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Effect of Residue and Nutrient Management on Productivity, Profitability and Greenhouse Gas Emission of Cowpea in Intensified Rice-Based Cropping Systems

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ABSTRACT

Rice based cropping systems are the most predominantly grown systems in India contributing a major share to India's food grain production. However, systems i.e., rice-rice and rice-wheat brought us second generation sustainability issues over long run. Cowpea being a multi-role legume crop can be considered for the intensification of rice-based system with limited resources and its residue having lower C:N ratio can easily decompose in soil and enhance soil fertility. Following experiment was conducted at Institutional Research Farm, ICAR-National Rice Research Institute, Cuttack, Odisha during *kharif, rabi* and summer season during 2017-18 and 2018-19. The treatments were laid out in split plot design and consisted of three replications. The main plot consisted of two rice-based cropping systems i.e., rice-maize-cowpea (R-M-C) and rice-groundnut-cowpea (R-G-C), sub-plots consisted of five nutrient and residue management practices i.e., C-C-C, R-R-R, RI+R_{75}-R-R, RI+R_{75}-SM+R-R and RI+R_{75}-SM+R-R_{50}. The pooled value for the season 2017-18 and 2018-19 revealed that, RI+R_{75}-SM+R-R and RI+R_{75}-SM+R-R_{50} resulted higher yield i.e., pod yield, seed yield, stover yield, HI, nutrient content, nutrient uptake, economic return i.e., gross return, net return and B:C ratio, higher CH_4 flux and lower N_2O flux than R-R-R. Between two cropping systems, R-M-C cropping system recorded highest yield and is more feasible to take over R-G-C. Among nutrient management, RI+R_{75}-SM+R-R recorded higher growth and yield but due to consistent residue retention and incorporation, even if using 50% of recommended dose of fertilizer in cowpea i.e., RI+R_{75}-SM+R-R_{50} recorded similar growth, yield, economic return, and even higher B:C ratio than RI+R_{75}-SM+R-R and recommended. Cowpea residue incorporation and 25% reduced dose of chemical fertilizer application in rice crop, rice straw mulch in *rabi* maize and 50% reduction in chemical fertilizer application in summer cowpea (RI+R_{75}-SM+R-R_{50}) received highest cowpea yield, and economic return and this system-based nutrient management should be recommended in R-M-C cropping system.

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INTRODUCTION

Rice and wheat are also considered as two central pillars of food security in India (Banjara *et al.* 2021) but extensive cultivation of both the crops has raised several sustainability issues i.e., environmental degradation (Bhatt *et al.* 2016), reduction in soil health (Jat *et al.* 2019), multi-nutrient deficiency (Ladha *et al.* 2003), decline in water use efficiency (Humphreys *et al.* 2010), decline in factor productivity (Dar *et al.* 2017), reduction in biodiversity (Singh *et al.* 2019), increase in incidence of pests (Gangwar and Prasad 2005) and yield stagnation (Bhatt *et al.* 2016, Banjara *et al.* 2021). All these negative impacts of rice-wheat system, lead to think of crop diversification as an alternative in irrigated tracks to maintain the soil as well as environmental quality and sustain the productivity. Cropping intensity in irrigated ecosystem of E-India is as low as 140%, although can be enhanced to 300% by adopting suitable diversified cropping system (Singh *et al*. 2012). In the irrigated coastal belt of Odisha, groundnut is a common crop after rice. However, groundnut cultivation is associated with several constraints i.e., S-mining, harvesting as well as shelling due to unavailability of manpower, processing for oil extraction or value-added products and marketing. Maize is an emerging crop spreading all over India as well as SE-Asia could be a candidate crop for diversification because of its profitability, high productivity, less water requirement and more profitability. Besides, human consumption and livestock feeding of maize can be used for several other purposes i.e., production of biofuel, alcohol, and biodegradable plastic. It is also nutritionally superior to widely consumed rice and wheat, containing 10% protein, 72% starch, 4.8% fat, 5.8% fiber and 1.7% ash (Zilic *et al.* 2011). This inclusion of summer legume may increase the economic yield, sustain the nutrient cycling by reducing the dependance on chemical fertilizers (Kumar *et al.* 2019), employment generation, enhance diversification and habitat conservation, provide green fodder to livestock, and improves soil quality (Choudhury *et al.* 2013). Among different legume crops, cowpea is one of the important pulse crops and is utilized as grain, vegetable or fodder crop. Inclusion of legume like cowpea enhanced the soil fertility and productivity of the system, reduced chemical fertilizer use and balanced the input-output ratio compared to the cereal-cereal system (Giri *et al.* 2020). To sustain the intensive agriculture for feeding the ever-increasing population, use of organic amendments or crop residue incorporation act as an alternative approach. Plant residues have a great potential to maintain soil fertility on their decomposition (Yuvaraj *et al.* 2020). Crop residue quality and quantity have significant impact on the resilience of soil quality and agronomic productivity (Jena *et al.* 2022). There are different crop residue management options available i.e., *in situ* burning, slash and incorporation, mulching, burnt residue incorporation, slash and pack, biochar preparation and incorporation, composting and application (Gliesman 2012), but return of crop residue results in improvement of soil quality as it increases nutrient accumulation, increases organic matter and improves soil structure (Nottidge *et al.* 2010). However, the adoption of legume incorporation in cropping system is poor because of several physical and socio-economic constraints (Ojiem *et al.* 2006).

