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Prosopis Wood Biochar on Reducing Greenhouse Gaseous (Co_2 and Ch_4) Emission from Agriculture Field

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ABSTRACT

Bio-materials are pyrolyzed to create biochar, a stable form of carbon. Because of its potential to boost crop productivity, reduce greenhouse gas emissions, and trap carbon in the soil, it is gaining attention on a global scale. Rice and maize were used as test crops in laboratory, pot, and field tests to assess the effects of biochar made from Prosopis wood on carbon dioxide (CO_2) and methane (CH_4) emission from the soil. The Prosopis wood biochar had an exchangeable acidity of 49 mmol kg-1 and a cation exchange capacity of 16 cmol kg-1, and its pH was neutral. The Prosopis-Biochar contained a significant amount of carbon (940 g kg-1). Under intermittent wetting and drying conditions, biochar application was observed to lower CO_2-C emission by 31 to 36%, and by 47 to 54% under continuous submersion. Additionally, it had an impact on the soil's CO_2-C emissions, which were decreased by 49%. in garden land soils. Due to the application of biochar, the C sequestration in garden land soil under maize ranged from 2644 to 5431 kg ha-1. When Biochar was added to the soil under submerged conditions at rates of 2.5 and 5 t ha-1, the CH_4 - C was reduced by 20% and 45.8%, respectively.The application of vermicompost and biochar together effectively reduced the CH_4 - C emission from the soil by 36.7 to 66.1%. Similarly to this, applying biochar reduces CH_4 - C emission under intermittent wetting and drying by 23.6 to 46.3% without any vermicompost and by 28.3 to 56.2% with vermicompost. The application of biochar has the inherent potential to increase crop output, decrease Co_2 and Ch_4 emissions, and sequester significant amounts of carbon in the soil.

Keywords: *Biochar, vermicompost, carbon, gaseous emission, nutrient content and crop output*

1. INTRODUCTION

By now, it has been established beyond a reasonable doubt that global warming is happening at a previously unheard-of rate (6). A large portion of agricultural areas' emissions to the atmosphere includes carbon dioxide (Co_2), methane (Ch_4), and nitrous oxide (N_2O). Plant litter burning or microbial decay, as well as the breakdown of organic materials in soil, are the main sources of carbon dioxide emissions. The average annual increase in these greenhouse gas (GHG) emissions during the past three decades was 1.6%, whereas the annual growth in Co_2 emissions due to the burning of fossil fuels was 1.9%.

The reduction of GHG emissions in agriculture can be accomplished in a number of ways. The main choices include better crop and land management (for example, better agronomic methods, nutrient use, tillage, and residue management), restoration of organic soils that are drained for crop production, and restoration of degraded lands.

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Black carbon (BC) continuum materials formed from plant biomass are commonly referred to as "biochar" (8). One of the biochar's distinguishing qualities is how well it retains nutrients and does so more efficiently than other organic matter like normal leaf litter, compost, or manures. For any soil bacteria that use biochar to colonize their environment, biochar serves as a source of reduced carbon compounds (organic molecules adsorb to the particle's matrix) (4). As a result, carbon entering the soil as char is a critical sink for atmospheric Co_2 and may be crucial for global carbon sequestration. Since biomass contains low-grade carbon, the carbon in it is easily degraded. Nevertheless, pyrolysis creates pyrogenic carbon in the biochar. Hence they remain in the soil for a long period. Therefore, the application of Biochar will lead to higher C sequestration in comparison to the application of equal amounts of non-charred organic matter.

