Alternative cropping systems to mitigate carbon dioxide emission in rice fields under different nutrient levels

ABSTRACT

The impact of different cropping systems and nutrient levels on carbon dioxide emission, soil temperature and soil moisture were studied. The experiment was carried out at Integrated Farming System Research Station, Karamana, during *kharif, rabi* and summer seasons of 2020-2021 in split plot design with five cropping systems as main plots (rice-rice-fallow(C_1), rice-rice-sweet potato(C_2), rice-sweet potato-amaranthus(C_3), rice-(cassava+bush cowpea)-daincha(C_4), rice-rice-daincha(C_5) and three fertilizer doses as sub plots (F_1:Full FYM+Full N+Full P+Full K(As per the recommendation of Kerala Agricultural University), F_2:3/4 FYM+3/4 N+3/4 P+Full K and F_3 :1/2 FYM+1/2 N+1/2 P + Full K) replicated thrice. Results showed that, during *kharif, rabi* and summer seasons, F_1 (Full FYM+ full N, P, K) recorded the highest CO_2 emission (321,331.4 and 322.33 ppm respectively) and the lowest CO_2 emission (290.13, 291.06 and 289.20 ppm respectively) was recorded in F_3 (½ FYM+ ½ N+ ½ P+ full K). Also, CO_2 flux was linearly related with soil temperature.

Keywords: *Greenhouse gas emission, diversified rice based cropping systems, tuber crops, fertilizer doses*

1.INTRODUCTION

A major greenhouse gas that accounts for 60% of the entire greenhouse effect is carbon dioxide (CO_2)[1]. It has been shown that vegetation and soils serve as important atmospheric CO2 storage sinks[2].According to reports, the amount of CO_2, in the atmosphere has progressively reached from 280 µmol mol^{-1} before the industrial revolution to 370 µmol mol^{-1} now and will continue to do so at an average of 0.5% per year [3].The farming soils are considered to contribute significantly to atmospheric CO_2 levels, bringing up around one-fourth of all CO_2 emissions caused by human activity [4]. The addition of stable manure amendment, rice transplanting, water management, harvest, harvest residual treatment, and ploughing are examples of cultivation and field management approaches that have a significant impact on emission of carbon dioxide [5]. Some parts of the land surface is covered in agricultural fields or wetlands, which add to both global and regional CO_2 budgets. In addition to weather, management strategies like tillage and N fertilisation might have both positive and negative impact on soil CO_2 emission [6][7]. Generally, soil moisture and temperature have been identified as the main factors that influence soil CO_2 emission due to their direct impacts on soil microorganisms and plant root growth as well as their indirect effects on nutrient availability and plant production [8][9][10]. The reduction of the soil organic pool due to CO_2 emissions has an impact on the structure, fertility and productivity of the soil. Therefore, minimising CO_2 emissions through soil carbon sequestration is extremely important. Scarce information on CO_2 emission from diverse rice based cropping systems under different nutrient levels has led us to carry out the research. It was hypothesized that emission of CO_2 may vary with the various rice based cropping systems and different nutrient levels. The objectives of the research were to determine the rates of CO_2 emission, soil temperature and soil moisture from rice based cropping systems under different nutrient levels and to identify the resilient rice based cropping system which restricts CO_2 emission in soil.

2. PHYSIOGRAPHICAL ASPECTS

The study was conducted in the double cropped low land rice fields of Integrated Farming Systems Research Station(IFSRS) located at Karamana, Thiruvananthapuram, Kerala, India.The experimental site is geographically located at 8^o 28' 43'' N latitude and 76^o 57'46'' E longitude and an altitude of 5m. A warm humid tropical climate prevails over the experimental site. The maximum temperature during *kharif* season (monsoon season i.e, June – September) varies from 31^{o}C to 33^{o}C and minimum from 23^{o}C to 27^{o}C. The relative humidity varies from 75.64 to 89.78 %. During the *rabi* season (winter season i.e, October to Januray) the maximum temperature varies between 31 ^{o}C and 33 ^{o}C and the minimum temperature between 21 ^{o}C and 26^{o}C. The relative humidity ranged from 77.64 to 94.14 %. The minimum temperature during the summer crop season 2020(February-May) varies from 22 to 25 °C while the maximum from 31 to 34 °C. The relative humidity varies from 76.85 to 93.14 per %.