Keeping all the above benefits and constraints, present investigation was designed to study the effect of residue and nutrient management on growth, productivity, GHG emission and economics of cowpea in intensified cropping system.

MATERIALS AND METHODS

The experiment was conducted at Institute Research Farm of ICAR- National Rice Research Institute, Cuttack (India), 20°27' N longitude, 85°56' E latitude, 24 m above mean sea level since 2012-13, but in this article, the observation taken during 2017-18 and 2018-19 has been presented and interpreted. The soil of the experimental site was sandy loam in texture, acidic (6.42) in nature, low in organic C (0.48%), available N (214.5 kg/ha), medium in available P_2O_5 (34.29 kg/ha) and available K_2O (183.05 kg/ha). Total rainfall received during the cowpea growth period (summer season) was 418 and 714.8 mm in the year 2018 and 2019, respectively. Higher rainfall was recorded in the year 2019, but the distribution of rainfall was uniform during 2018. During 2019, higher rainfall intensity from flowering to pod filling stage had negative impact on cowpea yield. Due to cyclone "*Fani*", complete crop loss recorded at early stage during 2019 and resowing was done after the field reached optimum moisture condition. The weekly mean minimum temperature during 2017-18 and 2018-19 ranged from 22 to 27.4°C and 24.4 to 26.7°C, respectively. The weekly mean maximum temperature during 2018 and 2019 ranged from 29.7 to 38.8°C and 30.4 to 38.6°C, respectively. The weekly mean morning time relative humidity (RH-I) during 2018 and 2019 ranged from 89.3 to 96.0% and 80.4 to 90.7%, respectively. The mean evening time relative humidity (RH-II) during 2018 and 2019 ranged from 41.1 to 86.6% and 59.3 to 77.1%, respectively. The average variation of weekly mean wind velocity during 2018 was 2.7 to 11.6 km h^{-1} but the same couldn't be recorded during 2019 due to the instrumental damage by cyclone "*Fani*". The mean weekly rate of evaporation ranged from 1.9 to 7.0 mm and 1.5 to 5.9 mm, respectively during 2018 and 2019. The mean weekly sunshine duration during 2018 and 2019 ranged from 1.9 to 8.3 h and 2.7 to 6.7 h respectively.