Methane is generated when organic materials break down in an oxygen-deficient environment, particularly when fermentative digestion occurs in ruminant livestock, manures are stored, and rice is grown in wetlands. One of the main human-caused sources of methane emissions into the atmosphere is paddy fields, which are thought to account for 15% of all methane emissions globally (6). The usage and burning of fossil fuels increased methane emissions overall by nearly 40% from 1970 to 1990 (11% from 1990), whereas agricultural emissions were

roughly steady as a result of balancing decreases in rice production and increases in livestock production. Understanding the organic structural makeup of biochar is crucial for predicting its stability and reactivity when added to the soil. The biogeochemistry of the biomass feedstock and the pyrolysis conditions have an impact on the structural shape of carbon in biochar (9). While biochars with larger quantities of single-ring aromatic and aliphatic C will mineralize more quickly, biochars largely constituted of condensed aromatic C are known to persist in soil settings for millennia (9). This study applied biochar with and without vermicompost under various moisture conditions to paddy soil to assess methane emissions.
The pyrolysis of a Prosopis wood log was used to produce biochar for the current study, and its effects on CO_2 and Ch_4 emission from agricultural fields were assessed by a series of laboratory, pot, and field experiments.

II. MATERIALS AND METHOD

2.1. Preparation and characterization of Biochar and experimental soil

Pyrolysis of wood in a stainless steel retort yielded prosophis wood biochar, which was then heated in an electric furnace at a rate of 20°C per minute up to 600°C and maintained there for two to three hours until the created condensed liquid product was completed. In order to use the biochar for further study, it was ground and put through a 2mm sieve. Initial soil from the experimental field was collected and examined for significant traits in accordance with the prescribed protocol.

2.2. Closed laboratory incubation experiment

At the Wetland Farm of the Tamil Nadu Agricultural University in Coimbatore, bulk soil samples were collected, which were then air dried, sieved (2 mm), and described. The incubation investigation made use of 110 mm-diameter, one-liter glass preserving jars. A Terumo project rubber insert was installed in the lid to allow the insertion of two syringe needles: one for the inflation of a balloon and the other for the suspension of a glass vial (25 ml) containing 10 ml of 0.5 M NaOH inside the jar using nylon thread. 100 grams of soil were well blended with biochar at two different ratios of 5 and 10% (w/w basis).
Two distinct moisture regimes, namely alternating wetting and drying and submerged (flooded) conditions, were used to incubate the biochar-amended soil. On alternating days, the NaOH was periodically withdrawn, and the amount of CO_2 trapped was measured by back titrating with 0.1N HCl after adding excessive BaCl2.

2.3. Pot experiment with rice

The test crop for the pot experiment was rice. The following treatments were included in the experiment in triplicate, and the pots were set up in a randomized block design. A gas chamber was used to assess the soil's CO_2 emission at the active tillering stage (60 DAP).

a). Wetting and Drying: T1 –NPK alone :T2 – NPK + Biochar (10t ha-1) :T3 – NPK + Biochar (20t ha-1)
b). Submerged Condition: T4–NPK alone:T5 – NPK + Biochar (10t ha-1):T6 – NPK+ Biochar (20t ha-1)

2.4. Pot experiment with Maize

The following treatments, each with three replications, were implemented.

T1 – Absolute Control; T2 – NPK alone ;T3 – NPK + Biochar (2.5t ha-1) ;T4 – NPK + Biochar (5t ha-1) ;T5 – NPK + Vermicompost (5t ha-1) ;T6 – NPK + Vermicompost (5t ha-1) + Biochar (2.5t ha-1) ;T7 – NPK + Vermicompost (5t ha-1) + Biochar (5t ha-1)

2.5. Field experiment with rice

In a split-plot design with three replications, the experiments were conducted. Details of the treatment area
Main plots: M1 - Alternate wetting and drying; M2 – Complete submergence
Subplots : T1 – NPK alone; T2 – NPK + Biochar (2.5t ha-1); T3 – NPK + Biochar (5t ha-1); T4 – NPK + Vermicompost (5t ha-1); T5 – NPK + Vermicompost (5t ha-1) + Biochar (2.5t ha-1) ; T6 – NPK + Vermicompost (5t ha-1) + Biochar (5t ha-1)
The collection of gaseous samples was done using closed gas chamber techniques. With the addition of excess 3 M BaCl2, the Co_2 trapped in 0.5 M NaOH was evaluated by titration with 0.1 M HCl (18).

