the difference of $p<0.05$ was statistically significant.

3 RESULTS AND ANALYSIS

3.1 CHARACTERISTICS OF CHANGES IN

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GREENHOUSE GAS EMISSION FLUXES AND TOTAL AMOUNT OF DIFFERENT FERTILIZATION TREATMENTS

3.1.1 CARBON DIOXIDE (CO_2) EMISSION CHARACTERISTICS

The results of CO_2 emission fluxes in spring wheat under different fertilization treatments are shown in Figure 1. The CO_2 emission fluxes of different fertilization treatments showed a trend of first increasing and then decreasing, all of which began to increase significantly after entering the tillering stage on April 27, reaching the peak emission stage of each treatment from the jointing stage on May 27 to the middle of the flowering stage on July 1, the emission fluxes of each treatment began to decrease at the end of the flowering stage on July 8, and the CO_2 emission fluxes of different fertilization treatments decreased steadily after entering the fallow period on August 14, close to 0.1 mg·m-2·s-1. During the whole growth period of spring wheat, the average CO_2 emission flux was treated with M (0.22 mg·m-2·s-1) > 1.5N (0.18 mg·m-2·s-1) > N (0.16 mg·m-2·s-1) > CK (0.13 mg·m-2·s-1); During the fallow period from pre-sowing to post-harvest fallow period, the emission flux of treatment M was higher than that of other treatments, reaching a peak of 0.45 mg·· m-2·s-1; There was little difference between treated N and treated 1.5N before entering the jointing stage on May 27, and the fluctuation of treated N increased and then decreased, reaching a peak of 0.35 mg··on July 1 m-2·s-1, the treatment of 1.5N showed an M-type trend, reaching a peak of 0.37 mg·. on June 3 m-2·s-1, which reached a second peak of 0.36 mg··, on July 1 m-2·s-1; The fluctuation trend of treatment CK was similar to that of treatment N, which also reached a peak of 0.26 mg··on July 1 m-2·s-1, but the relative treatment N is more stable, and the mid-term trend of grouting on July 22 is basically compatible.

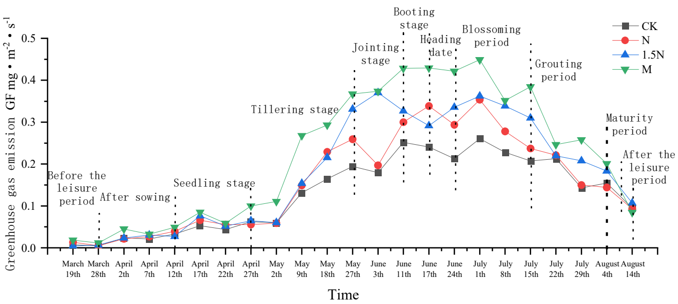

FIG.1 CHANGES IN CO_2 EMISSION FLUX OF SPRING WHEAT

The results of total CO_2 emissions from spring wheat under different fertilization treatments are shown in Figure 2. The total CO_2 emissions of spring wheat at different fertilization treatments showed an M-shaped trend as a whole, and the first peak was at the tillering stage, the first peak of 1.5N was at the jointing stage, and the second peak was at the flowering stage. During the whole growth period of spring wheat, the total CO_2 emission during the measurement period was treated with M (3064.04 g·m-2) > 1.5N (2531.52 g·.) m-2) > N (2194.13 g· m-2) > CK (1758.84 g· m-2); The total emission of M treatment was slightly lower than that of treatment 1.5 N at jointing stage, and higher than that of other treatments at other growth stages, and the total emission at tillering stage was 634.68 g·m-2, the total emission at the flowering stage was 727.94 g· m-2; There were significant differences between treatment 1.5N and treatment N only at jointing stage, flowering stage and grain filling stage, and the total emission of treatment 1.5N was higher than that of treatment N at each growth stage, and the total emission of treatment 1.5N at jointing stage was 483.48 g·m-2, and the total emission at the flowering stage was 619.17 g· m-2, the total emission of treatment N at tillering stage was 424.52 g· m-2, the total emission at the flowering stage was 524.54 g· m-2.