3.MATERIALS AND METHODS

The experiment was laid out during 2020-21 at IFSRS, Karamana, Kerala,India. Main plot treatments were five cropping systems viz; rice-rice-fallow, rice-rice-sweet potato, rice-sweet potato-amaranthus, rice-(cassava+bush cowpea)-daincha, rice-rice-daincha were studied in the experiment. Sub plots were different fertilizer levels viz, F1: Full FYM+Full N+Full P+Full K (As per the recommendation of Kerala Agricultural University), F2: 3/4 FYM+3/4 N+3/4 P+Full K and F3: 1/2 FYM+1/2 N+1/2 P + Full K. All crops were raised as per the Package of Practices Recommendations for crops of Kerala [11]. Recommended dose of nitrogen, phosphorus and potassium were applied through urea, rajphos and muriate of potash.

3.1 Soil analysis

A composite sample was collected before the commencement of the present study at a depth of 15cm. The composite sample from the experimental field before the experiment was analysed for physical and chemical properties.

3.2 CO_2 study

The following observations were recorded to study the effect of different cropping systems and nutrient levels on CO_2 emission from soil.

CO_2 emission from soil

Carbon dioxide release from soil was recorded using CO_2 sensor- GE Telaire ® 7001 CO_2/Temperature monitor (GE sunsing, USA) and expressed in ppm.

Soil Temperature

The soil temperature (ºC) at 15 cm depth was measured using Probe type digital thermometer (Divinest TP 101, India).

Soil moisture

The soil moisture at 15 cm depth was measured using Probe type digital soil moisture meter.
These three observations were taken during the active growth stage of each crop.

3.3. Statistical Analysis

GRAPES KAU statistical software [12] was used to analyse the data.

4. RESULTS AND DISCUSSIONS

4.1 Physical and chemical properties of soil

The soil is clayey sand loam in texture, moderately acidic with normal electric conductivity, medium in OC, available N, P and K. The physical and chemical properties of soil are shown in Table 1.

Table 1.Physical and chemical properties of soil

Parameter	Content	Rating
Soil reaction (pH)	5.2	Moderately Acidic
Electrical conductivity(1:2.5)(dSm^{-1})	0.20	Normal
Organic carbon (%)	1.1	Medium
Available N ($kg\ ha^{-1}$)	255.00	Medium
Available P ($kg\ ha^{-1}$)	34.8	High
Available K ($kg\ ha^{-1}$)	130	Medium
Granulometric distribution		
Fraction	Content (%)	
Sand	72.9	

Silt	07.1	Soil texture-
Clay	20.0	Clayey sand loam

4.2. CO_2 Emission, ppm

The results pertaining to the effect of different treatments on CO_2 emission in soil during three seasons are given in Table 2.

During *kharif, rabi* and summer seasons, F_1 (Full FYM+ full N, P, K) recorded the highest CO_2 emission (321,331.4 and 322.33 ppm respectively) and the lowest CO_2 emission (290.13, 291.06 and 289.20 ppm respectively) was recorded in F_3 (½ FYM+ ½ N+ ½ P+ full K). This may be due to the fact that, addition of nutrients can strengthen plant roots and boost soil microbial biomass, which raises CO_2 emissions from the soil. Similar results were reported by Hasselquist *et al*. [13]. Increase in plant growth under higher N fertilisation would increase the input of soluble organic compounds (e.g., exudates) exuded by roots, which could also cause an increase in heterotrophic respiration under N fertilisation [14]. Nitrogen fertilisation increased soil N availability, which might mitigate the N limitations on soil microbes [15] and thereby increase the heterotrophic respiration.

During the *rabi* season, cassava (C_4) recorded the lowest CO_2 emission (255.22 ppm). This may be due to the carbon sequestration capability of cassava. High rate of C sequestration by cassava can be attributed to its high leaf dry matter production to the tune of 3-6 t ha^{-1}, coupled with leaf residue incorporation in soil due to leaf shedding which in turn resulting an increase in SOC and sufficient foliage canopy giving a shade and thereby a cool soil climate slowing down organic matter mineralization and increases SOC accretion. Similar findings reported by Rajalekshmi and Bastin [16].