Collection of gaseous samples

Using a closed gas chamber technique, gas samples were taken for rice fields at the tillering stage. The gas chamber was flushed with a 100ml syringe many times before the gas samples were taken at 1-hour intervals. Using Gas Chromatography (Varian 3810 series) connected to a Flame Ionization Detector (FID) outfitted with a D 13-5 column, the methane concentration in the gas samples was measured. The column, injector, and detector were all maintained at temperatures of 500°C, 1800°C, and 2000°C, respectively. For nitrogen (the carrier gas), zero air (the supporting gas), and hydrogen (the combustion gas), respectively, the pressure of the gases was 4, 2, and 2 kg/cm-2, for a total of 8 kg/cm-2. The peak area was measured with a microprocessor – controlled integrator connected to a computer. The area of methane peaks was used to calculate methane concentration against standard peaks.

Ch_4 emission (mg day -1 ha -1) = [(Sc / Pastd) X (Pas /Vs)] X Vac /St X d /Sa X Ah

Where,

Sc	= standard concentration
Pastd	= peak area for standard
Pas	= peak area for sample
Vs	= sample volume
Vac	= volume of the air chamber
St	= sampling time (hr)
Sa	= sampling area
Ah	= area for one hectare
d	= per day (24 hrs)

3. RESULTS AND DISCUSSION

3.1. Experimental soil characteristics and biochar properties (Table 1 & 2)

A Prosopis wood log was pyrolyzed to produce biochar, which had a particle density of 0.54 Mg m-3 and a bulk density of 0.45 Mg m-3. It could contain 131% more water than it could hold. Even though the pH was 7.57, the exchangeable acidity was high (49 mmol kg-1). According to the EC an index of salt loading, very little salt was present in the biochar (Table 1). The Prosopis-Biochar exhibited a C/N ratio of 83.9 and a very high C content (940 g kg-1). In addition to more easily degradable aliphatic and oxidized C structures, charred biomass also contains resistant aromatic ring structures (17).

Clay loam from the Noyyal series was the soil used in the field experiment. According to USDA classification, the soil is classed taxonomically as Typic haplustalf. It had a pH of 8.12 and had few soluble salts (EC = 0.45 dS m-1). The amount of available N was low (143 mg kg-1), the available P was medium (9.95 mg kg-1), and the available K was high (232 mg kg-1) with a medium in organic carbon content (0.42%). (Table 2).

3.2. Effect of Biochar on carbon dioxide emission (Table 3, 4, 5, 6 &Fig.1)

Measurements were made of the Co_2 flow from soil incubated for 28 days at two different moisture levels (Table 3). The results showed that soil under intermittent wetting and drying produced more CO_2 emissions than soil during submersion (Fig.1). Pot and field trials also produced comparable outcomes. This might be caused by variations in how organic matter decomposes. In two ways—it is slower and the byproducts are different—organic matter decomposition in submerged soil varies from that in soil that is intermittently wet and dry. The decomposition of SOM under intermittent wetting and drying conditions is carried out by a vast number of microorganisms with assistance from the soil fauna. Because of the quick disintegration of SOM and synthesis of cell components caused by the high energy release associated with aerobic respiration in these organisms, significant volumes of CO_2 are produced. Under submerged conditions, facultative and obligate anaerobes are virtually solely responsible for the breakdown of SOM. Both breakdown and assimilation are slower in soil that is submerged because anaerobic bacteria function at a significantly lower energy level than aerobic organisms (12;16). Results from laboratory incubation and pot trials revealed that soil emits a significant amount of CO_2. (Table 4).

The field experiment's findings revealed that the CO_2 flux was higher early in the rice plant's growth than it was later (Table 5). Large volumes of CO_2 were found to be released from soil during the vegetative stage of rice in various investigations. Because decomposing microbes may have a larger energy supply and be more active in the early stages. The decrease in CO_2 flux from soil may be due to the nutrient and energy sources becoming depleted as crops are harvested, which causes microbial growth and activity to slow. Through the use of three biological processes, namely microbial respiration, root respiration, and faunal respiration, carbon dioxide is released from the soil through soil respiration. The majority of organic matter is concentrated at the soil surface or in a thin top layer, and one non-biological activity, chemical oxidation, which could be noticeable at higher temperatures, occurs there. In contrast to soil fauna, which contributes significantly less, soil microflora accounts for 99% of the CO_2 produced by the decomposition of organic matter. Yet, 50% of all soil respiration is contributed by root respiration (14)