According to the analysis, the application of nitrogen fertilizer and organic fertilizer could promote CO_2 emissions, and the emission flux of each treatment increased by 20.15% compared with treatment CK, treatment N increased by 37.35%, treatment M increased by 37.35%, treatment M increased by 69.77%, and the total emission of treatment N increased by 24.75%, treatment 1.5N increased by 43.93%, and treatment M increased by 74.21% compared with treatment CK. The application of nitrogen fertilizer and organic fertilizer significantly increased the flux and total amount of CO_2 emission in spring wheat.

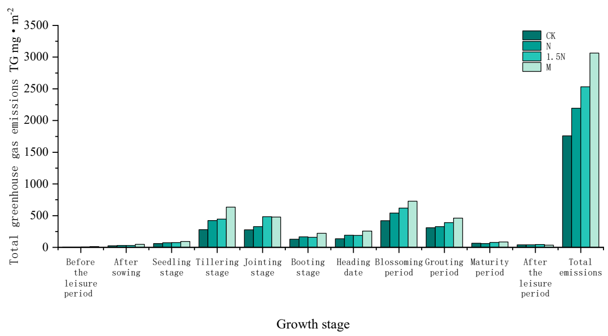

FIG. 2 CHANGES IN TOTAL CO_2 EMISSIONS FROM SPRING WHEAT

3.1.2 NITROUS OXIDE (N_2O) EMISSION CHARACTERISTICS

The results of N_2O emission flux in spring wheat under different fertilization treatments are shown in Figure 3. The trend of treatment CK was relatively stable, and there was a trough on June 3, with an emission flux of -0.075 μg·m-2·s-1; There was no significant fluctuation in treatment N, which was relatively stable below the 0 line, and the emission trough occurred on June 24, and the emission flux was -0.033 μg·m-2·s-1; The trend of treatment M was similar to that of treatment N, but there was a large fluctuation from May 2 to June 3, and the emission peak occurred on May 18, and the emission flux was 0.035 μg·m-2·s-1 showed a trough on May 27 with a emission flux of -0.033 μg·m-2·s-1; The emission trough of the treatment 1.5N occurred on April 27, and the emission flux was -0.088 μg·m-2·s-1, with a peak emission of 0.16 μg·, on July 1 m-2·s-1.

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During the whole growth period of spring wheat, the N2O emission flux during the measured period was 1.5 N (0.0047 μ g·). m-2·s-1) > M (-0.0024 μ g·m-2·s-1) > N (-0.0036 μ g·m-2·s-1) > CK (-0.0060 μ g·m-2·s-1).

