

# IMPACT OF PADDY STRAW INCORPORATION ALONG WITH DIFFERENT FERTILIZER DOSES ON MINERAL N DYNAMICS AND GHG EMISSIONS

## ABSTRACT

**Aim:** An incubation experiment was conducted, which aimed to investigate  $\text{NH}_4^+$  and  $\text{NO}_3^-$  release pattern and GHG emissions as influenced by paddy residue decomposition ~~with time over a~~ 120 ~~days-day period~~.

**Study design:** Completely randomized block design

**Place and duration of study:** The study was conducted at Agrometeorology laboratory, CRIDA, Hyderabad. The experiment was conducted between 2021-22.

**Methodology:** Sampling was ~~done-performed-on-at~~ 2, 4, 6, 8, 10, 20, 30, 45, 60, 75, 90, 105 and 120 days after incubation (DAI). The treatments included control ( $T_1$ ), soil + N ( $T_2$ ), paddy residue + 100% RDN - 33:33:33 ( $T_3$ ), paddy residue + 100% RDN - 43:23:33 ( $T_4$ ), paddy residue + 100% RDN - 43:33:23 ( $T_5$ ), paddy residue + 10% extra RDN - 43:23:33 ( $T_6$ ). Fertilizer N was applied in three splits (first at initiation of experiment, second and third at 30 and 60 DAI respectively).

**Results:** Residue incorporation along with inorganic fertilizer significantly influenced  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N, as well as GHG emissions. After addition of each split, there was an increase in  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N contents. Significantly higher  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N was recorded in  $T_6$ , compared to other treatments. The cumulative  $\text{CO}_2$  and  $\text{N}_2\text{O}$  emissions were significantly higher in paddy residue + 10% extra RDN - 43:23:33 *i.e.*,  $296.63 \mu\text{g C g}^{-1}$  of soil and  $1.81 \mu\text{g N g}^{-1}$  of soil respectively, while ~~the lowest~~ ~~emission~~ was observed in control.

**Key Words:** Residue incorporation, Cumulative emissions,  $\text{NH}_4^+$  - N,  $\text{NO}_3^-$  - N, Residue decomposition

### Introduction:

Rice stands out as the predominant crop residue producer in Asia, contributing ~~a-to a~~ substantial 826 million tons, which makes up 84% of the world's total production. Traditionally, rice straw is harvested from fields in South Asia for utilization as cattle feed and various other purposes. On an average, rice crop residues contain 0.7% N, 0.23% P and 1.75% K. Therefore, the amount of NPK ~~contained~~ in rice crop residues produced is about  $22.13 \times 10^6$  and  $26.26 \times 10^6 \text{ year}^{-1}$  in Asia and the world, respectively [1]. From the perspective of farmers, burning is perceived as the most suitable method for rice straw disposal, not only due to its cost-effectiveness but also for its effectiveness as a pest control measure [2].

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The rapid decomposition of soil organic matter, leading to a swift loss of nitrogen, poses a significant challenge in maintaining soil fertility and raises environmental concerns. The application of water-soluble nitrogen fertilizers results in increased levels of available nitrogen, surpassing plant requirements, particularly early in the crop growth season. This ~~excess~~-nitrogen ~~excess~~ has the potential for ~~leaching~~, contributing to ~~the generation of~~-NO<sub>x</sub> gases ~~generation~~, including nitrous oxide (N<sub>2</sub>O), a greenhouse gas associated with global warming. The likelihood of N<sub>2</sub>O production from ~~the~~-soil is contingent upon favorable denitrification conditions, such as temperature, soil moisture, organic carbon levels and pH, emphasizing the intricate interplay between nitrogen management and environmental impacts [3].

A synchrony between soil N availability and plant N requirement is highly essential and also serves as an important factor contributing to increased ~~plant~~-N ~~plant~~ uptake and grain yields. As the most ~~of the~~-rice residue is being burnt before taking up the succeeding crop, it is leading to release ~~of~~-GHG emissions and environmental hazards. So, efficient management of rice residue is of major concern. Residue incorporation serves as one of the best residue management options, which improves soil fertility and reduces environmental pollution.

The C/N ratio of organic material is commonly considered as a pivotal factor in predicting net nitrogen (N) immobilization or mineralization during the decomposition of residues. ~~The quality of the residue plays a crucial role in influencing decomposition, and b~~Thus, ~~y~~by carefully managing the balance between N mineralization and immobilization, it is possible to regulate this process. Hence, strategically incorporating nitrogen fertilizer along with low-quality crop residues (residues having C:N ratio > 30:1) holds promise for effectively curbing nitrogen losses [4]. The initial decline in mineral nitrogen (N) status, due to immobilization, resulting from the incorporation of crop residues with a high carbon-to-nitrogen (C/N) ratio, may contribute to a reduction in subsequent nitrous oxide (N<sub>2</sub>O) emissions. When the residues are incorporated along with inorganic fertilizer, immobilization followed by re-mineralization of mineral N occurs, which means that, after the initial immobilization, the mineral N is released back into the soil. Many previous studies proved that when wheat straw is incorporated along with inorganic N fertilizer, there was initial N mineralization, followed by release of N in later stages [5].

Agricultural management practices exert profound influence on soil CO<sub>2</sub> emissions through modifications in the soil environment, encompassing parameters such as soil aeration, pH levels, moisture content, temperature and C/N ratios. These inherent characteristics of ~~the~~-soil environment ~~plays~~ a pivotal role in modulating microbial activity and the decomposition mechanisms which are responsible for the conversion of plant-derived carbon into ~~soil~~-organic~~soil~~ matter and subsequent release of CO<sub>2</sub>. Crop

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residues with high C:N ratio, when incorporated into soil, C mineralization occurs, which also leads to GHG emissions. Therefore, we ~~had~~ conducted an incubation study, ~~with an objective~~ to examine the release patterns of  $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N and also to investigate the GHG emissions ( $\text{CO}_2$ ,  $\text{CH}_4$  and  $\text{N}_2\text{O}$ ), after incorporation of paddy straw with various changed split doses of inorganic nitrogen, throughout the incubation period.