Several more studies have demonstrated how variables including soil texture, temperature, moisture, pH, accessible C (labile and non-labile uptake of soil organic matter), and soil N concentration affect the emission of CO_2 from soil (14)

Soil respiration and subsequent CO_2 release are influenced by soil moisture. Increasing soil moisture would typically result in an increase in Co_2 emissions up to a certain point, after which it would lower emissions. Continuous soil wetting and drying have a significant impact on CO_2 evolution. When the soil is rewetted, the activity of the latent bacteria rises along with the release of air held in the soil pores, which enhances CO_2 emission (14).

The CO_2 emission varied greatly depending on the experimental conditions, the rate at which Biochar was applied, the SOC content, the microclimate, and the technique employed to collect and measure gaseous samples. Notwithstanding these variations, the influence of biochar on soil CO_2 emissions was amply shown. When the soil was held under intermittent wetting and drying conditions in a lab experiment without any crops, it released roughly 3443 kg CO_2 per hectare (T1). In contrast to this, the land exposed to continual submergence (T4) has seen a 36.5% decrease (2184 kg ha-1) in CO_2 emissions. The results of the maize pot experiment with garden soil have indicated that more carbon was released (as CO2 - C) than in the rice field. In the absence of fertilizers (NPK or vermicompost) and soil amendments (Biochar), it was found that the growth of maize released roughly 385.2 kg of CO2 - C from the soil. The amount of CO2 that was released from the soil was greatly reduced (49% reduction) by adding Biochar at a rate of 2.5 t ha-1. Yet, unlike in a rice field, vermicompost or a faster rate of application had no effect on the efficiency of biochar (Table 6).

Effect of Biochar on Methane Flux (Table 7)

According to various moisture levels, Table.7 shows the CH_4 flow from soil treated with various amounts of biochar. Whereas the rate of CH_4 emission varied from 10.07 to 46.42g ha-1 hr -1 during harvest, it ranged from 16.74 to 72.05g ha-1 hr -1 during tillering. In comparison to intermittent wetting and drying, the continuously submerged condition resulted in a much higher rate of CH_4 emission from the soil. The greatest rate of CH_4 emission (72.05g ha-1hr -1) from soil under submerged conditions was obtained with tillering phase application of vermicompost (5 t ha-1) and NPK fertilizers (T3).

A sizable reduction was observed as a result of the use of biochar. The rate at which Biochar (5tha-1) was applied caused the amount of CH_4 emission to be significantly reduced. Vermicompost increased rather than decreased Biochar's capacity to reduce CH4 emissions when it was present. The CH4 flux was considerably lower at harvest than at the tillering stage, regardless of treatments. The lowest rates of 10.07 and 15.30 g ha-1 hr-1 were measured at harvest following the application of 5 tonnes of biochar, 5 tonnes of vermicompost, and the recommended amount of NPK fertilizer (T6) to the soil under intermittent wetting and drying and submerged circumstances, respectively.

In accordance with the field experiment's findings, soil emits more CH_4 when it was continuously immersed (M2) as compared to when it gets intermittently wet and dries (M1). At the vegetative stage compared to the harvest stage, the CH4 flux was also higher. Based on the CH4 flux, the total amount of CH4 - C released from the rice field was determined (Table 1). Under intermittent wetting and drying (M1), the amount of CH_4 - C varied from 28.7 to 87.8 kg ha-1, whereas it was from 37.7 to 123.5 kg ha-1 under submergence (M2). The two major pathways that produce CH_4 in submerged soils (1) include:

I) Reduction of CO_2 with H_2

$$CO_2 + 4H_2 \rightarrow CH_2 + 2H2O$$

ii) Decarboxylation (transmethylation) of acetic acid

$$CH3COOH \rightarrow CH_4 + Co_2$$

The balance of two opposing processes, namely CH_4 generation and oxidation in the soil, determines how much CH_4 is released into the atmosphere from rice fields. Methanotrophic bacteria, which are strictly obligatory aerobes, oxidize CH_4 in the soil (10). All anaerobic situations where organic matter is decomposing undergo methanogenic activity, which produces CH_4. The typical growing environment for rice is saturated with water, which generates an anoxic environment that encourages methanogenic bacteria to generate CH_4. Methanogens convert organic carbon to CH_4 by using it as an electron source for energy and the synthesis of cellular components.