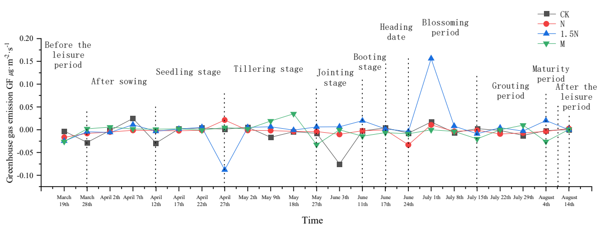

FIG.3 VARIATION OF N2O EMISSION FLUX IN SPRING WHEAT

THE RESULTS OF TOTAL N2O EMISSIONS FROM SPRING WHEAT UNDER DIFFERENT FERTILIZATION TREATMENTS ARE SHOWN IN FIGURE 4. THE OVERALL FLUCTUATION TREND OF TREATED K SHOWED NO OBVIOUS PEAK AND TROUGH, AND THE TOTAL EMISSION DURING THE WHOLE GROWTH PERIOD WAS 11.67 MG·M-2; COMPARED WITH CK, TREATMENT N FLUCTUATED MORE AND THE PERIOD SPAN WAS LONGER, REACHING THE PEAK EMISSION AT THE FLOWERING STAGE, WITH A TOTAL EMISSION OF 4.17 MG·M-2, THE TOTAL EMISSION TROUGH AT THE END OF THE GROUTING STAGE WAS -2.96 MG· M-2; THE TREATMENT OF 1.5N FLUCTUATED VIOLENTLY, SHOWING AN UPWARD AND UPWARD TREND, AND REACHED THE PEAK EMISSION AT THE TILLERING STAGE, WITH A TOTAL EMISSION OF 9.61 MG·M-2, WHICH REACHED A LOW EMISSION TROUGH AT THE FLOWERING STAGE, AND THE TOTAL EMISSION WAS -1.90 MG· M-2; THE CHANGE TREND OF THE TOTAL EMISSION OF TREATMENT M WAS SIMILAR TO THAT OF TREATMENT 1.5N, AND THE PEAK EMISSION REACHED AT THE TILLERING STAGE, AND THE TOTAL EMISSION WAS 4.07 MG·M-2, WHICH REACHED THE TROUGH AT JOINTING STAGE, WITH A TOTAL EMISSION OF -6.47 MG· M-2. DURING THE WHOLE GROWTH PERIOD OF SPRING WHEAT, THE TOTAL N2O EMISSION DURING THE MEASURED PERIOD WAS 1.5 N (17.45 MG·). M-2) > CK (11.67 MG· M-2) > N (6.00 MG· M-2) > M (0.30 MG· M-2).

The analysis showed that the appropriate application of nitrogen fertilizer could reduce N2O emissions, and the emission flux of treated N was reduced by 39.15% and the total emission was reduced by 48.59% compared with that of CK. The overapplication of nitrogen fertilizer would promote N2O emissions, and the emission flux increased by 179.44% and the total emission increased by 49.56% compared with that of CK. The application of organic fertilizer could effectively reduce N2O emissions, and the emission flux of M treatment was reduced by 59.56% and the total emission was reduced by 97.41% compared with that of CK.

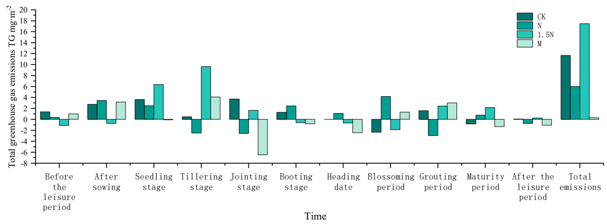

FIG. 4 CHANGES IN TOTAL N2O EMISSIONS FROM SPRING WHEAT

3.1.3 *METHANE (CH4) EMISSION CHARACTERISTICS*

The results of CH4 emission flux and total amount of spring wheat under different fertilization treatments are shown in Figure 5. There was no obvious trend in the total amount of CH4 emission in different treatments, but the average CH4 emission flux treatment was 1.5 N (0.0046 mg •) during the whole growth period of spring wheat m-2·s-1) > M (0.0016 mg·m-2·s-1) > N (-0.0024 mg·m-2·s-1) > CK (-0.0061 mg·m-2·s-1), total CH4 emission treatment M (63.31 g·m-2) > 1.5 N (46.02 g·.) m-2) > N (-31.62 g· m-2) > CK (-106.26 g· m-2). In general, the application of nitrogen fertilizer and organic fertilizer could promote CH4 emissions, and compared with CK, treatment N increased by 70.25%, treatment 1.5N increased by 143.31%, and treatment M increased by 159.58%.