The present experiment was laid out in a split plot design with two cropping systems and five nutrient management options in main plot and sub plot, respectively and replicated thrice. The cropping systems studied were Rice-maize-cowpea (C_1) and Rice-groundnut-cowpea (C_2) involving three crops in three seasons i.e., *kharif*, *rabi* and summer, respectively. Nutrient management options evaluated were: Control-control-control (F_1) where no fertilizer applied to the crops, RDF-RDF-RDF (F_2) where recommended dose of fertilizers applied to each component crops, RI+RDF_{75}-RDF-RDF (F_3) where cowpea residue was incorporated before transplanting of rice and 75% of recommended dose of fertilizer for rice was applied, RI+RDF_{75}-SM+RDF-RDF (F_4) where similar combination as of F_3 was taken along with rice residue was used as mulch in *rabi* season crops, and RI+RDF_{75}-SM+RDF-RDF_{50} (F_5) where similar treatments were used as of F_4 and 50% of recommended dose of fertilizer was used in summer cowpea. In these treatment combinations, where control indicates no fertilizer application, RDF indicates recommended dose of fertilizers for respective crops, RI indicates cowpea residue incorporation in succeeding rice crop before transplanting and SM indicates rice straw mulching in succeeding groundnut and maize. RDF_{50} and RDF_{75} refers to 50% and 75% of RDF to respective crops. The test crop variety for *kharif* season rice "Naveen" was transplanted at a row to row and plant to plant spacing of 15 cm × 15 cm. The recommended dose of fertilizer applied was 80:40:40 kg N, P_2O_5 and K_2O/ha, respectively. Half of the recommended dose of nitrogen along with full dose of phosphorus and potassium was applied to rice after final land preparation before transplanting and remaining half of nitrogen was applied in two splits at active tillering and panicle initiation respectively. The test variety for maize was "Vijaya-22" which was sown at a R-R and P-P spacing of 60 cm × 20 cm and applied with the recommended fertilizer dose of 150:50:50 kg N, P_2O_5 and K_2O/ha, respectively. Half of the recommended dose of nitrogen along with full dose of phosphorus and potassium was applied at the time of final land preparation and remaining half of nitrogen was applied in two splits at knee high and initiation of tasseling, respectively. The test variety for groundnut was "Smruti" which was sown at a R-R and P-P spacing of 30 cm × 10 cm and applied with the recommended fertilizer dose of 20:40:20 kg N, P_2O_5 and K_2O/ha, respectively. Full dose of RDF was applied before sowing as basal application. The test variety for cowpea was "Kashi Kanchan" which was sown at a R-R and P-P spacing of 30 cm × 10 cm and the recommended dose of fertilizer applied was 20:40:20 kg N, P_2O_5 and K_2O/ha, respectively. Full dose of RDF was applied before sowing as basal application. During land preparation of rice, the preceding crop residue of cowpea was incorporated in the soil in every plot except control (F_1) and RDF (F_2). The rice straw was applied as mulch in succeeding maize and groundnut @ 6 t/ha in nutrient management treatment F_4 and F_5. In cowpea, the recommended dose of fertilizer was applied to all treatments except F_1 (control) and F_5 (50% of the nutrient recommended nutrient application). Other agronomic management practices like weeding, irrigation, agrochemical application was similar irrespective of treatment variability.

After crop reached harvesting stage, the beans were harvested at 3-5 days interval from net plot to estimate the pod yield and stover sampling was done to estimate the stover yield and harvest index by converting them to t ha^{-1}. Similarly, dry pods were collected from one square meter that was tagged within the net plot area to estimate the seed yield. The economic return was calculated using cost involved in each treatment, output from each treatment, calculating gross return, net return, and B:C ratio. For greenhouse gas sampling, aluminum base plate was placed in the field and sampling was done from the gas chamber by stopcock syringe at 0 min and 30 min. Due care was taken to ensure proper mixing of gas inside the gas sampling chamber and any leakage of gas from the chamber. Gas sampling was done at 3, 7, 15 30, 45 days after sowing and 7 days after harvesting. Methane and nitrous oxide were estimated using Chemito 2000 gas chromatograph (M/s Thermo Scientific) equipped with a flame ionization detector (FID) for CH_4 and electron capture detector (ECD) for N_2O. The cumulative seasonal methane and nitrous oxide emission was calculated using daily flux data. Fluxes of CH_4 and N_2O were calculated by successive linear interpolation of the average emissions on the sampling days, assuming the emissions followed a linear trend during the periods when no sampling was done (Datta *et al.* 2009). Cumulative CH_4 and N_2O emissions for the entire cropping period were computed by plotting the flux values against the days of sampling and were expressed as kg ha^{-1}. Cumulative CH_4 and N_2O emissions were calculated using the formulae described by Cai *et al.* (2013).