## Materials and Methods:

### Soil and Crop residues:

The soil used for incubation study was collected from B block of college farm, College of Agriculture, Rajendranagar, PJTSAU, which is located in Rangareddy district of Telangana state at an altitude of 542.6 m above mean sea level (78°23' °E longitude and 17°19' N latitude). The weekly mean maximum temperature during the crop growth period in *Rabi* 2020-21 ranged from 29.5 °C to 38.1°C with an average of 34.9 °C, while the weekly mean minimum temperature ranged from 11.2°C to 25.3°C with an average of 19.3°C. The soil ~~for the incubation experiment~~ was collected from the maize experimental field. Soil samples were combined, homogenized, sieved (2 mm), ~~and~~ pre-incubated, and residues were collected, oven dried at 65 °C in a hot air oven, and crushed with a willey mill before sieving through a 2 mm sieve. The residues were then ~~biochemically characterised~~ characterized using appropriate techniques (Table 1). The texture of soil was sandy clay loam, with pH of 7.9, EC of 1.14 dSm<sup>-1</sup>, organic carbon of 0.72% and had a C:N ratio of 16:1.

### Incubation:

The experiment was conducted by taking 100 g of the soil in 150 ml plastic cups and the soil was kept at field capacity by adding 13 ml of distilled water and kept in dark for 10 days for pre-incubation. Pre-incubation was done prior to the start of incubation experiment to initiate microbial activity in the soil.

After pre-incubation, 0.18g powdered paddy straw was mixed ~~thoroughly to~~ with soil as per treatments and urea was added along with distilled water into the soil. After treatment imposition, the beakers were incubated at room temperature for 120 days.

The entire experiment was repeated so as to collect greenhouse gas emissions from one set and second set was used to monitor mineralization with destructive sampling at given intervals ~~and~~ ~~+~~ The samples were used for analysis of  $\text{NH}_4^+$ -N,  $\text{NO}_3^-$ -N, C:N ratio and available N. The constant soil moisture content of the experiment was maintained throughout the experimental period. Details of treatments is mentioned in Table 2.

**Table 1: Properties of paddy residue used in the lab study:**

S.No.	Particulars	Values
1	Lignin (%)	24.7
2	Cellulose (%)	35.0
3	Hemicellulose (%)	13.6
4	Total C (%)	48.98
5	Total N (%)	0.66
6	C:N	74.21
7	ADF (%)	43.6
8	Ash (%)	15.53
9	Proteins (%)	4.12
10	Total phenols (mg GAE / 100 g)	31.03

**Table 2. Treatment details:**

T <sub>1</sub>	Control (Soil only without residue and nitrogen)
T <sub>2</sub>	Soil + RDN in normal 3 splits (33:33:33)
T <sub>3</sub>	Crop residue incorporation + RDN in normal 3 splits (33:33:33)
T <sub>4</sub>	Crop residue incorporation + 100 % RDN but with changed quantities <i>i.e.</i> ,43:23:
T <sub>5</sub>	Crop residue incorporation + 100 % RDN but with changed quantities <i>i.e.</i> ,43:33:23
T <sub>6</sub>	Crop residue incorporation + 10 % extra N with changed quantities during crop growth <i>i.e.</i> , 43:33:33

\*Note: Rate of paddy straw added to 100g soil was based on top residue available from the *kharif* crop that is possible to deploy in succeeding *rabi* (maize) crop.

The treatments were replicated ~~three~~ twice and were laid out in Completely Randomized Design (CRD) Sampling was done on 2, 4, 6, 8, 10, 20, 30, 45, 60, 75, 90, 105, 120 days after incubation

#### **NH<sub>4</sub><sup>+</sup>, NO<sub>3</sub><sup>-</sup> and GHG emissions:**

Ten grams of soil was shaken with 100 ml of 2 M KCl for an hour and filtered. Then, the filtrate was steam distilled in presence of 0.2 g MgO. The distillate was collected in 4% boric acid containing mixed indicator was titrated with standard sulphuric acid (0.02 N) as described by [6] and expressed in mg kg<sup>-1</sup>. After removal of NH<sub>4</sub>-N<sup>+</sup> from the sample, the distillation flask was removed and then 0.2 g Devarda's alloy was added immediately and steam distillation was ~~done~~ performed. The distillate was collected in 4% boric acid containing mixed indicator was titrated with standard sulphuric acid (0.02 N) as described by [6] and expressed in mg kg<sup>-1</sup>.

100g of soil (2mm sieved) was taken in plastic cups to which urea (as per treatments) and paddy residue (0.18g) was added. Then, bulk density was adjusted to  $1.4 \text{ Mg } 1 \text{ mg m}^{-3}$ . Moisture was added to bring the soil samples to FC. Constant moisture content of the set was maintained in the soil throughout the experiment. Plastic cups were positioned within a gallon jar, with a small amount of water at the bottom of the jar to maintain soil moisture. Gas samples were collected using an airtight three-way stopcock syringe (60 ml capacity) from the headspace of the jar and then injected into pre-evacuated extainer vials at specific intervals of 2,4,6,8,10,20,30,45,60,75,90 and 120 days after incubation (DAI) for analysis using an autoanalyzer. The concentrations of  $\text{N}_2\text{O}$ ,  $\text{CO}_2$  and  $\text{CH}_4$  gases were simultaneously analyzed using a modified gas chromatography instrument (Bruker 450) equipped with three detectors: FID, ECD, and TCD. Nitrous oxide was separated by two stainless steel columns (column-1: 1 m length, 2.2 mm i.d.; column-2: 3 m length, 2.2 mm i.d.) packed with 80–100 mesh porapak Q and detected by ECD. Carbon dioxide was separated by a single stainless steel column (2 m length, 2.2 mm i.d.) packed with 50–80 mesh porapak Q, and then hydrogen reduced  $\text{CO}_2$  to  $\text{CH}_4$  in a Nickel catalytic converter at  $37.5^\circ\text{C}$ , with  $\text{CH}_4$  being detected by FID. The oven temperature was set at  $55^\circ\text{C}$ , the ECD operated at  $330^\circ\text{C}$ , and the FID at  $220^\circ\text{C}$ , respectively. Regular opening of the jars occurred at specified intervals to prevent  $\text{CO}_2$  buildup. During the experiment, the  $\text{CO}_2$  concentration was kept below 5%. The jars were opened, and the cups were briefly placed outside before being returned to the jars. Subsequently, the jars were flushed with ambient air for one minute.

