The Andhra Agric. J 69 (1): 86-93, 2022

Long-term Application of Inorganic Fertilizer and Organic Manures on Carbon Dioxide Emissions in Wet Land Rice Soils

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ABSTRACT

Long term impact of mineral fertilizers and manures on the emission of carbon dioxide was investigated in laboratory incubated soils with varying temperature and moisture regimes from wet lands soils under rice-rice cropping system.Thesoil samples were collected from experiment of intensive rice cropping for 23 years and treatments consisted vi., control, inorganic N (60 kg/ha), inorganic fertilizer (NPK @ 60-40-40 kg ha^{-1}), FYM @ 10 Mg $ha^{-1}$and inorganic fertilizer NPK @ 60-40-40 kg $ha^{-1}$and FYM @ 5 Mg ha^{-1} as treatments with three replications and days of incubation. A general decreasing trend of CO_2 production corresponding with decrease in total organic carbon (TOC) under different fertilization treatment was noted for all moisture and temperature regimes. Higher cumulative CO_2 production (2.25 mg CO_2-C g-1 dry soil) at 90 days of incubation in FYM + NPK treatments was presumably due to high TOC (1.39%) and POC (888.6 mg Kg-1) content and higher biological activity. Higher microbial biomass carbon (MBC) (250.7 mg g-1) and acid hydrolysable carbohydrates (AHC) in FYM treated soil caused considerable amount of cumulative CO_2 production at 90 days (1.90 mg CO_2-C g-1 dry soil)possibly acted as a source of bio-energy for higher amount of exogenous micro organisms.Temperature is a prime factor regulating microbial activity, soil respiration and hence CO_2 evolution regardless of fertilizer treatments. Mean cumulative CO_2 production increased by 8% at 35°C (from 1.09 mg to 1.18 mg CO_2-C g-1 dry soil) than at 25°C. Similarly, mean cumulative CO_2 production increased by 15% at 60% WHC (from 1.05 to 1.21 mg CO_2-C g-1 dry soil) than at submergence and was influenced by different fertilizer treatments.

Keywords: *Carbon dioxide production, Incubation, Moisture, Temperature, Pools of carbon*

In the last few decades, there has been an increase in the emission of naturally occurring greenhouse gases like Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (NO_2) of which CO_2 is accounting for 60% of the total greenhouse effect (Rastogi *et al.*, 2002). The greenhouse gases trap outgoing infrared radiation from the earth's surface. Human health, terrestrial and aquatic ecological systems, agriculture, forestry, fisheries, and water resources are sensitive to changing climate. The concentration of CO_2 in the atmosphere has increased from 280 ppmv at beginning of the industrial revolution to the present day value of 391 ppmv [WMO, 2012). This increase is attributed to the anthropogenic activities like agriculture and land use changes, burning of fossil fuel, deforestation, emission from automobiles, forest fires, etc. It is well known that vegetation and soils are major storage sinks of atmospheric CO_2 (Franzluebbers and Doraiswamy, 2007). Carbon dioxide is released from the soil through soil respiration, which includes three biological processes, namely microbial respiration, root respiration and faunal respiration primarily at the soil surface or within the thin upper layer where bulk of plant residue is concentrated (de Jong *et al.*, 1974). Soil organic carbon (SOC) is of paramount importance with respect to availability of plant nutrients [Kundu *et al*, 2006). Maintenance of SOC is essential for the sustainable agricultural production as declining soil C generally decreases crop productivity (Lal, 2006). Chemical, physical, and biological alteration and breakdown caused mineralization of soil organic matter increased the CO_2 emission (Van Gestel et al. (1991). The rate of soil C emissions is strongly influenced by the amount and properties of added organic materials and environmental conditions, especially temperature and water availability (Agehara and Warncke, 2005). Information on the emission of carbon dioxide at varying temperatures and moisture in flood rice soils is inadequate. Hence, a laboratory incubation study was undertaken by collecting the soil samples from long term experiment of inorganic fertilizers and manures on rice-rice cropping system with twin objectives to determine the emission of carbon dioxide at varying levels of moisture, temperature and carbon pools and to determine relation exist between the treatment with soil properties.