Cumulative CH_4 or N_2O emission=

$$\left(\sum_{i=0}^{n}\left(\left(\frac{F_i + F_{i+1}}{2}\right) \times (t_{i+1} - t_i)\right)\right) \times 0.24$$

Where F is the CH_4 or N_2O flux (mg N_2O/CH_4 m^{-2} h^{-1}), i is the i^{th} measurement, the term (t_i+1-t_i) is the time in days between two adjacent measurements, and n is the total number of measurements.

Statistical analysis

The data generated from the experiment during 2017-18 and 2018-19 were pooled and analyzed using the standard statistical procedure suggested by Gomez and Gomez (1984) for split plot design for the analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Yield and yield attributes

The yield attributes of cowpea i.e., number of branches per plant and beans per plant were not significantly affected by different rice-based cropping systems i.e., R-M-C and R-G-C but significantly influenced by nutrient management (Table 1). Highest number of branches per plant (7.38) was recorded with RI+R_{75-}+SM+R–R which was at par with RI+R_{75-}+SM+R-R_{50}, but 55.4% and 14.9% higher than C-C-C and R-R-R respectively. Similarly, highest number of beans $plant^{-1}$ (25.3) was recorded with RI+R_{75-}+SM+R-R, being at par with RI+R_{75-}+SM+R-R_{50}. RI+R_{75-}+SM+R–R recorded 90.2% and 18.8% higher beans per plant than C-C-C and R-R-R respectively.

Seed yield and beans yield of cowpea were significantly influenced by different types of rice-based cropping systems (Table 1). Significantly higher seed and bean yield was recorded with R-M-C than R-G-C. Significantly higher seed yield and beans yield in

Table 1. Effect of residue and nutrient management on yield attributes and yield of cowpea (Pooled over two years).

Treatments	Branches $plant^{-1}$	Beans $plant^{-1}$	Seed yield (t ha^{-1})	Bean yield (t ha^{-1})	Harvest index
Cropping system (C)					
R-M-C	6.40	21.7	0.80	4.65	0.28
R-G-C	6.33	21.1	0.70	4.09	0.26
SE(m)	0.19	0.4	0.01	0.05	0.01
CD	NS	NS	0.08	0.28	NS
Nutrient management (F)					
C-C-C	4.75	13.3	0.38	2.00	0.25
R-R-R	6.42	21.3	0.77	4.29	0.25
RI+R_{75-} R-R	6.42	22.0	0.84	4.87	0.28
RI+R_{75-} SM+R-R	7.38	25.3	0.89	5.37	0.28
RI+R_{75-} SM+R-R_{50}	6.88	25.0	0.87	5.32	0.28
SEm±	0.19	0.6	0.02	0.11	0.01
CD (p= 0.05)	0.58	1.9	0.06	0.32	NS
Interaction (C×F)	NS	NS	NS	0.46	NS

Table 2. Effect of residue and nutrient management on macro-nutrient content and uptake of cowpea (Pooled over two years).