The GWP of different treatments was calculated using the following equation [7], where the GWP for  $\text{CO}_2$  is taken as 1.

$$\text{GWP} = \text{CH}_4 \times 21 + \text{N}_2\text{O} \times 298$$

#### **Statistical Analysis:**

All the data was subjected to statistical analysis using OPSTAT software. The critical difference for assessing the significance of treatment means was computed at a 5% level of probability.

#### **Results and Discussion:**

The effect of different nitrogen fertilizer doses along with paddy straw application on changes in mineral N status ( $\text{NH}_4^+$  and  $\text{NO}_3^-$ ) for each split dose of fertilizer was studied for 120 days, where the sampling was done on 2,4,6,8,10,20,30,45,60,75,90,105 and 120 DAI. The  $\text{NH}_4^+$  and  $\text{NO}_3^-$  content in soil under

incubation was significantly influenced by different nitrogen fertilizer doses along with paddy straw application, throughout the incubation period (Table 3, 4 and Fig. 1).

#### **Ammoniacal nitrogen ( $\text{NH}_4^+$ - N):**

After application of first split dose of nitrogen along with paddy residue, the sampling was done on 2, 4, 6, 8, 10, 20 DAI (Fig. 1a). Here only basal dose of nitrogen was given. On day 2, application of paddy residue + 10 % extra RDN – 43:23:33 ( $T_6$ ) recorded significantly higher  $\text{NH}_4^+$  - N ( $117.60 \text{ mg kg}^{-1}$ ), followed by soil +N ( $T_2$ ) *i.e.*,  $102.00 \text{ mg kg}^{-1}$  which was on par to paddy residue + 100 % RDN - 43:23:33 ( $T_4$ ) and control ( $T_1$ ) where the ammoniacal nitrogen was  $97.00$  and  $97.00 \text{ mg kg}^{-1}$  respectively. The lowest  $\text{NH}_4^+$  - N was recorded in paddy residue + 100 % RDN - 33:33:33 ( $T_1$ ) *i.e.*,  $85.27 \text{ mg kg}^{-1}$ . From day 1 to day 8, there was an increase in  $\text{NH}_4^+$  - N content in all treatments except control ( $T_1$ ) and soil + N ( $T_2$ ), where the  $\text{NH}_4^+$  - N content increased upto 10<sup>th</sup> day and later decreased throughout the incubation period. However in all the sampling dates after day 2, upto day 8 (4,6,8 DAI),  $T_6$  recorded significantly higher  $\text{NH}_4^+$  - N ( $156.60, 174.13, 185.00 \text{ mg kg}^{-1}$  respectively). After day 8, the  $\text{NH}_4^+$  - N shown a decreasing trend upto day 30.  $T_6$  recorded significantly higher  $\text{NH}_4^+$  - N from day 10 to day 30.

The effect of second split dose application on  $\text{NH}_4^+$  - N was studied from 30<sup>th</sup> day to 60<sup>th</sup> DAI *i.e.*, second split application was done on 30<sup>th</sup> day after the application of first split. The sampling was done on 30, 45 days after the application of second split. Among all the treatments, paddy residue + 10 % extra RDN – 43:23:33 ( $T_6$ ) recorded significantly higher  $\text{NH}_4^+$  - N and the lowest  $\text{NH}_4^+$  - N was recorded in control ( $T_1$ ). The  $\text{NH}_4^+$  - N in  $T_6$  on 30<sup>th</sup> day was  $85.47 \text{ mg kg}^{-1}$ , later it was increased to  $94.53 \text{ mg kg}^{-1}$  on 45<sup>th</sup> day.

The effect of third split dose application on  $\text{NH}_4^+$  - N was studied from 60<sup>th</sup> day to 120<sup>th</sup> DAI *i.e.*, third split application was done on 60<sup>th</sup> day after the application of first split. The sampling was done 60, 75, 90, 105, 120 days after incubation. Here all the three split doses were applied. Results indicated that the  $\text{NH}_4^+$  - N content increased from day 60 to day 75 and later it has decreased upto 120<sup>th</sup> day. The paddy residue + 10 % extra RDN - 43:23:33 ( $T_6$ ) recorded highest  $\text{NH}_4^+$  - N and paddy residue + 100 % RDN - 43:33:23 ( $T_3$ ) recorded lowest  $\text{NH}_4^+$  - N. There was approximately 22.48 % decrease in  $\text{NH}_4^+$  - N content from day 75 to day 120.

Increase in N concentration increased mineral N status. Application of fertilizer along with rice straw increased mineral-N ( $\text{NH}_4^+$  -N +  $\text{NO}_3^-$  -N) concentration compared with no-straw [8]. Initial increase in  $\text{NH}_4^+$  -N after the application of N fertilizer along with rice straw, from day 2 to day 8 might be due to increased ammonification. Thereafter  $\text{NH}_4^+$  -N showed a decreased trend which might be due to immobilization, as the rice straw had high C:N ratio (73:1), which caused immobilization. After the application of second split, there was slight increase in  $\text{NH}_4^+$  -N upto 45<sup>th</sup> day, which is due to increased

mineralization and this continued even after application of third split (*i.e.*, upto 75<sup>th</sup> day) and later it has decreased due to increase in the nitrification.