Table 2. Effect of cropping systems and fertilizer doses on CO_2 emission in soil, ppm

Treatments	**CO_2 emission(ppm)**		
Main plots	***Kharif***	***Rabi***	***Summer***
C_1	303.77	313.44	303.11
C_2	308.33	337.89	275.89
C_3	309.00	294.00	308.56
C_4	313.33	255.22	313.33
C_5	299.55	337.56	321.33
SEm (±)	7.47	7.18	11.63
CD (0.05)	NS	23.428	NS
Sub plots			
F_1	321.00	331.40	322.33
F_2	309.26	300.40	301.80
F_3	290.13	291.06	289.20
SEm (±)	6.32	6.75	5.07
CD (0.05)	18.665	19.917	14.981
Interaction			
C_1F_1	317.33	334.66	318.00
C_1F_2	305.00	307.00	306.33
C_1F_3	289.00	298.67	285.00
C_2F_1	319.66	365.66	291.00
C_2F_2	307.67	328.66	279.00
C_2F_3	297.66	319.33	257.67
C_3F_1	325.67	307.33	324.67
C_3F_2	301.66	291.00	305.33
C_3F_3	299.67	283.67	295.66

C_4F_1	321.67	280.00	345.00
C_4F_2	318.33	249.67	306.66
C_4F_3	300.00	236.00	288.33
C_5F_1	320.66	369.33	333.00
C_5F_2	313.67	325.66	311.67
C_5F_3	264.33	317.67	319.33
SEm (±)	13.76	14.26	11.35
CD (0.05)	NS	NS	NS

(rice-rice-fallow(C_1), rice-rice-sweet potato(C_2), rice-sweet potato-amaranthus(C_3), rice-(cassava+bush cowpea)-daincha(C_4), rice-rice-daincha(C_5) and F_1:Full FYM+Full N+Full P+Full K(As per the recommendation of Kerala Agricultural University), F_2:3/4 FYM+3/4 N+3/4 P+Full K and F_3 :1/2 FYM+1/2 N+1/2 P + Full K)

4.3.Soil Temperature

The influence of different cropping systems and fertilizer doses on soil temperature during *kharif, rabi* and summer crops are given in Table 3.

The main plot, sub plot and interaction effects were found to be non-significant with respect to soil temperature during *kharif* season. Results showed that during both *rabi* and summer season, there was significant difference in soil temperature due to cropping systems and fertilizer doses. During rabi, rice (C_2) recorded the highest soil temperature (30.34 ºC) and was on par with C_5 (30.12 ºC) and C_1 (29.96 ºC). However, cassava+bush cowpea (C_4) recorded the lowest soil temperature (26.93 ºC). During summer, C_4 recorded the highest soil temperature (30.35 ºC) and was on par with C_3 (30.18 ºC) and C_5 (29.14 ºC). However, C_2 recorded the lowest soil temperature (27.06 ºC). It may be due to the fact that, green manuring reduces soil bulk density. CO_2 emission showed an increasing trend when bulk density decreases. Hence, soil temperature also showed an increasing trend. Similar results were obtained by Toufeeq [17].

Among the fertilizer doses, F_1 (Full FYM+ full N, P, K) recorded the highest soil temperature (30.58 ºC) during *rabi*. While the lower soil temperature (27.48 ºC) was recorded in F_3 (½ FYM+ ½ N+ ½ P+ full K). During summer, F_1 (Full FYM+ full N, P, K) recorded the highest soil temperature (31.34 ºC) and the lowest soil temperature (26.67 ºC) was recorded in F_3 (½ FYM+ ½ N+ ½ P+ full K). It may be due to the fact that CO_2 flux was linearly related with soil temperature. Soil temperature increases the processes such as organic matter decomposition, oxidation, microbial and root activity, and thus carbon mineralization accelerates. This will lead to the increase in CO_2 emission from the soil. Similar results were obtained by Toufeeq [17]. The interaction effect on soil temperature in soil was not significant during the three seasons.

Table 3. Effect of cropping systems and fertilizer doses on soil temperature, ºC

Treatments	**Soil Temperature**		
Main plots	***Kharif***	***Rabi***	***Summer***
C_1	29.70	29.96	28.08
C_2	29.82	30.34	27.06
C_3	29.32	28.26	30.18
C_4	29.60	26.93	30.35
C_5	30.07	30.12	29.14
SEm (±)	0.37	0.40	0.38
CD (0.05)	NS	1.325	1.263
Sub plots			
F_1	30.29	30.58	31.34
F_2	29.51	29.31	28.83
F_3	29.30	27.48	26.67
SEm (±)	0.35	0.18	0.40
CD (0.05)	NS	0.540	1.206

