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Effect of organic fertilizer on the greenhouse gas emission, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), produced from paddy field farming in Narsingh-Sunsari of Nepal.

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This research analyzed the effect of organic fertilizer on the greenhouse gas emission, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) that result from paddy field farming. Basmati-1 rice varieties were planted in Rice Research Center, Narsingh VDC Ward No: 3; Sunsari, District of Nepal. The paddy was divided into 4 plots, as follows: 1) control plots without added fertilizer, 2) plots with the addition of organic fertilizer (cow manure), 3) plots with the addition of organic fertilizer pellets and 4) plots with the addition of chemical fertilizers. The results showed that the carbon dioxide, methane and nitrous oxide emission rates in the chemical fertilizer plot were the highest at 534.11, 1.79 and 1.21 mg/m2/day, respectively. The second highest levels were with the addition of manure at 377.35, 1.35 and 0.88 mg/m^2/day, respectively. To help reduce greenhouse gas emissions from rice farming, it is recommended that organic fertilizer be utilized instead of chemical fertilizer, a practice that will also benefit the health of the farmers.

Keyword: Carbon dioxide, Methane, Nitrous Oxide, Chemical Fertilizer, Organic Fertilizer

1. Introduction

The ‘greenhouse effect’ means the increase of average air temperatures due to increases in the concentration of gases, which absorb heat radiation, through human activity. The six main types of greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro fluorocarbon (HFC), per fluorocarbon (PFC) and sulfur hexafluoride (SF_6) [1], which result from both industrial and agriculture activities. According to the report of The Greenhouse Gas Management Organization, which calculated the amount of greenhouse gases in the year 2000, Thailand, as an agricultural country, is a large contributor to the global greenhouse gas levels. The study showed that the amount of carbon dioxide emitted by the transportation sector was 229.08 million tons [2], constituting 69.9% of the total amount of greenhouse gases, whereas the agricultural sector ranked second for greenhouse gas production, contributing 22.6%. The report also found that paddy fields were the highest producers of greenhouse gases in the agricultural sector, accounting for 57.7% of total gases [1].

Greenhouse gases that are generated from paddy field activity include carbon dioxide, methane and nitrous oxide. The carbon dioxide from farming results from rice photosynthesis and respiration, the soil microbes and the loss of soil organic carbon. Because methane, per volume, more easily absorbs infrared rays than carbon dioxide, methane is the most prevalent greenhouse gas emission in the agricultural

sector, as it evolves under anaerobic conditions and through organic decomposition. Nitrous oxide results from the general use of nitrogen fertilizers, which decompose into nitrous oxide through the denitrification process caused by flooding [3].
Thus, this research focused on the use of organic fertilizers in paddy fields to reduce global warming by reducing greenhouse gas emission. The main issues of this study are to develop ways to reduce the contribution of paddy farming to global warming. The results of this study can be applied by the farmers in efforts to reduce greenhouse gas emissions from paddy farming.

2. Material and Methods

2.1 Experimental Design

2.1.1 Paddy Field Plot Preparations

Organic paddy fields belonging to Rice Research Center, Narsingh VDC Ward No: 3; Sunsari, District of Nepal., were used for the experiment. Each plot was 20x20 meters. Preparation of the area involved removing rice stubble, plowing to a depth not exceeding 30 centimeters and constructing a ridge in each plot to prevent the contamination or flooding from adjacent plots. Out-of-season rice was then planted by transplanting rice seedlings.

2.1.2 Seedling Preparation

Provided by NARC (National Agriculture Research Council), seeds of the Basmati-1 variety, which is uniform in seed size and weight, that were not contaminated and 80% sprouted were selected. The seeds were soaked in water for 12 hours then covered with gunny sacks for 2 nights. The seeds that sprouted were sowed into small plots, with a sowing ratio of 50 grams per cubic meter. The seeds were maintained for 25-30 days until the rice sprouted, and the seedlings were harvested and transplanted to the experimental plots.

2.1.3 Fertilizer Preparation

The fertilizers used included organic fertilizer (cow manure), which was obtained from non-contaminated sources, pellet organic fertilizer, and chemical fertilizer (formulas 16-20-0 and 46-0-0) that was purchased from the market of Janakpurdham, Dhanusha, Nepal. A random sampling of all of the fertilizers was performed to analyze for acid-forming or nonacid-forming properties, pH, moisture content, total nitrogen, the C/N ratio and total organic carbon.