#### **Nitrate Nitrogen (NO<sub>3</sub><sup>-</sup> - N):**

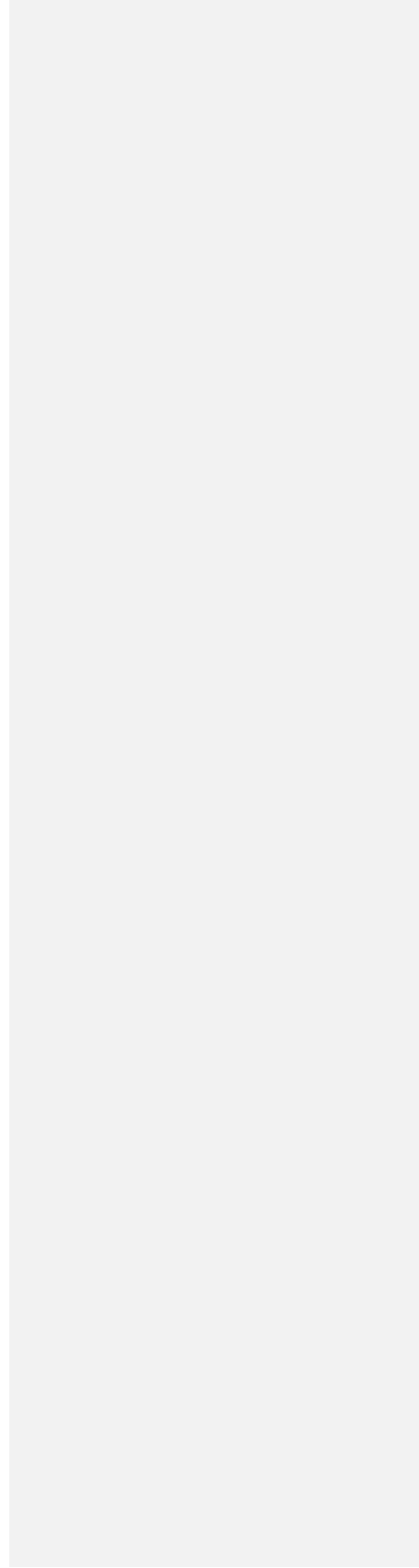
The NO<sub>3</sub><sup>-</sup> - N content on day 2 was higher in paddy residue + 10 % extra RDN - 43:23:33 (T<sub>6</sub>) *i.e.*, 69.17 mg kg<sup>-1</sup> which was on par to paddy residue + 100 % RDN - 43:33:23 (T<sub>5</sub>) *i.e.*, 67.00 mg kg<sup>-1</sup>, while the lowest NO<sub>3</sub><sup>-</sup> - N was recorded in control (T<sub>1</sub>) *i.e.*, 43.67 mg kg<sup>-1</sup> (Fig. 4.1b). From day 4 to day 20, T<sub>6</sub> recorded higher NO<sub>3</sub><sup>-</sup> - N at all the sampling dates. The NO<sub>3</sub><sup>-</sup> - N content has shown an increasing trend from day 2 to day 20 and later it showed a decreasing trend upto day 30, in all the treatments except in soil + N (T<sub>2</sub>), where there was increase in NO<sub>3</sub><sup>-</sup> - N upto 30<sup>th</sup> day. The NO<sub>3</sub><sup>-</sup> - N ranged from 65.23 to 87.83 mg kg<sup>-1</sup> from day 1 to day 20.

The effect of second split dose application on NO<sub>3</sub><sup>-</sup> - N content was studied from 30 to 60 DAI. On day 30, significantly higher NO<sub>3</sub><sup>-</sup> - N was observed in soil + N (T<sub>2</sub>) *i.e.*, 89.33 mg kg<sup>-1</sup>. and the lowest NO<sub>3</sub><sup>-</sup> - N was recorded in control (T<sub>1</sub>) *i.e.*, (60.33 mg kg<sup>-1</sup>). After the application of second split, the NO<sub>3</sub><sup>-</sup> - N increased from day 30 to day 45, the increase was approximately 44.79 %.

The effect of third split dose application on NO<sub>3</sub><sup>-</sup> - N content was studied from 60 to 120 DAI. On day 60, significantly higher NO<sub>3</sub><sup>-</sup> - N was observed in soil + N (T<sub>2</sub>) *i.e.*, (98.99 mg kg<sup>-1</sup>), while the lowest NO<sub>3</sub><sup>-</sup> - N was recorded in paddy residue + 100 % RDN - 43:33:23 (T<sub>5</sub>) *i.e.*, (75.17 mg kg<sup>-1</sup>). The NO<sub>3</sub><sup>-</sup> - N increased from 60 to 90 DAI and later it had decreased from 90<sup>th</sup> to 120<sup>th</sup> day. Compared to T<sub>6</sub>, on an average, 60.80 % of lower NO<sub>3</sub><sup>-</sup> - N was recorded in control (T<sub>1</sub>) throughout the incubation period, after third split application.

The NO<sub>3</sub><sup>-</sup> - N was significantly higher in T<sub>6</sub>, where extra nitrogen was applied. After the application of first split, from day 2 to day 20 there was increase in NO<sub>3</sub><sup>-</sup> - N which is due to increased nitrification in those days. The aerated conditions and the moisture conditions in soil favoured multiplication of nitrifiers, which in turn enhanced nitrification process [9]. After 20<sup>th</sup> day, there was slight decrease in NO<sub>3</sub><sup>-</sup> - N status, which was later increased after the application of second split dose *i.e.*, on 30<sup>th</sup> day. This increase in NO<sub>3</sub><sup>-</sup> - N status is due to increase in total mineral nitrogen due to application of second split dose. Then from day 30 onwards NO<sub>3</sub><sup>-</sup> - N status increased upto day 45, after which third split dose was applied. The NO<sub>3</sub><sup>-</sup> - N status continued to increase upto the end of incubation period. This is due to continuous nitrification process of nitrogen from both fertilizer nitrogen as well as the nitrogen from residue decomposition. Among all the treatments containing nitrogen, soil + N (T<sub>2</sub>) recorded highest NO<sub>3</sub><sup>-</sup> - N by the end of the experiment. This may be attributed to the apparent immobilization of nitrogen in the treatments where both paddy straw and nitrogen were applied [10].