MATERIAL AND METHODS

A long term field experiment was established in 1989 to assess the impact of organic and inorganic fertilizers on soil physico-chemical properties and crop yield in wet land soils of rice-rice cropping system at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station (APRRI-RARS), Maruteru, A.P., India (26.38°N, 81.44°E). The long term trail was set up with 14 treatments in a randomized block design with three replications and out of which five treatments were used for laboratory incubation studies. Mean annual temperature is 27.2°C and annual precipitation is about 1200 mm yr^{-1} of which 22-25% is received during Nov to March. The soil of the farm area is an inceptiol with clay loam in texture has been developed from the deltaic sediments of Godavari River

Laboratory Incubation Studies

Soil Analysis

The laboratory incubation studies were carried out from the field soil samples collected from the long term nutrient management trail in rice-rice cropping system. Five (5) treatments used in the study viz., control, N alone (90 kg ha^{-1}), Inorganic NPK @ 90:60:60 kg ha^{-1}), FYM @ 10 Mg ha^{-1} and Inorganic NPK FYM @ 90:60:60 kg ha^{-1} and FYM @ 5 Mg ha^{-1}. The moisture regimes are 60% Water Holding Capacity (WHC) and submergence (flooded conditions). The temperature regimes imposed are 25°C, 35°C and 45°C. The set up was maintained with three replications. The studies were carried out at 10,20,40,60 and 90 days of incubation (DOI).The amount of CO_2 produced at different moisture regimes and temperature regimes at different periods of incubation was recorded. The physico-chemical properties of the selected treatments for pH, Electrical Conductivity (EC) in 1:2.5 ratio were determined as per procedures outline by Jackson (1967). Available P was extracted with Olsen reagent (0.5 M NaHCO3 at pH 8.5 (Olsen et al.1954) at soil extractant ratio of 1:20, shaken for 30 min and quantified by molybdenum-blue colour method using a spectrophotometer. Available K was extracted with neutral normal ammonium acetate (pH 7.0) shaken for 5 min and measured by flame photometer (Jackson 1973). Microbial habitat groups in soil such as bacteria, fungi and actinomycetes were enumerated using nutrient agar, rose Bengal agar and Kenknight's agar as growth medium, respectively, following dilution plating viable count method (Weaver *et al*., 1994). After the required incubation period, the colony forming units (cfu) were counted and expressed as cfu g–1 of soil.Soil microbial biomass carbon (MBC) was measured by modified chloroform fumigation-extraction method with fumigation at atmospheric pressure (Witt *et al.,* 2000). Readily mineralizable carbon (RMC) content of the soil samples was estimated after extraction with 0.5 M K_2SO_4 (Inubushi *et al.,* 1991) followed by wet digestion of the soil extract with dichromate (Vance *et al*., 1987). The acid hydrolysable and water soluble carbohydrate carbon (AHC, WSC) were estimated following the procedure of Haynes and Swift (1990). Permanganate oxidizablecarbon (POSC) was determined following the method described by Blair *et al.,* (1995).

Carbon Dioxide Emission Measurement

The rate of carbon dioxide production is commonly used as a measure of microbial activity in the soil. The method of CO_2 determination involves trapping CO_2 in an alkali solution and then determining CO_2 concentration indirectly by titration of the remaining alkali in the solution [Jain, 2003].). The soil samples from the selected treatments were transferred into scott bottles. The study was conducted for 90 days (3 months). A CO_2 trap was prepared using NaOH solution (20 ml 1.0 N NaOH in 25 ml distilled water) in vial for trapping CO2. The trap solution in a beaker was placed in the air-tight Scott bottle of the experiment. On 10th day of incubation the alkali beaker present in different Scott bottle pertaining to different temperature and moisture regimes were removed and titrated with 0.1 N HCl solution using phenolphthalein indicator and $BaCl_2$solutions and the carbon dioxide production was expressed as mg CO_2-C g-1 dry soil.

All data was recalculated on the basis of oven-dry soil weight and was analysed using two way ANOVA considering main treatments and assay time at specific periods of incubation and individual character datasets were statistically analysed and mean comparison between treatments was established by Duncan's multiple range test (Gomez and Gomez 1984). Simple correlations between soil chemical and biochemical properties and interrelations between the enzymes were also worked out.

RESULTS AND DISCUSSION

In the present study, the soil samples (triplicated) collected the selected treatments were used for laboratory studies. These samples were analysed for physico-chemical, chemical and microbiological properties. Data presented in Table 1 suggested that the soils slightly acidic in reaction and non-saline. Among the treatments, Inorganic NPK FYM @90:60:60 kg ha$^{–1}$ and FYM @ 10 Mg ha$^{–1}$ .recorded higher Total Organic Carbon (TOC) of 13.9 g kg^{-1} and significantly higher than that of all other treatments while the lower TOC was observed in control (7.40 g kg^{-1}). Similarly, the available nitrogen, available phosphorus and available potassium were found to be higher in Inorganic NPK and FYM treatments. High population of bacteria, fungi and actinomycetes were also recorded by FYM and inorganic NPK.