One of the most perplexing variables affecting CH_4 emission from rice soil is the moisture condition. Generally speaking, continuous soaking produces more CH_4 emissions than intermittent wetting and drying (Fig. 2). As methanogens are exclusively anaerobes, submersion produces anaerobic conditions that are favorable for the generation of CH_4. The activity of methanogens decreases as the soil dries up, turning it into an aerobic environment where less CH_4 is produced. Moreover, considerable amounts of CH_4 can be trapped in submerged soil as gaseous cages or as a solution in the soil pore water. Around 10% of the CH_4 generated over an entire rice crop cycle is held in the soil, according to (3), and is released when the rice fields are dried. Differential CH_4 flux from the soil may have occurred as a result of changes in soil pH, redox potential, and physical characteristics as a result of intermittent wetting and drying. These factors all play a key influence in the CH_4 generation. Intermittent wetting and drying were shown to reduce CH_4 emission by 25 to 58% and by 38 to 65% compared to continuous flooding (submerged).

When compared to a continuous submerged condition, the drying cycle frequently results in an increase in soil Eh and a decrease in CH_4 flux, which results in a large reduction (22–88%) in CH_4 emission (7). As crop growth progresses, the population of methanotrophs in flooded soil rises (13), which may gradually boost CH_4 production and reach its peak during the rice peak growth phase. However, due to the exhaustion of their energy supply during harvest time, methanogen activity and population reduced, which led to a reduction in the amount of CH_4 produced in the soil. Because they can oxidize NH3, methanotrophic bacteria are also strongly tied to the N cycle in rice soil. The decrease in methanogen population and activity could also be explained by the reduction in mineral N (NH4 - N + NO3 - N) concentration, SOC, and enzyme activity shown at the harvest stage.

The addition of vermicompost at a rate of 5t ha-1 considerably increased the CH_4 discharge from rice soil regardless of the soil moisture conditions. Due to the application of vermicompost, soil subjected to submergence (M2) and intermittent wetting and drying (M1) was reported to produce 123.5 and 87.8 kg CH_4 - C ha-1, respectively (T4). It was higher than that of the control treatment by 11 (M2) and 33 (M1) values (T1). According to (1), the addition of any organic materials, such as manures, crop residue, green manure, compost, etc., to a wetland rice field might increase the generation of CH4 by providing the N and C necessary for microbial activity as well as acting as a source of electrons.

Compost and other organic manures reduce the soil's redox potential (Eh) and provide carbon to methanogens. Even a slight variation in the carbon balance between fields and seasons can have a significant impact on CH_4 emissions. However, compared to what (2) reported, less Ch_4 was released during the application of vermicompost in the current investigation. Moreover, the quantity and quality of organic manure affect CH_4 generation. For instance (20) demonstrated that the amount of CH_4 produced rose proportionally to the rate at which rice straw was applied, demonstrating that most soils are C restricted in the generation of CH_4. In a field investigation, it was revealed that when 50% of inorganic N was replaced with FYM instead of applying the complete amount of N by urea, the CH_4 emission increased by 172%. In a different investigation, the application of the full amount of N from organic sources resulted in the highest CH_4 emission, whereas the unfertilized condition had the lowest (5).