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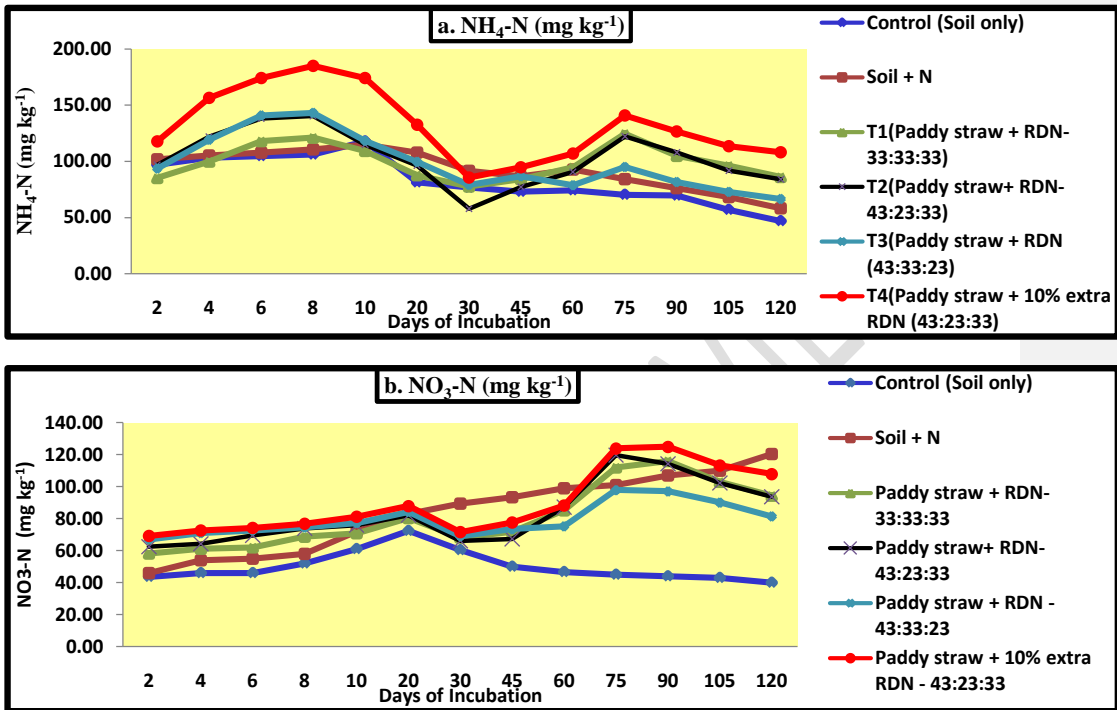
**Table 3. Effect of different fertilizer doses employing paddy straw on  $NH_4^+$ -N ( $mg\ kg^{-1}$ ) during incubation**

Treatments	DAYS OF INCUBATION												
	2	4	6	8	10	20	30	45	60	75	90	105	120
Control (T <sub>1</sub> )	97.00	103.33	104.67	106.00	117.67	81.33	76.67	73.00	74.33	70.33	69.67	57.00	47.00
Soil + N (T <sub>2</sub> )	102.00	105.33	108.00	110.67	115.00	107.78	91.67	86.67	92.67	84.33	76.33	68.33	58.33
Paddy straw + RDN-33:33:33 (T <sub>3</sub> )	85.27	99.80	117.93	121.00	109.27	87.73	77.70	84.23	94.83	124.50	104.87	96.17	86.17
Paddy straw+ RDN-43:23:33 (T <sub>4</sub> )	97.00	121.93	138.27	140.53	114.87	96.20	57.80	77.20	90.67	122.33	108.00	91.67	84.17
Paddy straw + RDN - 43:33:23 (T <sub>5</sub> )	93.73	119.33	140.87	143.17	118.53	99.73	79.00	86.83	78.80	95.17	81.73	72.87	66.60
Paddy straw + 10% extra RDN - 43:23:33 (T <sub>6</sub> )	117.60	156.60	174.13	185.00	174.23	132.57	85.47	94.53	106.83	140.67	126.67	113.47	108.13
C.D. (5 %)	5.93	8.54	8.97	12.81	8.88	6.66	6.73	5.31	5.54	4.54	5.46	4.68	4.97
SE(m) ±	1.90	2.74	2.88	4.11	2.85	2.14	2.16	1.71	1.78	1.46	1.75	1.50	1.59
SE(d)	2.69	3.88	4.07	5.82	4.03	3.02	3.05	2.41	2.51	2.06	2.48	2.13	2.25

**Table 4. Effect of different fertilizer doses employing paddy straw on  $NO_3^-$ -N ( $mg\ kg^{-1}$ ) during incubation**

Treatments	DAYS OF INCUBATION												
	2	4	6	8	10	20	30	45	60	75	90	105	120
Control (T <sub>1</sub> )	43.67	46.00	46.00	52.00	61.00	72.33	60.33	50.00	46.67	45.00	44.00	43.00	40.00
Soil + N (T <sub>2</sub> )	46.00	54.00	55.00	58.00	72.00	83.00	89.33	93.33	98.99	101.00	107.00	110.00	120.33
Paddy straw + RDN-33:33:33 (T <sub>3</sub> )	58.13	61.17	62.00	68.67	70.83	80.33	68.17	71.67	85.13	112.00	116.00	103.00	94.33
Paddy straw+ RDN-43:23:33 (T <sub>4</sub> )	62.50	64.27	69.50	73.83	75.83	82.17	66.13	67.33	87.17	119.67	114.33	102.33	93.67
Paddy straw + RDN - 43:33:23 (T <sub>5</sub> )	67.00	71.00	72.67	74.50	77.17	84.17	69.00	73.50	75.17	97.83	97.00	90.00	81.37
Paddy straw + 10% extra RDN - 43:23:33 (T <sub>6</sub> )	69.17	72.50	74.17	76.83	81.17	87.83	71.50	77.50	88.17	123.83	124.83	113.17	107.83
C.D. (5 %)	4.66	4.58	4.57	3.56	3.62	2.67	3.09	5.22	7.11	4.02	5.85	7.08	4.57
SE(m) ±	1.50	1.47	1.47	1.14	1.16	0.86	0.99	1.68	2.28	1.29	1.88	2.27	1.47
SE(d)	2.11	2.08	2.07	1.62	1.64	1.21	1.40	2.37	3.23	1.83	2.65	3.21	2.07

Fig. 1 Effect of different fertilizer doses employing paddy straw on inorganic N fractions during incubation