Pools of carbon

Different carbon fractions in the soil samples were segregated and quantified and the results revealed that Inorganic NPK @ 90:60:60 kg ha$^{–1}$ and FYM @ 10 Mg ha$^{–1}$ treatment recorded significantly higher content of Microbial biomass Carbon (MBC), Readily Mineralizable Carbon (RMC), Acid hydrolysable Carbon (AHC), Water soluble carbon (WSC), Permanganate oxidizable

Table 1. Initial physico-chemical and microbiological properties of selected treatments for laboratory incubation studies

Treatments/ Soil properties	Control	Nitrogen alone @90 kg ha^{-1})	Inorganic NPK @ 90-60-60 kg ha^{-1})	FYM @ 10 Mg ha^{-1}	Inorganic NPK and FYM @ 5 Mg ha^{-1}
pH	6.20 (±0.01)^{d}	6.47((±0.01)^{b}	6.59(±0.01)^{a}	6.34(±0.01)^{c}	6.35(±0.01)^{c}
EC (dS/m)	0.52(±0.01)^{d}	0.79(±0.01)^{a}	0.59(±0.01)^{c}	0.67(±0.01)^{b}	0.54(±0.01)^{d}
Total Organic Carbon (g/kg)	7.40(±0.01)^{e}	8.13(±0.01)^{d}	10.4(±0.04)^{c}	12.5(±0.02)^{b}	13.9(±0.02)^{a}
Available –N (kg/ha)	151(±1.15)^{e}	180(±0.881)^{d}	284(±1.45)^{c}	263(±1.20)^{b}	339(±0.88)^{a}
Available- P_2O_5 (kg/ha)	18.40(±0.12)^{e}	22.40(±0.61)^{d}	29.41(±1.69)^{c}	69.08(±0.60)^{b}	53.18(±1.28)^{a}
Available-K_2O (kg/ha)	265(±3.0)^{e}	293(±2.60)^{d}	341(±2.08)^{c}	410(±1.76)^{b}	428(±1.20)^{a}
Fungi (x 103 cfu/g)	22.60(±0.01)^{e}	30.53(±0.01)^{d}	38.45(±0.01)^{c}	43.43(±0.00)^{b}	45.83(±0.00)^{a}
Bacteria (x 106cfu/g)	25.45(±0.01)^{e}	36.40(±0.01)^{d}	42.49(±0.01)^{c}	60.53(±0.01)^{a}	52.53(±0.00)^{b}
Actinomycetes (x 103cfu/g)	24.10(±0.00)^{d}	28.46(±0.00)^{c}	32.55(±0.00)^{b}	39.56(±0.01)^{a}	33.46(±0.01)^{b}

Values are mean (± standard error) (n= 5) and values are followed by the same letter in each row are not significantly different from each other as determined by Duncan's Multiple Range Test (p d" 0.05).

Table 2. Different pools of carbon in an alluvial soil of rice-rice cropping system in a long term trial

Treatments	TOC (g kg^{-1})	MBC/ TOC (%)	RMC (mg kg^{-1})	WSC (mg kg^{-1})	AHC kg^{-1})	POSC (mg kg^{-1})
Control	7.4e	1.46e	46.2e	21.8e	235.9e	721.5e
Inorganic N @90 kg ha^{-1}	8.1d	1.78d	72.4d	58.2d	276.6d	807.3d
NPK @90-60-60 kg ha^{-1}	10.4c	1.69c	86.4c	96.5c	301.8c	830.8c
FYM @ 10 Mg ha^{-1}	12.5b	1.67b	101.2b	123.4b	420.1b	847.2b
NPK @90-60-60 kg ha^{-1} and FYM @ 5 Mg ha^{-1}	13.9a	1.80a	119.3a	141.7a	440.4a	888.7a

TOC-Total Soil Organic Carbon, MBC- Microbial biomass Carbon, RMC- Readily Mineralizable Carbon, AHC-Acid hydrolysable Carbon , WSC-Water soluble carbon, POSC-Permanganate Oxidizable Carbon. Values are mean (± standard error) (n= 5) and values are followed by the same letter in each row are not significantly different from each other as determined by Duncan's Multiple Range Test ($p \leq 0.05$).

carbon (POC) followed by FYM @ 10 Mg ha^{-1}, Inorganic NPK @ 90:60:60 kg ha^{-1} inorganic N @ 90 kg ha^{-1} and control (Table 2).The MBC content increased by 33%, 29%, 31% and 38% in N, NPK and NPK and FYM treatments, respectively, over that of control.

