

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(C₁), rice-rice-sweet potato(C₂), rice-sweet potato-amaranthus(C₃), rice-(cassava+bush cowpea)-daincha(C₄), rice-rice-daincha(C₅)) and three fertilizer doses as sub plots (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) replicated thrice. Results showed that, during *kharif*, *rabi* and summer seasons, F₁ (Full FYM+ full N, P, K) recorded the highest CO₂ emission (321, 331.4 and 322.33 ppm respectively) and the lowest CO₂ emission (290.13, 291.06 and 289.20 ppm respectively) was recorded in F₃ (½ FYM+ ½ N+ ½ P+ full K). Also, CO₂ flux was linearly related with soil temperature.

Keywords: CO₂ emission, rice based cropping systems, tuber crops, nutrient levels (avoid using words from the title as keywords)

1. INTRODUCTION

A major greenhouse gas that accounts for 60% of the entire greenhouse effect is carbon dioxide (CO₂) [1]. It has been shown that vegetation and soils serve as important atmospheric CO₂ storage sinks [2]. According to reports, the amount of CO₂ 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 CO₂ levels, bringing up around one-fourth of all CO₂ 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 CO₂ budgets. In addition to weather, management strategies like tillage and N fertilisation might have a significant impact (positive or negative impact?) on soil CO₂ emission [6] [7]. Generally, soil moisture and temperature have been identified as the main sources of (factors that influence) soil CO₂ 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 CO₂ emissions has an impact on the structure, fertility and productivity of the soil. Therefore, minimising CO₂ emissions through soil carbon sequestration is extremely important. Scarce information on CO₂ emission from diverse rice based cropping systems under different nutrient levels has forced (led) us to carry out the research. It was hypothesized that emission of CO₂ may vary with the various rice based cropping systems and different nutrient levels. The objectives of the research were to determine the rates of CO₂ 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 CO₂ emission in soil.

The next paragraph and table 1 do not make any reference to materials and methods). To solve this issue, you can create another topic, as follows:

2. PHYSIOGRAPHICAL ASPECTS

The study was conducted in the double cropped low land rice fields of IFSRS (Integrated Farming Systems Research Station) (the acronym must come after the complete name) located at Karamana, Thiruvananthapuram, Kerala (which country? this is important for foreign readers). The experimental site is geographically located at 8° 28' 43" N latitude and 76° 57' 46" E longitude [] and an

altitude of 5m above mean sea level (altitude is always above the sea level). A warm humid tropical climate prevails over the experimental site. The maximum temperature during virippu season (a foreign reader will not understand what is Virippu season, please, explain. Are you referring to winter or summer?) varied (do not use the past tense: "varies from...") from 30.64 °C to 32.57 °C and minimum from 23.36 °C to 26.64 °C (use round numbers for temperature). The relative humidity varied (varies) from 75.64 to 89.78 per cent (use %). The total rainfall received (this is redundant) during the season (which season?) was 1263.7 mm. During the Mundakan season (what is Mundakan season. Are you referring to winter or summer?) the maximum temperature varied between 31.07 °C and 33.28 °C and the minimum temperature between 21.35 °C and 26.14 °C. The relative humidity ranged from 77.64 to 94.14 per cent (%). The total rainfall received during the season was 437.4 mm. The minimum temperature during the summer crop season 2020 varied from 21.71 to 24.92 °C while the maximum from 30.68 to 33.92 °C. The relative humidity varied from 76.85 to 93.14 per cent (%). The total rainfall received during the crop season was 782.06 mm. The soil was (is) sandy clay (according to table 1, the soil is formed of 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 were (are) shown in Table 1. (what are the sources of these physiographical data?)

Table 1. Physical and chemical properties of soil (what are the sources of these soil data? If the data are from this work, they should be in the "results")

Sl. No.	Parameters	Content	Rating
Chemical and physical properties (this line should be the first of the table as you did with physical properties)			
1	Soil reaction (pH)	5.2	Moderately Acidic
2	Electrical conductivity (1:2.5) (dSm ⁻¹) This is a physical property	0.20	Normal
3	Organic carbon (%)	1.1	Medium
4	Available N (kg ha ⁻¹)	255.00	Medium
5	Available P (kg ha ⁻¹)	34.8	High
6	Available K (kg ha ⁻¹)	130	Medium
Physical properties (delete) Granulometric distribution			
Sl. No.	Fractions	Content (%)	Soil texture- Sandy clay loam Clayey sand loam
1	Coarse sand (what about medium, fine and very fine sand? I think here you are referring to "sand", not "coarse sand")	72.9	
2	Silt	07.1	
3	Clay	20.0	