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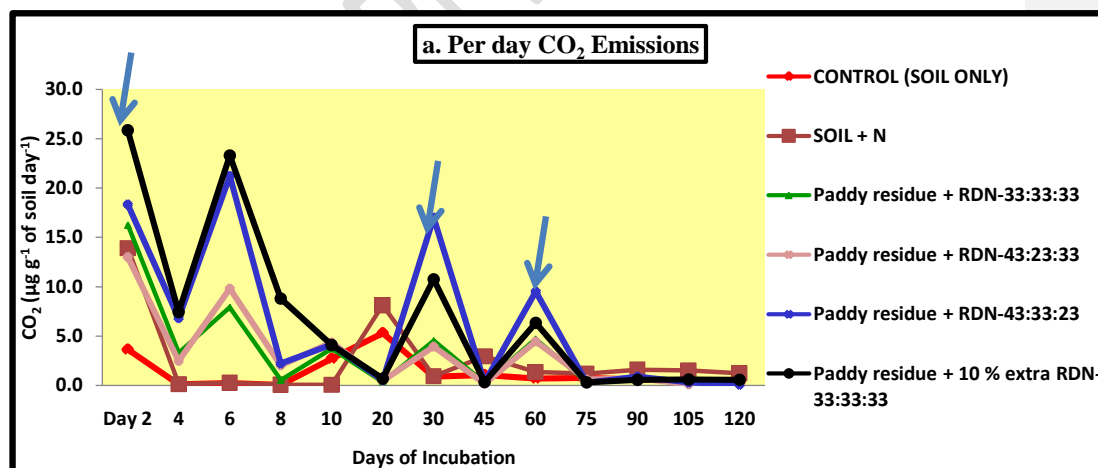
## GHG emissions:

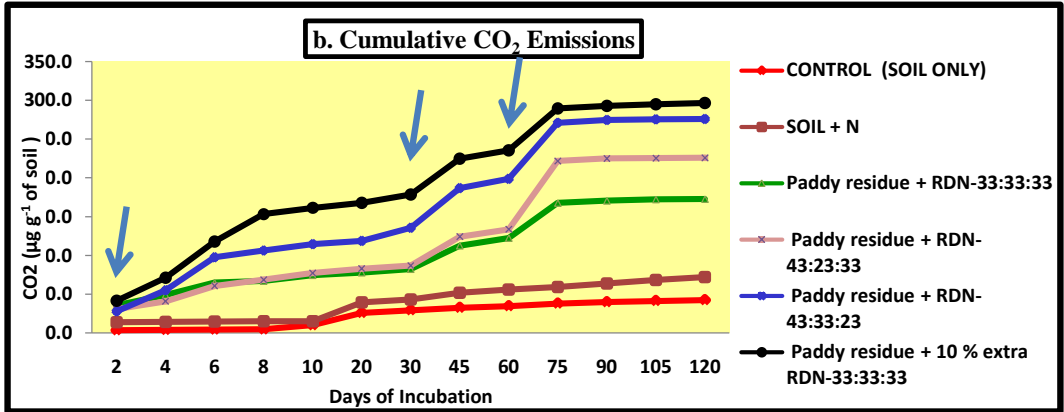
### CO<sub>2</sub> emissions:

The data indicated that, in all the treatments, after addition of only fertilizer or fertilizer along with residue, there was increase in CO<sub>2</sub> emissions (Fig. 2a). CO<sub>2</sub> emissions decreased upto day 4, after which CO<sub>2</sub> emissions increased and reached peak on day 6, later CO<sub>2</sub> emissions decreased upto day 20. After day 20, the CO<sub>2</sub> emissions increased and reached peak on day 30. After day 30, upto day 45, CO<sub>2</sub> emissions have decreased and from day 45 to day 60, CO<sub>2</sub> emissions have increased and reached peak on day 60. From day 60 to day 75, CO<sub>2</sub> emissions decreased and almost reached a constant value upto the end of the incubation.

The cumulative CO<sub>2</sub> emissions (Fig. 2b) were significantly higher in paddy residue + 10 % extra RDN – 43:23:33 (T<sub>6</sub>) i.e., 296.63 μg C g<sup>-1</sup> of soil (Table 5 and Fig. 3). The lowest cumulative CO<sub>2</sub> emissions were observed in control (T<sub>1</sub>) i.e., 42.59 μg C g<sup>-1</sup> of soil. The addition of residue enhanced carbon source and energy which had boosted microbial activity and lowered soil redox potential, there by increased CO<sub>2</sub> emissions in all treatments containing residue. Similar results were reported by [11], who reported that, in a 100 days incubation experiment, incorporation of rice residue significantly increased soil CO<sub>2</sub> emissions.

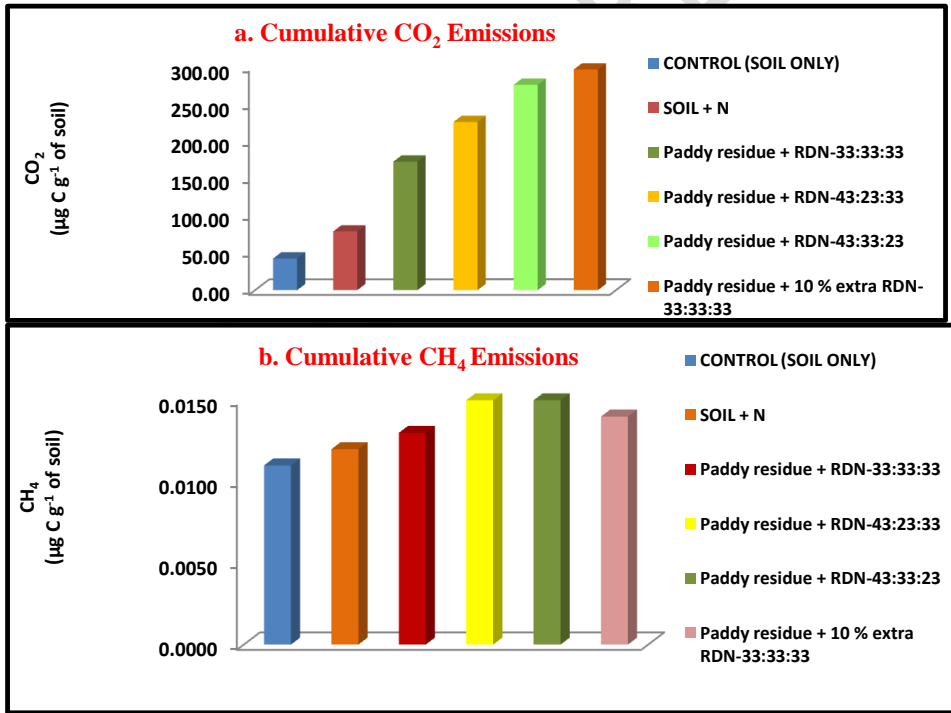
Fig. 2 Effect of different fertilizer doses employing paddy straw on CO<sub>2</sub> emissions during incubation