Significantly reducing soil CH_4 emissions by the use of biochar, both with and without vermicompost (Fig.2). When Biochar was added to the soil under submerged conditions at rates of 2.5 (T2) and 5 (T3) t ha-1, respectively, it lowered the CH_4 - C by 20% and 45.8%. (M2). When used in conjunction with vermicompost, biochar's capacity to reduce CH_4 flux was increased. In order to reduce the CH_4 - C emission from the soil by 36.7 (T5) to 66.1%, vermicompost and biochar was found to be an efficient combination (T6). Similar to this, applying biochar reduces CH_4-C emission under intermittent wetting and drying by 23.6 (T2) to 46.3% (T3) in the absence of vermicompost and 28.3 (T5) to 56.2% (T6) in the presence of vermicompost.

The Biochar, both with and without vermicompost, was found to be extremely successful in lowering the CH_4 emission from rice fields, regardless of the soil moisture condition. The methanotrophic activity in soil may be connected to the decrease in CH_4 flow. The use of Biochar was observed to diminish the net soil methanotrophic activity in various investigations (19).

The sorption of CH_4 gas on biochar processes may also be responsible for the decrease in CH_4-C emission. Research done by [11] on the CH_4 adsorption capability of activated carbons revealed that CH_4 adsorption increased with increase in activated carbon surface area. The microbial community in soil is affected by chemisorption, which biochar offers as a source.

According to(15), applying Biochar to the soil at a rate of 2% weight/weight resulted in a nearly total suppression of CH_4. It was proposed that improved soil aeration, which results in a decrease in the frequency and severity of anaerobic conditions in which methanogens occurs, is the mechanism causing a reduction in CH_4 emission.

4. SUMMARY AND CONCLUSIONS

In the present study, biochar, a stable form of carbon, was created through the pyrolysis of Prosopis wood logs. It was described, and a field experiment was carried out to assess its effects on carbon dynamics and sequestration in soil. Although having relatively low nutrients, Prosopis-Biochar had a high C content, giving it a high C/N ratio (83.9). During intermittent wetting and drying conditions, the use of biochar was found to reduce Co_2 emissions by 31 to 36%, and by 47 to 54% under continuous submersion. When Biochar was applied to the soil under submerged conditions at rates of 2.5 (T2) and 5t ha-1 (T3), the Ch_4 - C was reduced by 20% and 45.8%, respectively (M2). Vermicompost was found to increase the efficiency of biochar when it was used in combination with it. A high and stable C content (longer half-life), a low rate of decomposition, a decrease in C emission, reduced microbial activity, and other factors may be responsible for the high soil C sequestration brought on by the addition of biochar. However the precise mechanisms underlying this still need to be identified. Studies have shown that biochar has a tremendous potential to trap carbon in soils, which could help to mitigate climate change.

Table 1. Physical ,chemical and biochemical properties of Biochar

S.No.	Characters	Values*
a).Physical Properties		
1.	Bulk Density (Mg m^{-3})	0.45
2.	Particle Density (Mg m^{-3})	0.54
3.	Percent Pore space	48
4.	Water Holding Capacity (%)	131
b).Chemical Properties		
5.	pH (1: 5 soil water suspension)	7.57
6.	EC (dSm^{-1}) (1: 5 soil water extract)	1.30
7.	Cation Exchange Capacity (cmol(+) kg^{-1})	16
8.	Exchangeable Acidity (mmol kg^{-1})	49
9.	Organic Carbon (g kg^{-1})	940
10.	Total Nitrogen (g kg^{-1})	1.12
11.	Total Phosphorus (g kg^{-1})	1.06
12.	Total Potassium (g kg^{-1})	29
13.	Sodium (g kg^{-1})	38
14.	Calcium(g kg^{-1})	11
15.	Magnesium (g kg^{-1})	0.36
c). Biochemical Properties		
16.	Cellulose (%)	36
17.	Hemicelluloses (%)	31
18.	Lignin (%)	22

** Mean of triplicate samples*

Table 2. Physico-chemical and biological characteristics of soil used in the laboratory, pot and field experiments

S.No	Properties	Values*
I. Physical properties		
1.	Clay (%)	34.4
2.	Silt (%)	22.1
3.	Coarse sand (%)	16.4