(The first column of the table can be deleted)

3. MATERIALS AND METHODS

The experiment was laid out during 2020-21 at Integrated Farming System Research Station, Karamana, Trivandrum, Kerala (you already informed the location in the previous paragraph/ now and then you must use the acronym IFSRS instead of the long name). 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 (do not use capital letters). Sub plots were different fertilizer levels viz, F1: Full FYM+FullN+FullP+FullK (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 MOP. The following observations were recorded to study the effect of different cropping systems and nutrient levels on CO₂ emission from soil.

CO₂ emission from soil

Carbon dioxide release from soil was recorded using CO₂ sensor- GE Telaire ® 7001 CO₂/Temperature monitor (GE sunsing, USA) and expressed in ppm.

Soil Temperature

The soil temperature (°C) 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.

Statistical Analysis

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

3.RESULTS AND DISCUSSIONS

3.1. CO₂ Emission, ppm

The results pertaining to the effect of different treatments on CO₂ emission in soil during three seasons are given in Table 2.

During *kharif*, *rabi* (explain these terms in the introduction, they sound to be local) and summer seasons, F₁ (Full FYM+ full N, P, K) recorded the highest CO₂ emission (321,331.4 and 322.33 ppm respectively) and the lowest CO₂ emission (290.13, 291.06 and 289.20 ppm respectively) was recorded in F₃ (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 CO₂ 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]. In the beginning of a sentence, use "Nitrogenium" instead of N. N 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 (C₄) recorded the lowest CO₂ emission (255.22). 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 CO₂ emission in soil, ppm

Treatments	CO ₂ emission(ppm)		
	<i>Kharif</i>	<i>Rabi</i>	<i>Summer</i>
Main plots			
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 (\pm)	6.32	6.75	5.07
CD (0.05)	18.665	19.917	14.981
Interaction			
C ₁ F ₁	317.33	334.66	318.00
C ₁ F ₂	305.00	307.00	306.33
C ₁ F ₃	289.00	298.67	285.00
C ₂ F ₁	319.66	365.66	291.00
C ₂ F ₂	307.67	328.66	279.00
C ₂ F ₃	297.66	319.33	257.67
C ₃ F ₁	325.67	307.33	324.67
C ₃ F ₂	301.66	291.00	305.33
C ₃ F ₃	299.67	283.67	295.66
C ₄ F ₁	321.67	280.00	345.00
C ₄ F ₂	318.33	249.67	306.66
C ₄ F ₃	300.00	236.00	288.33
C ₅ F ₁	320.66	369.33	333.00
C ₅ F ₂	313.67	325.66	311.67
C ₅ F ₃	264.33	317.67	319.33
SEm (\pm)	13.76	14.26	11.35
CD (0.05)	NS	NS	NS

(rice-rice-fallow(C₁), rice-rice-sweet potato(C₂), rice-sweet potato-amaranthus(C₃), rice-(cassava+bush cowpea)-daincha(C₄), rice-rice-daincha(C₅) and F₁:Full FYM+FullN+FullP+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)

3.2. 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 (C₂) recorded the highest soil temperature (30.34°C) and was on par with C₅ (30.12 °C) and C₁ (29.96 °C). However, cassava+bush cowpea (C₄) recorded the lowest soil temperature (26.93 °C). During summer, C₄ recorded the highest soil temperature (30.35°C) and was on par with C₃ (30.18 °C) and C₅ (29.14 °C). However, C₂ recorded the lowest soil temperature (27.06 °C). It may be due to the fact that, green manuring reduces soil bulk density. CO₂ 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, F₁ (Full FYM+ full N, P, K) recorded the highest soil temperature (30.58 °C) during *rabi*. While the lower soil temperature (27.48 °C) was recorded in F₃ (½ FYM+ ½ N+ ½ P+ full K). During summer, F₁ (Full FYM+ full N, P, K) recorded the highest soil temperature (31.34 °C) and the lowest soil temperature (26.67 °C) was recorded in F₃ (½ FYM+ ½ N+ ½ P+ full K). It may be due to the fact that CO₂ 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 CO₂ 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, °C