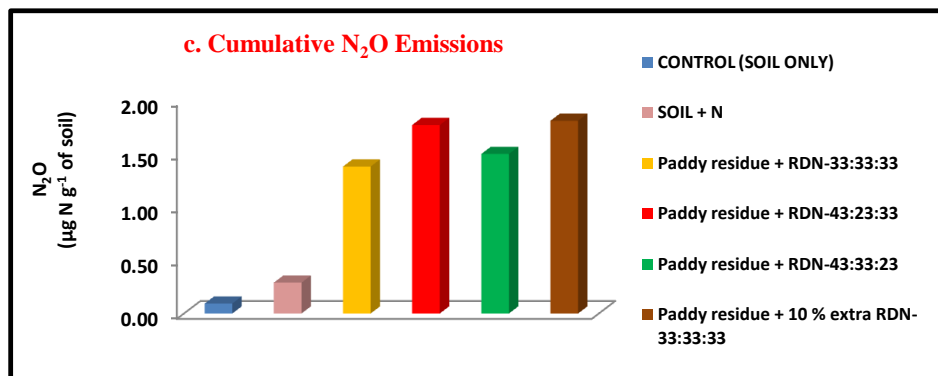




Note :Arrows indicates split application of N fertilizer

Fig. 3 Effect of different fertilizer doses employing paddy straw on cumulative emissions during incubation



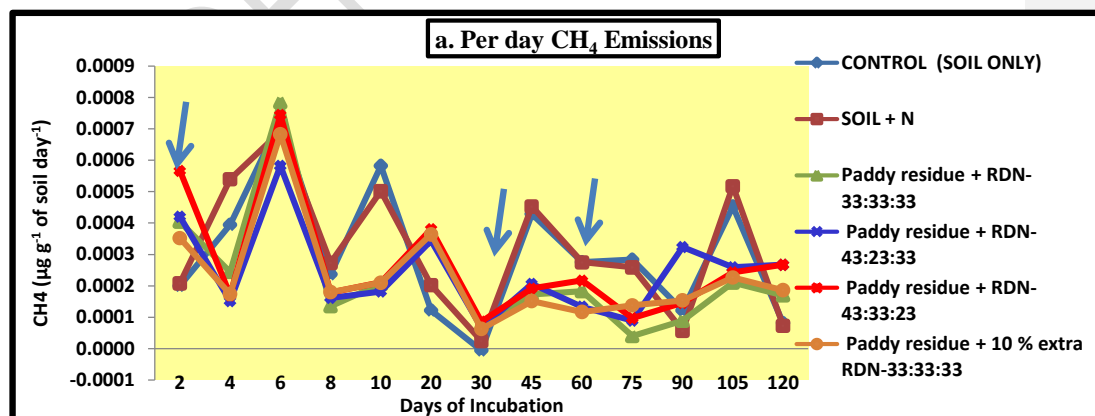


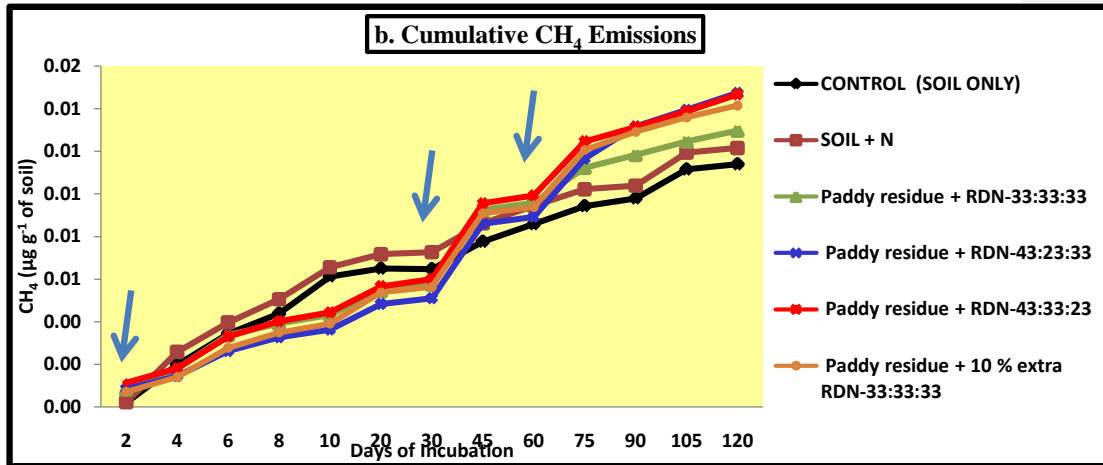
**CH<sub>4</sub> emissions:**

The methane emissions decreased from day 2 to day 4, the increased upto day 6, later decreased upto day 8 and then increased upto day 10, after which the methane emissions decreased upto day 30 (Fig. 4a). On day 30, after addition of second split, methane emissions increased and reached peak upto day 45, after which there was a decrease upto day 90, then increased upto day 105 and later methane emissions decreased upto day 120. The treatments did not differ significantly (Fig. 4b) with respect to cumulative CH<sub>4</sub> emissions (Table 5 and Fig. 3).

**Comment [F6]:** The authors must explain methane emissions, they just described it

*Fig. 4 Effect of different fertilizer doses employing paddy straw on CH<sub>4</sub> emissions during incubation*





Note :Arrows indicates split application of N fertilizer

#### N<sub>2</sub>O emissions:

The N<sub>2</sub>O emissions reached peak on day 6, after which there was a decrease upto day 10 and almost reached zero from 10<sup>th</sup> day to 20<sup>th</sup> day (Fig. 5a). From day 20, there was increase in N<sub>2</sub>O emissions upto 30<sup>th</sup> day, where it reached peak. After 30<sup>th</sup> day, there was decrease upto 45<sup>th</sup> day. From 45<sup>th</sup> day, the N<sub>2</sub>O emissions increased and reached peak on 60<sup>th</sup> day and later it has decreased upto 120<sup>th</sup> day.