Interaction			
C_1F_1	30.60	31.43	30.56
C_1F_2	29.20	30.03	27.66
C_1F_3	29.30	28.43	26.03
C_2F_1	30.70	31.86	28.43
C_2F_2	29.46	30.90	26.90
C_2F_3	29.30	28.26	25.86
C_3F_1	29.73	29.56	33.06
C_3F_2	29.63	28.73	30.13
C_3F_3	28.60	26.50	27.36
C_4F_1	29.60	28.66	32.63
C_4F_2	29.56	26.30	30.83
C_4F_3	29.63	25.83	27.60
C_5F_1	30.83	31.36	32.00
C_5F_2	29.70	30.60	28.93
C_5F_3	29.70	28.40	26.50
SEm (±)	0.75	0.40	0.84
CD (0.05)	NS	NS	NS

(rice-rice-fallow(C_1), rice-rice-sweet potato(C_2), rice-sweet potato-amaranthus(C_3), rice-(cassava+bush cowpea)-daincha(C_4), rice-rice-daincha(C_5) and F_1:Full FYM+Full N+Full P+Full K(As per the recommendation of Kerala Agricultural University), F_2:3/4 FYM+3/4 N+3/4 P+Full K and F_3 :1/2 FYM+1/2 N+1/2 P + Full K)

4.4. Soil Moisture

Effect of different cropping systems and fertilizer doses on soil moisture during *kharif, rabi* and summer crops are given in fig. 1.

The main plot, sub plot and interaction effects were found to be non-significant with respect to soil moisture during both *kharif* and summer season. There was no significant variation in soil moisture due to main plot treatments and interaction effects in *rabi* season. Regarding sub plot treatments, significant variations was observed among fertilizer doses and F_1 (Full FYM+ full N, P, K) recorded the highest soil moisture (24.40%) and was on par with F_2 (¾ FYM+ ¾ N+ ¾ P+ full K) (23.46%). The lowest soil moisture (21.18%) was recorded in F_3 (½ FYM+ ½ N+ ½ P+ full K). Soil moisture content affects soil respiration, higher moisture content provides better conditions for microbial habitat activities, increasing microbial oxygen consumption and CO_2 production and emission from soil. Li et al., [18] reported that low moisture reduced the CO_2 emission rates and cumulative emissions. On contrary, Lee et al.[19] observed the negative effect of water filled pores on soil CO_2 emission. The main cause for this could be the reduction of the soil air-filled pore space resulting in reduced gaseous diffusivities.

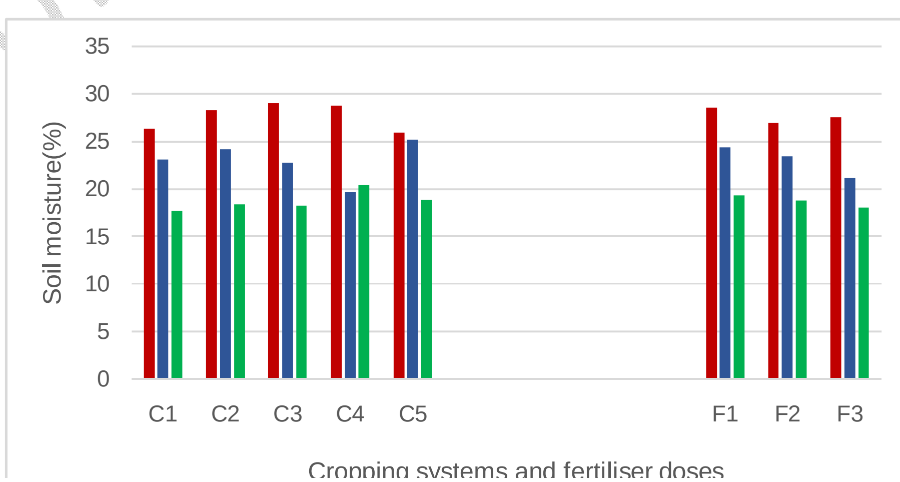

Fig.1. Effect of cropping systems and fertiliser doses on soil moisture(%)

(rice-rice-fallow(C_1), rice-rice-sweet potato(C_2), rice-sweet potato-amaranthus(C_3), rice-(cassava+bush cowpea)-daincha(C_4), rice-rice-daincha(C_5) and F_1:Full FYM+Full N+Full P+Full K(As per the recommendation of Kerala Agricultural University), F_2:3/4 FYM+3/4 N+3/4 P+Full K and F_3 :1/2 FYM+1/2 N+1/2 P + Full K)

5. CONCLUSION

From the findings, it could be apprehended that cropping systems including tuber crops such as cassava could be the alternative cropping systems in rice fields, which reduces CO_2 emission from the soil and also provides resilience which enhances nutrient availability in soil and yield. Reducing fertilizer doses with respect to the optimum need of cropping systems also helps to mitigate CO_2 emission.