Treatments	Grain nutrient content (%) N	P	K	Straw nutrient content (%) N	P	K	Nutrient uptake (kg ha^{-1}) N	P	K
Cropping system (C)									
R-M-C	3.91	0.290	0.90	2.50	0.291	1.76	119.8	12.7	69.7
R-G-C	4.00	0.291	0.90	2.49	0.302	1.72	118.3	13.1	68.5
SE(m)	0.03	0.003	0.01	0.02	0.004	0.03	2.9	0.4	2.0
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management (F)									
C-C-C	3.83	0.278	0.87	2.41	0.265	1.66	59.3	6.0	34.2
R-R-R	3.92	0.281	0.92	2.46	0.306	1.81	124.7	13.9	76.5
RI+R_{75}-R-R	4.01	0.299	0.88	2.54	0.310	1.80	132.1	14.6	77.4
RI+R_{75}-SM+R-R	3.99	0.293	0.91	2.55	0.298	1.73	142.2	15.1	80.6
RI+R_{75}-SM+R-R_{50}	4.01	0.301	0.91	2.53	0.304	1.71	136.9	14.8	76.7
SEm±	0.05	0.006	0.01	0.04	0.013	0.04	2.4	0.5	2.3
CD (p=0.05)	NS	NS	NS	NS	NS	NS	7.2	1.5	6.9

R-M-C than R-G-C was due to intense rain during harvesting of cowpea in R-G-C cropping system, but cowpea harvesting in R-M-C escaped the intense rain due to early harvesting. Nutrient management also had significant influence on seed and bean yield of cowpea. Among nutrient management, highest seed yield (0.89 t ha^{-1}) recorded with RI+R_{75-}+SM+R–R which was 134.2% and 15.6% higher than C-C-C and R-R-R respectively. Highest bean yield (5.37 t ha^{-1}) recorded with RI+R_{75-}+SM+R–R which was 168.5% and 25.2% higher than C-C-C and R-R-R respectively. Increase in cowpea yield on crop residue incorporation was also reported by Ndiso *et al.* (2018).

Nutrient content and uptake

Nutrient content is mostly genetically driven and less affected by management factors. However,

Table 3. Effect of residue and nutrient management on micro-nutrient content and uptake of cowpea (Pooled over two years).

Treatments	Grain nutrient content (mg kg^{-1}) Zn	Fe	Mn	Cu	Straw nutrient content (mg kg^{-1}) Zn	Fe	Mn	Cu	Nutrient uptake (g ha^{-1}) Zn	Fe	Mn	Cu
Cropping system (C)												
R-M-C	26.63	54.83	19.19	4.64	18.65	59.93	35.96	3.18	86.80	255.87	142.72	14.91
R-G-C	26.47	54.84	19.36	4.51	18.00	60.13	35.76	3.29	83.87	252.85	142.59	14.98
SE(m)	0.05	1.31	0.18	0.03	0.36	0.77	0.77	0.04	0.99	7.55	3.45	0.31
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management												
C-C-C	26.21	56.24	19.34	4.62	17.45	59.60	34.78	3.18	42.12	131.14	71.54	7.62
R-R-R	25.75	52.75	18.61	4.34	17.47	57.03	34.86	3.12	86.71	258.77	148.73	15.34
RI+R75-R-R	27.63	56.75	20.23	4.96	19.80	63.84	37.17	3.50	99.94	295.71	161.46	17.76
RI+R75-SM+R-R	26.01	53.13	19.07	4.31	17.74	58.32	35.39	3.13	97.25	290.93	165.31	16.92
RI+R75-SM+R-R50	27.14	55.32	19.15	4.66	19.17	61.35	37.11	3.24	100.66	295.25	166.23	17.08
SEm±	0.56	1.52	0.42	0.16	0.63	2.72	0.92	0.10	2.06	9.75	4.59	0.55
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	6.19	29.24	13.75	1.66

comparatively higher nutrient content in residue incorporated treatments might be due to higher nutrient availability in rhizosphere and higher dry matter accumulation that enhanced the nutrient uptake by plant. Nutrient uptake was not significantly influenced by cropping systems, but nutrient management had significant impact on nutrient uptake of cowpea (Tables 2 - 3). Highest N uptake (142.2 kg ha^{-1}) was recorded with RI+R_{75-}+SM+R-R which was at par with RI+R_{75-}+SM+R–R_{50} and significantly higher compared to C-C-C, R-R-R and RI+R_{75}-R-R. The N uptake with RI+R_{75} -SM+R–R was 139.8% and 14.0% higher than C-C-C and R-R-R respectively. Highest P uptake (15.1 kg ha^{-1}) was recorded with RI+R_{75}-SM+R-R which was at par with other fertilizer applied treatments i.e., R-R-R, RI+R_{75}-R-R and RI+R_{75}-SM+R-R_{50}. The P uptake by RI+R_{75}-SM+R-R was 151.7% and 8.6% higher than C-C-C and R-R-R respectively. Highest K uptake (80.6 kg ha^{-1}) was recorded with RI+R_{75}-SM+R-R which was at par with other fertilizer applied treatments i.e., R-R-R, RI+R_{75}-R-R and RI+R_{75}-SM+R-R_{50}. The K uptake by RI+R_{75}-SM+R-R was 135.7% and 5.4% higher than C-C-C and R-R-R respectively.