2.1.4 Rice Planting and Maintenance

The rice planting was divided into 2 stages: the first stage was to plant seeds in small plots by sowing the paddy seeds and allowing them to sprout in approximately 25-30 days; the second stage was to harvest and replant into experimental plots. A water level of 5-10 centimeters was maintained throughout the experiment.

2.1.5 Fertilizer Application

The conditions for each experimental plot were as follows: 1) no added fertilizer; 2) organic fertilizer (cow manure) added during the plot preparation at a rate of 3.13 ton/ha, at 60 days after rice transplantation at a rate of 1.88 ton/ha and the addition of 1.25 ton/ha at the maturation and panicle-formation stages; 3) initially adding pellet organic fertilizer during the paddy field preparation at a rate of 0.13 ton/ha, adding pellet organic fertilizer at the vegetative stage at a rate of 0.13 ton/ha or after 60 days of transplanting the rice seedlings and adding pellet organic fertilizer at a rate of 0.06 ton/ha at the maturation stage and 4) adding chemical fertilizer, formula 16-20-0, during the initial stage at a rate of 0.19 ton/ha and adding chemical fertilizer formula 46-0-0 at a rate of 0.05 ton/ha at the vegetative stage and 0.05 ton/ha at the maturation stage.

2.2 Sample Collection and Analysis

The air was sampled during the following 5 stages: before planting, initial stage, vegetative stage, panicle-formation stage and maturation stage. Air samples were collected in a canister using the following sampling method. The chamber used was 0.6 meters wide, 0.6 meters long and 0.8 meters high, with an area of 0.29 cubic meters. Prior to the sampling period, the chamber was placed in the plots after the rice was planted, and an air pump was used to draw an air sample, which was stored in a sample bag. The air samples were analyzed for carbon dioxide and methane using gas chromatography (GC), and nitrous oxide was analyzed using flourier transform infrared spectroscopy (FTIR). The concentration of greenhouse gas was analyzed for flux using the following equation [4].

$$[F] = \frac{BVSTDxdCxMWx1000x60}{104x22400xAxdt} \quad \ldots\ldots\ldots (1)$$

$$[BV_{std}] = \frac{BVxB.P.x273}{(273+T)X760} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where,
F = Flux value for each gas ($mg/m^2/hr$)
BV = Volume inside the plastic box at a point located above the flooding level (cm^3)
B.P = Ambient Pressure at that time (mm Hg)
MW= Molecular weight for each gas
T = Temperature of the air in the box (^0C)
A = Cross Section of the box (m^2)
dC = Differential concentration of each gas at time zero and t (minute)
dt = Contact time (minute)

2.2.1 Statistical Analysis

Variation of carbon dioxide, methane and nitrous oxide emission data from the experiment was analyzed using ANOVA, and the differences of the data were compared using duncan's new multiple range Test (DMRT). The statistical analysis was implemented using statistical package for the social science (SPSS).

3. Results and Discussion

3.1 Quantity of Greenhouse Gas Emission

Different fertilizers were used for the experiment: organic fertilizer (cow manure), pellet organic fertilizer and chemical fertilizer (formulas 16-20-0 and 46-0-0). Both the organic fertilizer (cow manure) and pellet organic fertilizer, composed of nitrogen, phosphorus, and potassium (N:P:K), were expected to affect the greenhouse gas emissions due to agricultural activity. The overall analysis concluded that the carbon dioxide, methane and nitrous oxide were emitted at statistically significant differences ($P<0.05$). Detail of the greenhouse gas emission is shown in Table 1.

Table 1: Quantity of Greenhouse Gas Emission after Fertilizer Application in Plots

Plots	Emission of greenhouse gas ($mg/m^2/day$)		
	CO_2	CH_4	N_2O
C Plots	269.72±39.59**a**	1.20±0.16	$0.27±0.05^{a}$
A Plots	377.35±27.87**a**	1.35±0.3	$0.88±0.03^{ab}$
B Plots	272.56±33.3**a**	1.28±0.18	$0.42±0.04^{ab}$
R Plots	534.11±109.05**b**	1.79±0.28	$1.21±0.06^{b}$

Note: Mean ± SEM, n=3. Numbers followed by the same letter in each column are not significantly different at P<0.05 using DMRT.
C Plots = control plots without added fertilizer
A Plots = plots with the addition of organic fertilizer (cow manure)
B Plots = plots with the addition of organic fertilizer pellets
R Plots = plots with the addition of chemical fertilizer

