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Residue-based nitrogen regimes and decomposer applications as determinants of growth and yield performance in *rabi* rice

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ABSTRACT

The present investigation was conducted on clay soils during *rabi* 2024–2025 at the Regional Agricultural Research Station, Maruteru, to evaluate the effect of different rice residue management practices on the growth, yield attributes and yield of rice. The experiment was laid out in a randomized block design with nine treatments replicated three times. The results indicated that among the residue management practices, 100% RDN recorded the highest number of productive tillers (323), plant height (107.3 cm), dry matter accumulation (13,584 kg ha^{-1}), straw yield (7,470 kg ha^{-1}) and grain yield (6,137 kg ha^{-1}). However, it was statistically comparable to 75% RDN + 25% N through residue + PUSA decomposer, which produced 309 productive tillers, plant height of 105.5 cm, dry matter accumulation of 12,353 kg ha^{-1}, straw yield of 7,373 kg ha^{-1} and grain yield of 6,057 kg ha^{-1}. Similarly, 75% RDN + 25% N through residue + ANGRAU decomposer recorded 304 productive tillers, plant height of 102.4 cm, dry matter accumulation of 12,279 kg ha^{-1}, straw yield of 7,177 kg ha^{-1} and grain yield of 5,833 kg ha^{-1}. Overall, the study concludes that residue management practices involving 75% RDN + 25% N through residue along with PUSA or ANGRAU decomposers provide a promising strategy to reduce chemical fertilizer use and enhance the sustainability of *rabi* rice cultivation.

Keywords: *Chemical fertilizer, N management, Residue management and Sustainability*

Rice (*Oryza sativa* L.) is a major staple crop globally, supplying nearly 20% of total calorie intake and adapting well to diverse agro-climatic conditions (Fukagawa and Ziska, 2019). India, one of the largest producers and exporters of rice, produces about 130.29 million tons annually, with major rice-growing states including West Bengal, Uttar Pradesh, Tamil Nadu, Andhra Pradesh, Odisha, Jharkhand and Assam (MoAFW, 2022). Andhra Pradesh cultivates rice over 2.29 million ha with a production of 7.76 million tonnes and a productivity of 3,392 kg ha^{-1} (MoA, 2021–22). The country also generates large quantities of rice straw, contributing to the global 126.6 million tonnes, of which nearly 60% is burned (Bhattacharya *et al*., 2020).

Studies suggest that combining leguminous and gramineous residue incorporation enhances growth and yield of subsequent crops (Zhou *et al*., 2019). Integrating green manure with rice straw return can improve production without increasing chemical fertilizer use. However, standardized information on combining legume residues and paddy straw with microbial decomposers is still required for sustaining productivity in the rice–rice system.

Open-field burning (OFB) of rice straw is highly detrimental due to emissions of CO_2, SO_2, NOx, VOCs, PAHs, dioxins, furans and particulate matter ($PM_{2.5}$, PM_{10}), causing severe health risks (Oanh. *et al*, 2011). It also emits CO_2, CH_4, N_2O and trace gases contributing to Atmospheric Brown Clouds and ozone depletion (Arai *et al* 1998; Torigoe *et al*., 2000; Gullett and Touati, 2003; Tipayarom and Oanh, 2007; Kanokkanjana, 2011). One kilogram of burnt rice straw releases 700–4100 mg CH_4 and 19–57 mg N_2O (Kritee *et al*., 2018; Islam *et al*., 2018; Josh G., 2018).

Mechanized harvesting leaves large amounts of straw in fields, offering opportunities for residue recycling (Mandal *et al*., 2004). Rice straw mulching has been shown to effectively suppress weeds and improve yields, contributing to integrated plant management with reduced agrochemical use (Mendoza and Samson, 1999). In-situ residue management, through mulching or incorporation, conserves moisture, suppresses weeds and reduces erosion (Chaudhary *et al*., 2019; Kaur *et al*., 2020). Hence the present research was conducted to develop a residue management option for rice growing regions of Andhra Pradesh with an aim to reduce environmental pollution and promote sustainable utilization of rice straw.