Highest Zn uptake (100.66 g ha^{-1}) was recorded with RI+R_{75}-SM+R-R_{50} which was at par with RI+R_{75}-R-R and RI+R_{75}-SM+R-R. RI+R_{75}-SM+R-R_{50} recorded 138.9% and 16.1% higher Zn uptake than C-C-C and R-R-R respectively (Table 3). Highest Fe uptake (295.25 g ha^{-1}) was recorded with RI+R_{75}-SM+R-R_{50} which was at par with RI+R_{75}-R-R and RI+R_{75}-SM+R-R. RI+R_{75}-SM+R-R_{50} recorded 125.5% and 14.3% higher Fe uptake than C-C-C and R-R-R respectively. Highest Mn uptake (166.23 g ha^{-1}) was recorded with RI+R_{75}-SM+R-R_{50} which was at par with RI+R_{75}-R-R and RI+R_{75}-SM+R-R. RI+R_{75}-SM+R-R_{50} recorded 132.4% and 11.8% higher Mn uptake than C-C-C and R-R-R respectively. Highest Cu uptake (17.76 g ha^{-1}) was recorded with RI+R_{75}-R-R which was at par with RI+R_{75}-SM+R-R and RI+R_{75}-SM+R-R_{50}. RI+R_{75}-R-R recorded 130.7% and 15.8% higher Cu uptake than C-C-C and R-R-R respectively.

Economics

Higher cost of cultivation with respect to nutrient management was recorded in recommended dose of fertilizer application i.e., R-R-R, RI+R_{75}-R-R and RI+R_{75}-SM+R-R (₹45202/ha) followed by half of the recommended dose of fertilizer application in cowpea (₹43576/ha), and lowest in control (₹41950/ha). Gross return, net return, and B:C ratio of cowpea was significantly influenced by cropping systems i.e., R-M-C and R-G-C. Gross return (₹119870/ha), net return (₹75643/ha) and B:C ratio (1.69) was significantly higher in R-M-C than R-G-C. Highest economic output in rice-maize-cowpea was also recorded by Bastia *et al.* (2008). Nutrient management also significantly influenced the economic return of cowpea (Fig. 1). Highest gross return (₹138334/ha) was recorded with RI+R_{75}-SM+R-R which was at par with RI+R_{75}-SM+R-R_{50}. The net return obtained from RI+R_{75}-SM+R-R_{50} (₹93473/ha) was at par with RI+R_{75}-SM+R-R (₹93132/ha) and significantly higher than C-C-C, R-R-R and RI+R_{75}-R-R. Gross return recorded in RI+R_{75}-SM+R-R was 166.5 and 24.5% higher than C-C-C and R-R-R respectively. Net return recorded in RI+R_{75}-SM+R-R_{50} was 838.5 and 41.9% higher than C-C-C and R-R-R, respectively. Highest B:C ratio (2.15) was obtained with RI+R_{75}-SM+R-R_{50} which was significantly higher than C-C-C (0.24), R-R-R (1.46) and RI+R_{75}-R-R (1.78). Higher return on cowpea residue incorporation was also reported by Gangaiah *et al.* (2012).