REFERENCES

1. Rastogi M, Singh S, Pathak H. Emission of carbon dioxide from soil. Curr Sci 2002;82:510–517
2. Franzluebbers AJ, Doraiswamy PC.Carbon sequestration, and land degradation. In: Climate and land degradation, chapter 18. Springer, Berlin; 2007.
3. Yi C, Yan WC, Guo SJ, Yu WJ. Emission and fixation of CO2 from soil system as influenced by long-term application of organic manure in paddy soils. Agric. Sci. Chin. 2006;5(6):456–461
4. Fang HJ, Yang XM, Zhang XP. The progress of study on soil organic carbon dynamics in cropland. Chin. J. Soil Sci. 2003;34: 562–568.
5. Makoto S, Miyata A, Nagai H, Yamada T. Seasonal variation of carbon dioxide exchange in rice paddy field in Japan. Agr. Forest. Meteorol. 2005;135(1): 93– 109.
6. Zhang Q, Lei HM, Yang DW. Seasonal variations in soil respiration, heterotrophic respiration and autotrophic respiration of a wheat and maize rotation cropland in the North China Plain. Agric. Forest Meteorol. 2013;180: 34–43.
7. Liu W, Sun Z, Qu J, Yang C, Zhang X, Wei X. Correlation between root respiration and the levels of biomass and glycyrrhizic acid in Glycyrrhiza uralensis. Exp. Ther. Med.2017; 14 (3): 2323–2328.
8. Chen Z, Xu Y, Fan J, Yu H, Ding W. Soil autotrophic and heterotrophic respiration in response to different N fertilization and environmental conditions from a cropland in Northeast China. Soil Biol. Biochem.2017; 110: 103–115.
9. Yan L, Chen S, Huang J, Lin G. Differential responses of auto- and heterotrophic soil respiration to water and nitrogen addition in a semiarid temperate steppe. Global Change Biol. 2010;16 (8): 2345–2357.
10. Tu L, Hu T, Zhang J, Li X, Hu H, Liu L, Xiao Y. Nitrogen addition stimulates different components of soil respiration in a subtropical bamboo ecosystem. Soil Biol. Biochem.2013; 58: 255–264.
11. KAU (Kerala Agricultural University). Package of Practices Recommendations: Crops (15th Ed.). Kerala Agricultural University, Thrissur, 393p;2016
12. Gopinath PP, Parsad R, Joseph B, Adarsh VS. GRAPES: General Rshiny Based Analysis Platform Empowered by Statistics.2020. Accessed 29 MaY 2023 Available: https://www.kaugrapes.com/home. version 1.0.0. DOI: 10.5281/zenodo.4923220
13. Hasselquist NJ, Metcalfe DB, Hogberg P. Contrasting effects of low and high nitrogen additions on soil CO2 flux components and ectomycorrhizal fungal sporocarp production in a boreal forest. Global Change Biol. 2012;18 (12): 3596–3605.
14. Chen F, Yan G, Xing , Zhang J, Wang Q, Wang H, Huang B, Hong Z, Dai G, Zheng X, Liu T. Effects of N addition and precipitation reduction on soil respiration and its components in a temperate forest. Agr. Forest Meteorol. 2019;271: 336–345.

15. Zhong Y, Yan W, Shangguan Z. Impact of long-term N additions upon coupling between soil microbial community structure and activity, and nutrient-use efficiencies. Soil Biol. Biochem. 2015;91: 151–159.
16. Rajalekshmi K, Bastin B. Potential of wastelands for carbon sequestration-A review. IJCS, 2020;8(3):2873-2881.
17. Toufeeq S. Soil CO_2 emission under different tillage practices in redloam/laterite, clay and coastal sandy soils of Kerala, Doctoral dissertation, Academy of Climate Change Education and Research, Vellanikkara.2015.
18. Li LJ, You MY, Shi HA, Ding XL, Qiao YF, Han XZ. Soil CO2 emissions from a cultivated Mollisol: Effects of organic amendments, soil temperature, and moisture. European Journal of Soil Biology. 2013 Mar 1;55:83-90.
19. Lee MS, Nakane K, Nakatsubo T, Mo WH, Koizumi H. Effects of rainfall events on soil CO_2 flux in a cool temperate deciduous broad-leaved forest. Ecol Res.2002; 17(1): 401–409.