3.2 Carbon Dioxide Emission

Paddy fields with the added chemical fertilizer emitted the most carbon dioxide gas, averaging 534.11 $mg/m^2/day$. The lowest was found in the paddy fields that contained added organic fertilizer (cow manure). The organic fertilizer pellet plot and control plot emitted carbon dioxide gas at rates of 377.35, 272.56 and 269.72 $mg/m^2/day$, respectively. The carbon dioxide emission rates were not statistically significant different; however, the results of this study indicate that the addition of fertilizer in paddy fields increases the carbon dioxide emission rates. The carbon dioxide emission is generated by organic decomposition in the soil under aerobic conditions. Hence, a high quantity of organic matter is an important factor in increasing carbon dioxide emissions, which corresponds to Tattao [5] who studied the total density of fertilizer by varying the ratio for agriculture: the N: P_2O_5 ratio was varied at a level of 9.6:9.6 and 28.8:28.8, and the results indicated that the soil density increases from 1.15 gram per cubic meter to 1.47 gram per cubic meter when the ratio is increased. When adding fertilizer to the soil, both the nitrogen and soil density will increase. In the present study, the quantity of carbon dioxide in each plot experiment found that carbon dioxide emitted through rice plant. The panicle-formation stage displayed the highest carbon dioxide level, after the plot with added chemical fertilizer, which had the highest carbon dioxide emission during the harvest period. This finding corresponds to Redeker's [6] research, which indicated that plants of the Chainat variety had the highest emission rate (539.6 mg/m^2/day) during the panicle-formation stage.

3.3 Methane Emissions

The methane emission quantity shows that adding fertilizer in each plot effected the methane emissions. The highest rate of methane emission occurred in the plot with the added chemical fertilizer and measured an average rate of 1.79 mg/m^2/day. The plot with the added organic fertilizer (cow manure) and organic fertilizer pellets emitted methane at the average rate of 1.35 and 1.28 mg/m^2/day, respectively. In addition, the control plot emitted the lowest methane level, at the rate of 1.20 mg/m^2/day. All of the methane emission rates in all of the plots showed differences that were not statistically significant. Most of the methane emitted by the paddy field was generated by the microbiological decomposition in the soil. It was also found that the rice in each growth stage has a statistically significant difference in the emission rate ($P<0.05$). When compared with the methane emission rate of each plot during the rice growth stages, we found that the rice in the vegetative stages had the highest emission rate, with a statistically significant difference ($P<0.05$). In addition, the plot with the added chemical fertilizer had the highest methane emission rate, at 3.03 mg/m^2/day. The ranking order for the methane emission rate is the plot with added organic fertilizer pellets, the organic fertilizer (cow manure) and the control plot, at 2.88, 1.68 and 1.03 mg/m^2/day, respectively. A similar study by Ying and Tai [7] evaluated the methane emission from pre-germinated direct-seeded lowland rice of different seed varieties combined with water management and chemical fertilizer addition during out-of-season rice growth. The results of the present study showed that the highest methane emission rate was generated during the plant growth between 16-40 days or by rice in the vegetative stage.

3.4 Nitrous Oxide Emission

The control plot, added organic fertilizer (cow manure) plot and organic fertilizer pellet plot emitted nitrous oxide at averages of 0.27, 0.88 and 0.42 mg/m^2/day, respectively. The plot with added chemical fertilizer emitted the most nitrous oxide during the rice season, at a rate of 1.21 mg/m^2/day. In addition, adding fertilizer increased the nitrous oxide emissions, a finding that was especially noted in the plot with the chemical fertilizer. The nitrous oxide emission was directly affected by the chemical fertilizer component, the N:P:K ratio of 16:20:0 and 46:0:0, which corresponds to Stevenson and Cole [8] who studied the use of fertilizer with a high nitrogen component in agriculture, reporting higher amounts of nitrous oxide emissions. Moreover, the comparison of the nitrous oxide emission rate during each rice growth stage found that the plants in the vegetative stage emitted the highest amount of nitrous oxide. In addition, newly germinated rice seedlings depend on large quantities of nutrients for strong and complete [9] growth. Hence, fertilizer formula 46-0-0 was added to the paddy field, and the results showed that the nitrous oxide emission was the highest during the vegetative stage because the high quantity of nitrogen in the fertilizer increased the nitrous oxide emission rate.

The application of fertilizer increased the greenhouse gas emission during rice cultivation. The plot with the added chemical fertilizer formulas, 16-20-0 and 46-0-0, which are considered appropriate for rice growth [10], increased some of the greenhouse gas emissions. The highest levels of carbon dioxide emission (36.74%), methane emission (31.85%) and nitrous oxide (43.53%) of the total greenhouse gas emissions during rice growth are illustrated in Table 2. The application of chemical fertilizer caused higher greenhouse gas emissions than the organic fertilizer because chemical fertilizers indirectly affect soil reactions, resulting in microbial changes that slow the decomposition of organic substances and increase the accumulation of organic substances in the soil. Moreover, the increase in organic substances contained in the soil raises the amount of methane that will be emitted [11]. In addition, the denitrification process will be initiated, whereby nitrate is converted to nitrogen gas under anaerobic conditions by microorganisms in the soil [12].