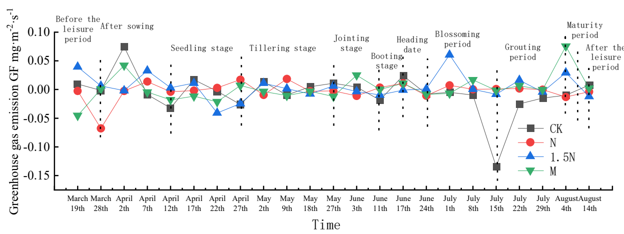

FIG.5 VARIATION OF CH4 EMISSION FLUX IN SPRING WHEAT

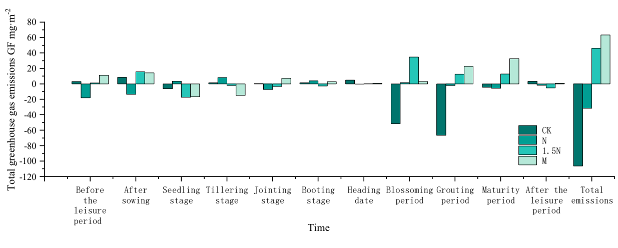

FIG. 6 CHANGES IN TOTAL CH4 EMISSIONS FROM SPRING WHEAT

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Since there was no obvious change trend in the emission flux and total amount of CH4 under different treatments, the CH4 concentration was analyzed on the day of measurement, and the results are shown in Figure 7. Overall, the CH4 concentration of different treatments showed a downward trend and decreased with the planting time, but increased from July 1 to July 29, that is, from the middle of flowering to the end of grain filling. The average concentration of CH4 in different treatments was 2.28 mg·Kg-1) > N (2.24 mg·Kg-1) > 1.5N (2.20 mg·Kg-1) > M (2.19 mg·Kg-1).

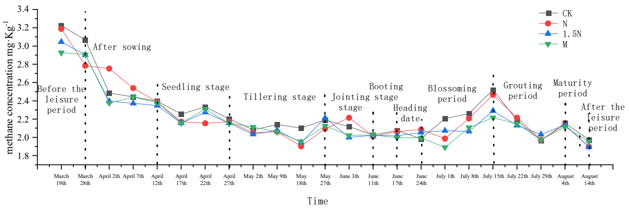

FIG.7 CHANGES IN CH4 CONCENTRATION IN SPRING WHEAT

3.2 *CHARACTERISTICS OF GLOBAL WARMING POTENTIAL (GWP).*

The 100-year warming potentials (G100) for N2O and CH4 were determined to be 265 and 28, and the GWP for N2O and CH4 is shown in Table 1. Compared with the treatment of CK, the GWP of N, 1.5N and M increased by 175.46%, 341.59% and 445.36%, respectively, of which the main contribution of GWP came from CO2 and CH4, while the contribution rate of N2O was less than 0.5%. Treatment 1.5N increased GWP by 60.31% relative to treatment N, but only 50% more nitrogen fertilizer was applied, so excessive application of nitrogen fertilizer would increase GWP excessively. The application of organic fertilizer promoted the emission of both CO2 and CH4, resulting in the GWP of treated M being 545.36% of that of treated CK.

Table 2 Global warming potential of CO2, N2O and CH4

Global warming potential				
	CK	N	1.5N	M
CO2	2763.90	3447.92	3978.09	4814.82
N2O	4.86	1.59	4.62	0.08
CH4	-1700.13	-505.84	736.30	1012.89
Summation	1068.63	2943.67	4719.018	5827.89

4 DISCUSSION

In recent years, farmland greenhouse gases have received extensive attention and attention, and in this study, the application of nitrogen fertilizer and organic fertilizer increased the CO2 emission flux and total amount of spring wheat farmland, which is consistent with previous studies [20-21]. Before the end of tillering on May 18, the emission flux and total amount of N and 1.5N CO2 were almost the same, and after topdressing at the end of tillering period, the emission flux and total amount of 1.5N CO2 treatment increased rapidly, which was also consistent with the results of this study. The CO2 emissions from spring wheat farmland were mainly due to soil CO2 emissions and wheat respiration. During the whole wheat growth process, the emission of CO2 emission fluxes peaked at the jointing stage and the flowering stage, because these two periods were the vigorous vegetative growth and reproductive growth of wheat respectively [22], and June, July, and August were the rainy seasons in Qinghai Province, and the increased rainfall promoted the activity of soil microorganisms and wheat roots, and the enhanced respiration increased CO2 emissions [23].. The number of secondary roots reached the highest before the heading stage [24], and after the heading stage, the wheat root system matured or died, and the respiration of wheat roots weakened, thereby reducing CO2 emissions, so the soil CO2 emissions gradually decreased from flowering stage to maturity stage.