In the present study, the MBC content was lowest in the control plots probably because of high stress due to inadequate nutrient supply, lack of fertilizer application and lower amounts of rhizodeposition (root exudates and root biomass). Integrated use of NPK and FYM results in the increased production of different fractions of carbon in flooded rice soils. Similar results of application of mineral fertilizer in combination with organic manure as a source of energy and nutrients was reported by (Manna et al. 2007). In the study, the enhanced microbial biomass could to attributed to adequate availability of both C and N to the soil microbial pool. The finding are supported by Dhull *et al.,* (2004) and Leita *et al.,* (1999).

Effect of varying moisture and temperatures on CO_2 emissions as influenced by long term nutrient management

The results of the study indicated a significant increase in carbon dioxide emission upto 90 days of incubation and later decrease was noticed. Among the moisture regimes, submergence of soil caused a significant reduction in CO_2 emission compared to 60% WHC. Significantly higher CO_2 production was observed under Inorganic NPK @90:60:60 kg ha^{-1} and FYM @ 5 Mg ha^{-1} followed by FYM @ 10 Mg ha^{-1}. and Inorganic NPK @ 90:60:60 kg ha^{-1}, Inorganic N @ 90 kg ha^{-1} and control treatments under the laboratory incubated soils.. Cumulative CO_2 production (2.763 mg CO_2-C g-1 dry soil) was found to be higher at 90 days of incubation in FYM + inorganic fertilizer NPK treatment where as carbon dioxide production was lowest in unfertilized control irrespective of the treatments (Fig 1). The mean cumulative CO_2 production increased by 24 % at 45°C (2.801 mg to 3.481 mg CO_2 -C g-1 dry soil) at 60% water holding capacity compared to submergence and was influenced by different fertilizer treatments.The decrease in CO_2 production with increase in moisture compared to alternate wetting and drying and application of cowdung helps in restricting the emission of CO_2 as reported by Rehman (2013). Similar findings were also made by Oliver and Horwath (2000).

Temperature is a prime factor regulating microbial activity, soil respiration and hence CO_2 evolution regardless of fertilizer treatments. In this study, significantly higher production of CO_2 per unit of dry soil was recorded in all fertilization treatments at 45°C than at 35°C and 25°C (Fig 1). A logarithemic increase in CO_2 evolution between 20 and 40°C followed by a decrease above 50°C was also reported by Wiant (1967). At higher temperatures partial inhibition of microbial respiration occurs, which is attributed to inactivation of biological oxidation systems. Similarly, Bunt and Rovira (1954) found increased CO_2 evolution with a rise in temperature above 50°C.

Apart from the direct effects of temperature and moisture, the interaction of these assumes great significance in view of the global warming and likely disturbance of precipitation pattern. In the study, interactive effect temperature and moisture showed higher CO_2 production across the treatments. Moore and Dalva (1997) also stated that soil temperature and water table position determine the CO_2 production. Similar finding were made by Kowalenko (1978) who observed that temperature was the most dominant factor in determining CO_2 evolution from the soil.