GHG emission

Cumulative methane emission from cowpea crop was significantly higher in R-G-C (12.4 kg ha^{-1}) than R-M-C (10.1 kg ha^{-1}). However, the nitrous oxide emission was higher in R-M-C (148.6 g ha^{-1}) than R-G-C (115.5 g ha^{-1}). Nutrient management also had

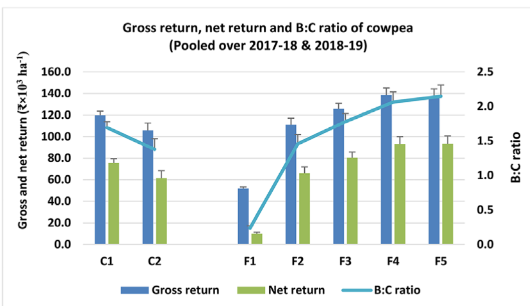

Fig. 1. Economics of cowpea.

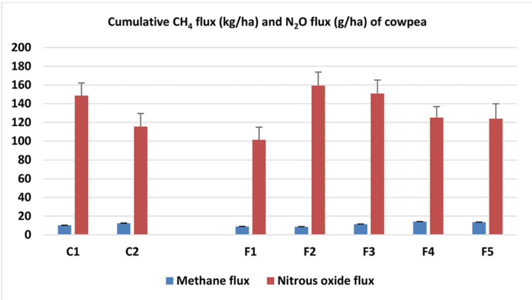

Fig. 2. Cumulative seasonal CH_4 and N_2O flux from cowpea.

significant impact on both cumulative methane and nitrous oxide emission from cowpea (Fig. 2).The highest cumulative methane emission (14.1kg ha^{-1}) from cowpea was recorded in RI+R_{75}-SM+R-R followed by RI+R_{75}-SM+R-R_{50} (13.5 kg ha^{-1}). The lowest cumulative methane emission (8.5 kg ha^{-1}) from cowpea was recorded in R-R-R. Cumulative methane emission from RI+R_{75}-SM+R-R was 60.2% and 65.9% higher than C-C-C and R-R-R respectively. The highest cumulative nitrous oxide emission (159.2 g ha^{-1}) from cowpea was recorded in R-R-R followed by RI+R_{75}-R-R (150.8 g ha^{-1}). The lowest cumulative nitrous oxide emission (101.3 g ha^{-1}) from cowpea was recorded in C-C-C. Cumulative nitrous oxide emission from R-R-R was 57.2% and 28.5% higher than C-C-C and RI+R_{75}-SM+R-R_{50} respectively. Higher methane emission from residue incorporated treatments is due to higher organic carbon status and higher microbial activity in soil. Enhanced methane emission in residue amended treatments reported by Jena *et al.* (2021). However, Frimpong *et al.* (2011) proposed that in tropical legume-cereal cropping system, combined application of high C:N ratio maize residue with low C:N ratio cowpea residue can minimize nitrous oxide emission.

CONCLUSION

Present study established that 25% chemical fertilizer substitution with cowpea crop residue incorporation in rice, straw mulching in *rabi* season crops and 50% reduction in recommended dose of fertilizer in cowpea gives similar yield and economic return compared to 100% recommended dose of fertilization in cowpea. Rice-based cropping systems in irrigated area of Eastern India can be intensified with short duration legume crop i.e., cowpea. Cowpea being a short duration and highly nutritious crop having narrow C:N ratio, its residue could be easily and rapidly decomposed in soil after incorporation and boost the microbe population near the rhizosphere leading to increased nutrient availability and the productivity of the component crops. In the present study, R-M-C recorded higher yield and can be suitably adapted in irrigated tract of eastern India than R-G-C. Cowpea residue incorporation and rice straw mulching in *rabi* season crop could build up soil phosphorus and even applying 50% of recommended dose of fertilizer application in cowpea similar yield and economic return could be achieved. Hence, cowpea residue incorporation during the land preparation for rice transplanting along with 25% reduction in recommended dose of fertilizer application in rice, rice straw mulching in *rabi* season crops and half of the recommended dose of fertilization in cowpea i.e., RI+R_{75}-SM+R-R_{50} in Rice-maize-cowpea (R-M-C) cropping system can be recommended for higher productivity and profitability.

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