MATERIALS AND METHOD

Field experiments were conducted on rice (*Oryza sativa* L.) during *rabi* season of 2024-25 in Godavari alluvials (Vertic chromusters) at Regional Agricultural Research Station, Maruteru, A.P. India (26.380 N, 84. 440 E and 5 m above mean sea level) to study the impact of rice straw management on *rabi* rice cropping system. The weekly mean maximum temperatures ranged from 28.0°C to 36.9°C, while the minimum temperatures varied between 19.4°C and 25.7°C. The average maximum and minimum temperatures for the entire period were 32.8°C and 23.1°C, respectively. The weekly mean relative humidity at 8:30 AM ranged from 83.0% to 92.0% and at 2:30 PM from 50.6% to 78.3%, with average values of 87.6% and 58.4%, respectively. A total rainfall of 31.6 mm was received in one rainy day during the crop. The soil (0-15) of the experimental site was clay in texture, slightly acidic in reaction with pH 6.8, EC 1.5 $dSm^{-1}$was non-saline to slightly saline range, high in Organic Carbon 0.9, low in available Nitrogen 122 kg ha^{-1}, medium in available Phosphorus 41.3 kg $ha^{-1}$and high in available Potassium 256 kg ha^{-1}.

In the present study two decomposers, ANGRAU developed and PUSA decomposer was used to test their efficacy in decomposition of straw. The experiment consists of nine treatments, 100% recommended N, two paddy straw residue treatments with 25% and 50% N substitution with and without decomposers (ANGRAU, PUSA decomposers), 50% N through residue plus 50% through green leaf manure, finally one treatment with absolute control. PUSA decomposer solution was uniformly sprayed over the crop residue and incorporated into the soil, with adequate moisture maintained to ensure rapid decomposition within 20–25 days. For ANGRAU decomposer, 1 kg decomposer along with 50 kg FYM was applied per 2 tons of rice straw during incorporation. Nutrients were applied as per treatments using urea, single superphosphate and muriate of potash at 180 kg N ha^{-1}, 90 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1}. Nitrogen was applied in three equal splits—basal, active tillering and panicle initiation—while phosphorus was applied entirely at basal. Potassium was applied in two splits: 2/3 basal and 1/3 at panicle initiation along with the final N split. Zinc sulphate foliar sprays were applied at the onset of Zinc deficiency symptoms. The general recommendation is 50 kg of zinc sulphate per hectare. Biometric and post-harvest observations were recorded on tagged hills at three growth stages: active tillering, panicle initiation and at harvest. Yield parameters were assessed at harvest. Based on observations from five tagged plants, average per-plant values were computed.

RESULTS AND DISCUSSION

Growth parameters

Growth parameters (Table 1) were significantly influenced by the different rice straw management practices. The combined use of inorganic and organic nutrient sources notably impact on plant height, drymatter accumulation and productive tillers.

Plant height

At 30 DAT, the tallest plants were recorded under 100% RDN (50.7 cm), which was on par with 75% RDN + 25% N through residue + PUSA (47.2 cm) and + ANGARU (44.9 cm), while the lowest height (32.7 cm) occurred in the absolute control. At 60 DAT, 100% RDN again produced the tallest plants (70.7 cm), on par with the corresponding PUSA (68.5 cm) and ANGARU (66.9 cm) treatments and the minimum height (52.7 cm) was noted in the control. Plant height at harvest followed a similar trend. Similar findings were reported by Jat *et al*. (2019) and Khatri *et al*. (2020), who observed improved rice plant height with residue management practices. The current findings are also supported by Nayak *et al*. (2022).

Tillers m^2

At 30 DAT, the highest tiller count was recorded with 100% RDN (282 m^{-2}), which was on par with 75% RDN + 25% N through residue + PUSA (273 m^{-2}), 75% RDN + 25% N through residue + ANGRAU (268 m^{-2}). The lowest tillers were observed in the absolute control (172 m^{-2}). At 60 DAT, 100% RDN again recorded the maximum tillers (409 m^{-2}), followed by T_5 (389 m^{-2}) and T_7

Table 1. Plant height (cm), Tillers m^{-2}, Dry matter accumulation (kg ha^{-1}) at different growth stages of crop as influenced by residue management in *rabi* rice