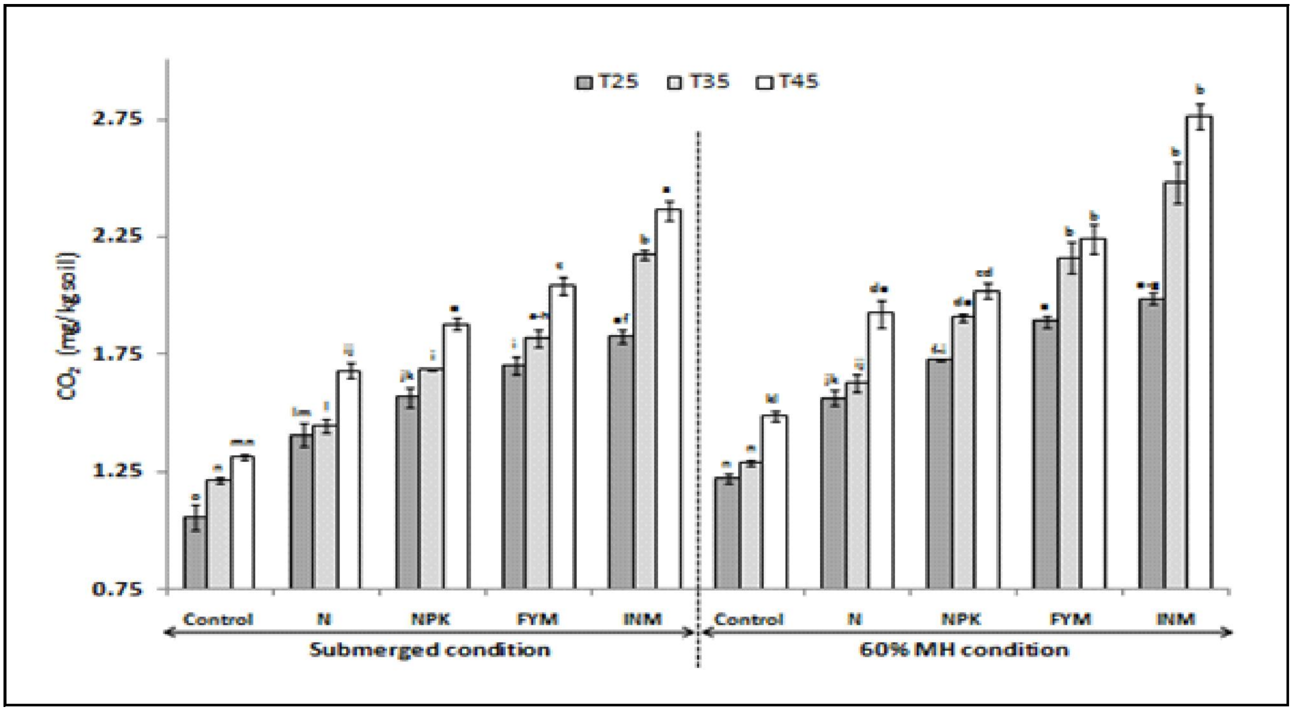

Fig 1. Effect of water regimes and increased temperatures on the emission of CO_2 under long term nutrient management in rice soil

The application of organic manure in soil can increase CO_2 emission (Pathak and Rao, 1998), In the study, the Inorganic NPK and FYM recorded significantly higher production of CO_2 both at 60% WHC and above 45°C temperature. In the study, the highest CO_2 evolution might be due to higher mineralization rate of native SOM as well as from the added organics sources. Similar observations made by Mc Gill *et al.*, (1981) indicated that addition of soluble organic C in the soil acts an immediate source of C for soil microorganisms which inturn emit CO_2. Further, large quantities of organic manure that are added to agricultural soils every year for supplying nutrients to crops may contribute significantly CO_2 emission (Rastogi, 2002). Further, higher microbial biomass carbon (MBC) (250.7 mg g-1) and acid hydrolysable carbohydrates (AHC) in FYM treated soil caused considerable amount of cumulative CO_2 production at 90 days possibly acted as a source of bio-energy for higher amount of exogenous microorganisms and also due to high TOC content of soil. This is evidenced by the significant and positive correlation between carbon pools with TOC of soil (r=0.88**). Further, the lower carbon dioxide production in unfertilized control soil due to lower labile and active pools (MBC, RMC, AHC, POC and WSC) of C responsible for lower biological activity in soil.

CONCLUSION

The effect of fertilization and interaction with varying temperature and moisture regimes on CO_2 production in a laboratory incubation study under rice-rice cropping system showed a significant increase in CO_2 production at the moisture regime of submergence and at a temperature of above 45°C. Significantly higher CO_2 production was observed under FYM and NPK followed by FYM, NPK, inorganic N and control treatments. Higher cumulative CO_2 production at 90 days of incubation in FYM + NPK treatments was presumably due to higher MBC and TOC content of soil. The study indicated inorganic fertilizers and FYM not only might have released more CO_2 evolution in soil but also helps in the improving the quality of soil organic matter.

ACKNOWLEDGMENTS

The authors are thankful to the support extended by the NAIP project on Soil organic carbon dynamics vis-a-vis anticipatory climatic change and crop adaptation strategies of Indian Council of Agricultural Research (ICAR), New Delhi and also to the Acharya N. G. Ranga Agricultural University, Guntur.

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Received on 09.01.2022 and Accepted on 23.03.2022