Soil N2O is produced by nitrification and denitrification under aerobic and anaerobic conditions [25], which is regulated by many factors, such as soil moisture, temperature, pH, and other nutrients [26], and the agricultural practice that contributes the most to N2O emissions is the application of nitrogen fertilizers on farmland [27]. In this study, it was found that the emission fluxes of CK, N and M N2O treatments were similar and did not fluctuate violently, while the 1.5N treatment fluctuated violently at tillering stage and flowering stage, and the total N2O emission of 1.5N treatment was higher than that of other treatments, indicating that excessive nitrogen application significantly increased soil N2O emissions. The application of nitrogen fertilizer promotes nitrification and denitrification, and the application of organic fertilizer promotes mineralization [28]. Wheat growth and soil microbial activity deplete large amounts of nitrogen, reducing substrate nitrogen required for nitrification and denitrification processes [29], which in turn reduces N2O emissions. This study showed that treatment N reduced soil N2O emissions compared to CK, suggesting that appropriate nitrogen fertilizer application reduced soil N2O emissions, which is consistent with the results of other studies [30–31]. In addition, some studies have shown that soil N2O emission is positively correlated with NO3- concentration [32], and that soil nitrification and denitrifying bacterial abundance affect nitrification and denitrification processes [33], which in turn affects N2O emissions.

The results showed that both nitrogen fertilizer and organic fertilizer application promoted CH4 emission in spring wheat farmland, but the CH4 concentration in spring wheat field decreased with wheat growth. Methane is the end product of CO2 or organic carbon bioreduction under anaerobic conditions, mainly produced under flooded conditions. The emission of CH4 from farmland soil is constrained by a variety of factors,

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such as soil physicochemical properties (soil organic matter, temperature, water content, and pH), soil microorganisms, and agricultural management measures (fertilization and land use patterns) [34]. Temperature is an important factor affecting the seasonal variation of soil CH4 uptake flux, and with the increase of temperature, the activity of CH4 oxidizing bacteria increases, and the uptake flux increases[35]. There is a lack of research on the influencing factors of CH4 emission in spring wheat farmland, such as soil temperature and humidity, physical and chemical properties monitoring, etc., and should be more comprehensive and in-depth in future studies.

5 CONCLUSION

1. Compared with CK, the total CO2 emissions of each treatment increased by 24.75% for N and 43.93% for 1.5N, and 74.21% for M. The application of nitrogen fertilizer and organic fertilizer significantly increased the flux and total amount of CO2 emission in spring wheat.

2. Appropriate application of nitrogen fertilizer reduced N2O emissions, and the total emissions of treated N were reduced by 48.59% compared with CK. The overapplication of nitrogen fertilizer promoted N2O emissions, and the total emissions increased by 49.56% compared with CK treatment. The application of organic fertilizer can effectively reduce N2O emissions, and the total emission of M treatment is reduced by 97.41% compared with CK.

3. The application of nitrogen fertilizer and organic fertilizer could promote CH4 emissions, and compared with CK, treatment N increased by 70.25%, treatment 1.5N increased by 143.31%, and treatment M increased by 159.58%.

4. Compared with the treatment of CK, the GWP of treatment N, 1.5N and M increased by 175.46%, 341.59% and 445.36%, respectively, of which the main contribution of GWP came from CO2 and CH4, while the contribution rate of N2O was less than 0

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