Treatments	Soil Temperature		
	<i>Kharif</i>	<i>Rabi</i>	<i>Summer</i>
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 ₁ F ₁	30.60	31.43	30.56
C ₁ F ₂	29.20	30.03	27.66
C ₁ F ₃	29.30	28.43	26.03
C ₂ F ₁	30.70	31.86	28.43
C ₂ F ₂	29.46	30.90	26.90
C ₂ F ₃	29.30	28.26	25.86
C ₃ F ₁	29.73	29.56	33.06
C ₃ F ₂	29.63	28.73	30.13
C ₃ F ₃	28.60	26.50	27.36
C ₄ F ₁	29.60	28.66	32.63
C ₄ F ₂	29.56	26.30	30.83
C ₄ F ₃	29.63	25.83	27.60
C ₅ F ₁	30.83	31.36	32.00
C ₅ F ₂	29.70	30.60	28.93
C ₅ F ₃	29.70	28.40	26.50
SEm (±)	0.75	0.40	0.84
CD (0.05)	NS	NS	NS

(rice-rice-fallow(C₁), rice-rice-sweet potato(C₂), rice-sweet potato-amaranthus(C₃), rice-(cassava+bush cowpea)-daincha(C₄), rice-rice-daincha(C₅) and F₁:Full FYM+FullN+FullP+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)

3.3. Soil Moisture

Effect of different cropping systems and fertilizer doses on soil moisture during *kharif*, *rabi* and summer crops are given in Table 4.

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 were observed among fertilizer doses and F₁ (Full FYM+ full N, P, K) recorded the highest soil moisture (24.40%) and was on par with F₂ (3/4 FYM+ 3/4 N+ 3/4 P+ full K)(23.46%). The lowest soil moisture (21.18%) was recorded in F₃ (1/2 FYM+ 1/2 N+ 1/2 P+ full K). Soil moisture content affects soil respiration, higher moisture content provides better conditions for microbial habitat activities, increasing microbial oxygen consumption and CO₂ production and emission from soil. On contrary, Lee et al.[18] reported the negative effect of water filled pores on soil CO₂ emission. The main cause for this could be the reduction of the soil air-filled pore space resulting in reduced gaseous diffusivities.

Table 4. Effect of cropping systems and fertilizer doses on soil moisture, %

Treatments	Soil moisture		
	<i>Kharif</i>	<i>Rabi</i>	<i>Summer</i>
Main plots			
C ₁	26.40	23.16	17.78
C ₂	28.35	24.23	18.41
C ₃	29.04	22.74	18.27
C ₄	28.76	19.72	20.41
C ₅	25.98	25.22	18.87
SEm (±)	0.73	1.60	0.63
CD (0.05)	NS	NS	NS
Sub plots			
F ₁	28.59	24.40	19.36
F ₂	26.94	23.46	18.85
F ₃	27.59	21.18	18.04
SEm (±)	0.47	0.70	0.63
CD (0.05)	NS	2.08	NS
Interaction			
C ₁ F ₁	26.60	24.13	18.70
C ₁ F ₂	25.46	22.76	16.90
C ₁ F ₃	27.13	22.60	17.76
C ₂ F ₁	29.90	24.50	18.50
C ₂ F ₂	26.30	23.23	18.76
C ₂ F ₃	28.86	24.96	17.96
C ₃ F ₁	29.30	25.70	18.23
C ₃ F ₂	29.70	25.56	18.93
C ₃ F ₃	28.13	16.96	17.66
C ₄ F ₁	29.53	21.16	20.86
C ₄ F ₂	27.83	20.83	21.50
C ₄ F ₃	28.93	17.16	18.86
C ₅ F ₁	27.63	26.53	20.53
C ₅ F ₂	25.43	24.93	18.16
C ₅ F ₃	24.90	24.20	17.93
SEm (±)	1.05	1.57	1.31
CD (0.05)	NS	NS	NS

(rice-rice-fallow(C₁), rice-rice-sweet potato(C₂), rice-sweet potato-amaranthus(C₃), rice-(cassava+bush cowpea)-daincha(C₄), rice-rice-daincha(C₅) and F₁:Full FYM+FullN+FullP+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)

4.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 CO₂ emission from the soil and also provides resilience which enhances nutrient availability in soil, yield and profitability(**how it increases profitability?**). Reducing fertilizer doses with respect to the optimum need of cropping systems also helps to **mitigate** CO₂ emission.

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