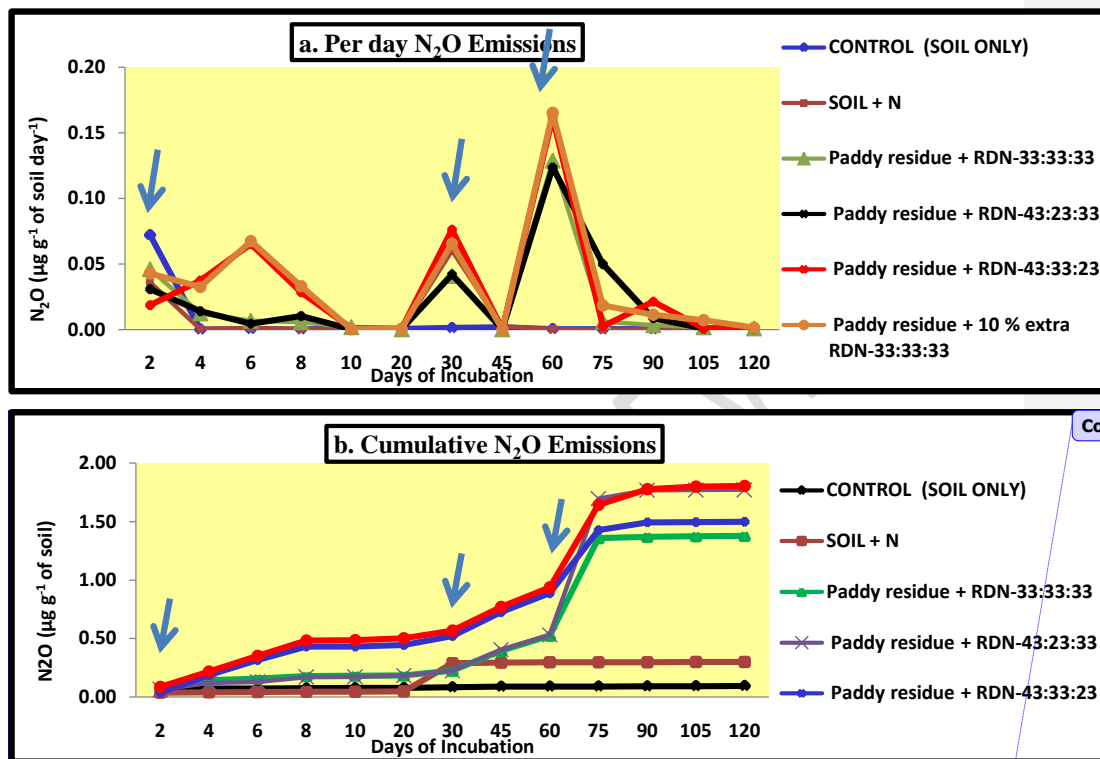
The cumulative N<sub>2</sub>O emissions (Fig. 5b) were significantly higher in paddy residue + 10 % extra dose of N (1.81 µg N g<sup>-1</sup> of soil), followed by paddy residue + 100 % RDN (43:23:33) *i.e.*, 1.77 µg N g<sup>-1</sup> of soil. The lowest cumulative N<sub>2</sub>O emissions were observed in control (T<sub>1</sub>) *i.e.*, 0.09 µg N g<sup>-1</sup> of soil (Table 5 and Fig. 3).

The incorporated straw stimulated N<sub>2</sub>O emissions by providing readily available C as an energy source for denitrifiers. Our results were in line with studies conducted by [12] and [13], who reported that residues with high C:N ratio, when incorporated into soil along with inorganic fertilizer, increased N<sub>2</sub>O emissions via enhanced denitrification after fertilization. The increased nitrogen dose in paddy residue + 10 % extra dose of N (T<sub>6</sub>) treatment increased the nitrogen substrate and thus increased N<sub>2</sub>O emissions [14].

**Comment [F7]:** What does this mean?

**Comment [F8]:** The authors should discuss in more detail the N<sub>2</sub>O emission

Fig. 5 Effect of different fertilizer doses employing paddy straw on N<sub>2</sub>O emissions during incubation



Comment [F9]: Correct Y axis

Table 5. Effect of different fertilizer doses employing paddy straw on cumulative GHG emissions during incubation

Treatment	Cumulative CO <sub>2</sub> Emissions (µg C g <sup>-1</sup> of soil)	Cumulative CH <sub>4</sub> Emissions (µg C g <sup>-1</sup> of soil)	Cumulative N <sub>2</sub> O Emissions (µg N g <sup>-1</sup> of soil)
Control (T <sub>1</sub> )	42.59	0.011	0.09
Soil + N (T <sub>2</sub> )	78.97	0.012	0.29
Paddy straw + RDN- 33:33:33 (T <sub>3</sub> )	172.81	0.013	1.38
Paddy straw+ RDN-43:23:33 (T <sub>4</sub> )	226.09	0.015	1.77
Paddy straw + RDN -43:33:23 (T <sub>5</sub> )	276.05	0.015	1.50
Paddy straw + 10% extra RDN - 43:23:33 (T <sub>6</sub> )	296.63	0.014	1.81
C.D.	9.05	NS	0.04
SE(m) ±	2.90	0.001	0.01
SE(d)	4.11	0.001	0.02

## Conclusion:

Our observation showed that, from day 1 to 8,  $\text{NH}_4^+$ -N content increased in most treatments, except control and soil + N. After application of each split dose of fertilizer, there was increase in release of  $\text{NH}_4^+$ -N content in all the treatments. Paddy residue + 10% extra RDN - 43:23:33 treatment recorded significantly higher  $\text{NH}_4^+$ -N content. Approximately 22.48% decrease in  $\text{NH}_4^+$ -N content from day 75 to day 120. On day 2, paddy residue + 10% extra RDN - 43:23:33 had higher  $\text{NO}_3^-$ -N. Second split application on day 30 increased  $\text{NO}_3^-$ -N. From day 30 to 45,  $\text{NO}_3^-$ -N increased by approximately 44.79%. Third split application from day 60 to 120 showed variations among treatments, with soil + N recording the highest on day 60. Cumulative  $\text{CO}_2$  emissions significantly higher in paddy residue + 10% extra RDN - 43:23:33, lowest was observed in control. Cumulative  $\text{CH}_4$  emissions showed no significant differences among treatments. Cumulative  $\text{N}_2\text{O}$  emissions was significantly higher in paddy residue + 10% extra dose of N and was lowest in control. Our results suggest that, incorporation of crop residues along with inorganic fertilizer serves as best residue management practice compared to residue burning, in croplands. It increases N availability, besides improving soil fertility and decreasing GHG emissions.

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