Table 2: Percentage of greenhouse gas emission

Plots	Emission of greenhouse gas (%)		
	Carbon dioxide	Methane	Nitrous oxide
C Plots	36.74	21.35	9.71
A Plots	25.96	24.02	31.65
B Plots	18.75	22.78	15.11
R Plots	18.55	31.85	43.53
Total	100	100	100

Note:
C Plots = control plots without added fertilizer
A Plots = plots with the addition of organic fertilizer (cow manure)
B Plots = plots with the addition of organic fertilizer pellets
R Plots = plots with the addition of chemical fertilizer

Therefore, to reduce greenhouse gas emissions due to paddy field farming, agriculturists should add organic fertilizer instead of chemical fertilizer, which would also afford benefits to the health of the agriculturists. However, it may be difficult for agriculturists to switch to organic fertilizer because chemical fertilizer results in good production and many individuals neglect to consider the negative effects on the environment. Based on this research, the highest rice production occurred under the treatment of added organic fertilizer (cow manure), and the remaining ranking order was paddy fields with added chemical fertilizer, pellet organic fertilizer and the control plots, respectively; the production for each field was 3.59, 3.34, 2.71 and 2.00 ton/ha, respectively. To promote the use of organic fertilizer, relevant agencies should provide information that is relevant to environmental effects and health impacts on both the producer and consumer. Moreover, such guidance for the reduction of greenhouse gases due to agriculture should be provided for acceptance by the agriculturist in addition to the consideration of rice production. Furthermore, agriculturists should be encouraged to utilize organic fertilizer, as it results in the reduction of greenhouse gas emissions from agriculture and is considered as part of the Clean Development Mechanism (CDM) for Nepal to reduce greenhouse gas emission. Additionally, organic fertilizer is more efficient in enriching the soil, promotes soil aeration and looseness and contains more and varied nutrients than chemical fertilizer

[13]. Furthermore, modifications of water management by adding a small amount of water and draining when the rice plants reach the vegetative stage and then allowing evaporation as a natural process complies with the study of Tsuruta and Hirose [14] and results in the reduction of methane and nitrous oxide production.

4. Conclusion

4.1 Effect of Fertilizer on the Quantity of Greenhouse Gas Emission

The quantity of greenhouse gas emitted from the experimental plots indicated that paddy field with added chemical fertilizer had the highest emission rates when compared to all of the plots. The greenhouse gases in this study were carbon dioxide, methane and nitrous oxide, and the emission rates were 534.11, 1.79 and 1.21 mg/m2/day, respectively. The plot with the added organic fertilizer pellets had the lowest emission rates of 272.56, 1.28 and 0.42 $mg/m^2/day$, respectively. The greenhouse gas emission rates for each gas type and paddy field were statistically significant ($P<0.05$).

4.2 Effect of Greenhouse Gas Emission during Rice Growth

The study of the greenhouse gas emission from the plots also compared each rice growth stage, with all of the fields emitting carbon dioxide mostly during the panicle-formation stage. Furthermore, during the vegetative stage, methane and nitrous oxide were mostly emitted by all of the plots; the drainage of water from the paddy fields after the vegetative stage resulted in decreased greenhouse gas emission in all of the plots. The lowest greenhouse gas emission rate for all stage was found prior to the harvest rice stage. The difference in each rice growth stage was statistically significant ($P<0.05$).

4.3 Guidance for the Reduction of Greenhouse Gas Emission from Paddy Field Farming

To reduce carbon dioxide, agriculturists should be encouraged to discard organic waste instead of burning, decrease plowing and provide mostly carbon dioxide in the carbon cycle in an organic form to slow organic decomposition and increase photosynthesis. For methane reduction, agriculturists should avoid adding large amounts of organic fertilizer, improve soil quality by increasing aeration and drain water from the paddies prior to the panicle-formation stage. For nitrous oxide reduction, farmers can add organic fertilizer instead of chemical fertilizer; however, organic fertilizer must also contain a low quantity of nitrate.

Finally, the application of organic fertilizer in agriculture, especially paddy field farming, would protect and conserve the environment through pollution prevention from non-point sources.

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