4.	Fine sand (%)	26.8
5.	Textural class	Clay loam
6.	Bulk density (Mg m^{-3})	1.22
7.	Particle density (Mg m^{-3})	2.58
8.	Pore space (%)	54.63
9.	Water holding capacity (%)	36.5
II. Chemical properties		
10.	pH (1:2.5)	8.12
11.	Electrical conductivity (dS m^{-1})	0.45
12.	Organic carbon (%)	0.42
13.	$KMnO_4$ –N (mg kg^{-1})	143
14.	$NaHCO_3$ – P (mg kg^{-1})	9.95
15.	NH_4OAc – K (mg kg^{-1})	232
16.	Cation exchange capacity (c mol (P^+) kg^{-1})	20.8
17.	Exchangeable Ca (c mol (P^+) kg^{-1})	9.72
18.	Exchangeable Mg (c mol (P^+) kg^{-1})	5.81
19.	Exchangeable Na (c mol (P^+) kg^{-1})	2.65
III. Biological properties		
20.	Total bacteria (CFU x 10^6 g^{-1} soil)	17
21.	Total fungi (CFU x 10^3 g^{-1} soil)	9
22.	Total actinomycetes (CFU x 10^4 g^{-1} soil)	5
23.	Dehydrogenase (µg of TPF released g^{-1} of soil hr^{-1})	8.20
24.	Urease (µg NH_4^+ g^{-1} soil hr^{-1})	27.73
25.	Phosphatase (µg of p-nitrophenol released g^{-1} of soil hr^{-1})	12.04

**Mean of triplicate samples*

Table 3. Effect of Biochar on carbon-di-oxide (mg kg -1day-1) emission in soil under different moisture regimes during incubation (laboratory closed experiment)

Treatments	Incubation period (days)							Total (mg kg^{-1})
	1	2	3	8	14	21	28	

Intermittent Wetting and Drying								
T_1- Soil	739	295	394	597	449	471	378	3323
T_2 -Soil+ Biochar 5%	722	167	356	537	342	367	273	2763
T_3 - Soil+ Biochar 10%	421	139	322	514	320	330	233	2279
Continuous Submergence								
T_4 - Soil	251	188	324	493	249	314	290	2108
T_5 - Soil+ Biochar 5%	231	155	267	451	224	258	173	1760
T_6 - Soil+ Biochar 10%	179	148	215	402	211	216	151	1523

Table 4. Effect of Biochar on carbon-di-oxide flux from rice soil under two different moisture conditions (pot experiement)

Treatments	**CO_2 - C (mg pot $^{-1}$day $^{-1}$)**
T_1 – NPK **(Wetting & Drying)**	96
T_2 – NPK + Biochar (10t ha^{-1})	78
T_3 – NPK + Biochar (20t ha^{-1})	65
T_4 – NPK alone **(Submergence)**	68
T_5 – NPK + Biochar (10t ha^{-1})	47
T_6 – NPK + Biochar (20t ha^{-1})	42
Mean	66

Table.5. Effect of Biochar on CO2 - C emitted from rice soil (field experiment)

Treatments	**CO_2 - C (kg ha^{-1})**		
	M_1	**M_2**	**Mean**
T_1 – NPK alone	59.58	48.06	53.82
T_2 – NPK + Biochar (2.5t ha^{-1})	47.24	41.97	44.61
T_3 – NPK + Biochar (5t ha^{-1})	29.32	25.13	27.23
T_4 – NPK + VC (5t ha^{-1})	73.32	54.19	63.76
T_5 – NPK + VC (5t ha^{-1}) + Biochar (2.5t ha^{-1})	35.79	33.01	34.40
T_6 – NPK + VC (5t ha^{-1}) + Biochar (5t ha^{-1})	26.83	21.45	24.14
Mean	45.35	37.30	41.33

VC- Vermicompost *M1-Intermitant Wetting and drying* *M2- Submerged condition*

Table 6. Effect of Biochar on CO2 flux from soil under maize

Treatments	**Emission CO_2 – C (mg kg^{-1}day $^{-1}$)**		
	Vegetative stage	**Harvest stage**	**Mean**
T_1 – Absolute control	55.94	44.37	50.16
T_2 – NPK alone	43.45	38.28	40.87
T_3 – NPK + Biochar (2.5t ha^{-1})	28.53	23.92	26.23
T_4 – NPK + Biochar (5t ha^{-1})	29.52	15.98	22.75
T_5 – NPK + Vermicompost (5t ha^{-1})	47.74	53.17	50.46
T_6 – NPK + VC (5t ha^{-1}) + Biochar (2.5t ha^{-1})	29.12	23.36	26.24
T_7 – NPK + VC (5t ha^{-1}) + Biochar (5t ha^{-1})	29.34	16.06	36.12
Mean	37.66	30.73	36.12
SEd	0.38	0.49	
CD (p=0.05)	0.83	0.75	

Table 7. Effect of different levels of Biochar on CH4 flux (g hr-1ha-1) emission from soil (field condition)

Treatments	Tillering			Harvest		
	M_1	M_2	Mean	M_1	M_2	Mean
T_1 – NPK alone	38.26	64.86	51.56	32.28	43.34	37.81
T_2 – NPK + Biochar (2.5t ha^{-1})	29.23	51.84	40.54	23.82	35.75	29.79
T_3 – NPK + Biochar (5t ha^{-1})	20.56	35.11	27.84	12.06	26.07	19.07
T_4 – NPK + VC (5t ha^{-1})	51.21	72.05	61.63	35.31	46.42	40.86
T_5 – NPK + VC (5t ha^{-1}) + BC (2.5t ha^{-1})	27.45	41.00	34.23	23.43	35.63	29.53
T_6 – NPK + VC (5t ha^{-1}) + BC (5t ha^{-1})	16.74	22.00	19.37	10.07	15.30	12.68
Mean	30.58	47.81	39.19	22.83	33.75	28.29
	SEd	CD(0.05)		SEd	CD(0.05)	
T	0.05	0.12		0.03	0.08	
M	0.01	0.03		0.08	0.18	
M x T	0.06	0.14		0.04	0.89	
T x M	0.04	0.09		0.02	0.45	

VC- Vermicompost *M1-Intermitant Wetting and drying* *M2- Submerged condition*

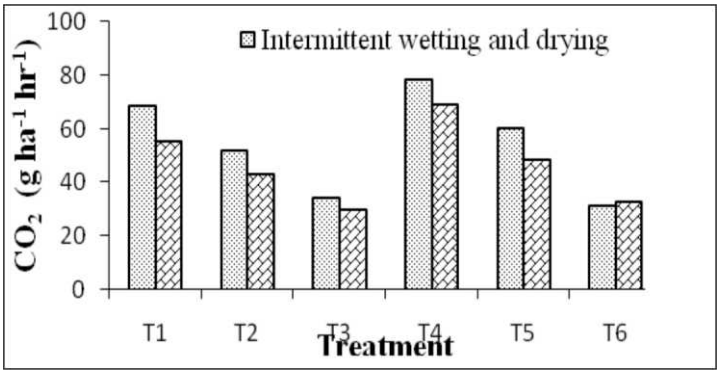

Fig. 1. Effect of Biochar on Co_2 emission from rice soil (field condition)

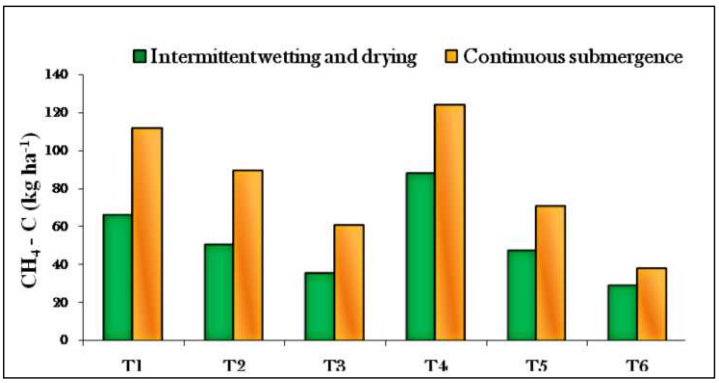

Fig.2. Effect of Biochar on CH4 - C emission from rice soil

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