Treatments	Plant height (cm)			Tillers (m^{-2})		Productive tillers m^{-2}	Drymatter accumulation (kg ha^{-1})		
	30 DAT	60 DAT	At harvest	30 DAT	60 DAT		30 DAT	60 DAT	At harvest
T_1 : 100% RDN (Recommended Dose of nitrogen)	50.70	70.70	107.30	282.0	409.0	323.0	4581.0	8458.0	13584.0
T_2 : 50% RDN + 50%N through Residue	40.90	61.90	96.30	219.0	343.0	263.0	3472.0	7032.0	10923.0
T_3 : 75% RDN + 25%N through Residue	42.30	64.50	99.80	227.0	364.0	286.0	3950.0	7512.0	12036.0
T_4 : 50% RDN + 50%N through Residue + PUSA Decomposer	42.20	63.50	99.20	231.0	365.0	295.0	3947.0	7508.0	11633.0
T_5 : 75% RDN + 25% N through Residue + PUSA Decomposer	47.20	68.50	105.50	255.0	389.0	309.0	4270.0	8228.0	12353.0
T_6 : 50% RDN + 50% N through Residue + ANGRAU Decomposer	41.90	62.30	98.50	229.0	363.0	293.0	3610.0	7245.0	11370.0
T_7 : 75% RDN + 25%N through Residue + ANGRAU Decomposer	44.90	66.90	102.40	243.0	377.0	304.0	4156.0	8154.0	12279.0
T_8 : 50% N through Residue + 50% N through GLM	37.50	57.50	93.50	213.0	334.0	264.0	3351.0	6716.0	9841.0
T_9 : Absolute control	32.70	52.70	85.40	172.0	289.0	211.0	2612.0	4761.0	8752.0
S Em±	2.57	2.50	3.23	18.0	21.3	14.5	304.5	318.0	931.5
CD (P=0.05)	7.72	7.52	9.70	53.9	63.9	43.7	913.0	953.0	2492.0
CV %	10.50	6.80	5.60	13.5	10.3	8.8	13.9	7.5	12.6

(377 m^{-2}), while the control remained lowest (289 m^{-2}). A similar trend was found for productive tillers, with 100% RDN recording the highest (323 m^{-2}), comparable with T… (309 m^{-2}), T‡ (304 m^{-2}). The lowest productive tillers occurred in the control (211 m^{-2}). These results agree with Shah *et al*. (2015) and Ali *et al*. (2016).

Drymatter accumulation

At 30 DAT, the highest dry matter accumulation was recorded in T (100% RDN) with 4581 kg ha^{-1}, which was on par with $_5$ (4270 kg ha^{-1}) and T_7 (4156 kg ha^{-1}). The lowest was in T_9 (control) with 2612 kg ha^{-1}. At 60 DAT, T again registered the highest biomass (8458 kg ha^{-1}), followed by T_5 (8228 kg ha^{-1}) and T_7 (8154 kg ha^{-1}), while T‰ remained lowest (4761 kg ha^{-1}). At harvest, maximum dry matter was observed in T_1 (13,584 kg ha^{-1}), which was on par with T_5 (12,353 kg ha^{-1}) and T_7 (12,279 kg ha^{-1}). The minimum was recorded in T‰ (8752 kg ha^{-1}). These results are in conformity with the findings of Gurdeep and Reddy (2017), Hari Narayan (2017) and Chaudhary *et al.* (2020).

Yield Attributes

Yield attributes (Table 2) were significantly influenced by the different rice straw management practices. The combined use of inorganic and organic nutrient sources notably affected panicle length, grains per panicle and 1000-grain weight.

Panicle Length

The 100% RDN treatment (T_1) recorded the longest panicle length (26.2 cm), followed by treatments involving residue-based nitrogen with decomposers, such as T_5 (25.1 cm) and T_7 (24.5 cm). The shortest panicles were observed in T_9 (19.6 cm). Similar reports of enhanced panicle length and grain number with adequate nitrogen supply were noted by Vijayaprabhakar *et al*. (2020) in rice–wheat systems.

Number of grains per panicle

The 100% RDN treatment (T_1) recorded the highest number of grains per panicle (189), which was statistically on par with T_5 , T_7 , T_4 and T_6 (175, 169, 166 and 161, respectively). Differences among treatments were non-significant. The lowest grain number was observed in the control (T_9) with 143.9 grains. These results align with the findings of Lamba and Gill (2024).

1000 seed weight (gms)

The 1000-grain weight of rice was not significantly affected by residue management treatments. The highest test weight was recorded in T_1 (100% RDN) with 21.6 g, while the lowest was observed in the control T_9 (17.5 g).

Grain and Straw yield

Grain and straw yields (Table 3) were significantly influenced by the different rice straw

Table 2. panicle length (cm), number of grains panicle^{-1} & test weight (g) as influenced by residue management in *rabi* rice

Treatments	Panicle length (cm)	Number of grains panicle-1	Test weight (g)
T_1 : 100% RDN (Recommended Dose of nitrogen)	26.6	189	21.6
T_2 : 50% RDN + 50%N through Residue	23.5	147	18.8
T_3 : 75% RDN + 25%N through Residue	23.8	157	19.7
T_4 : 50% RDN + 50%N through Residue + PUSA Decomposer	24.1	166	19.6
T_5 : 75% RDN + 25% N through Residue + PUSA Decomposer	25.4	175	20.1
T_6 : 50% RDN + 50% N through Residue + ANGRAU Decomposer	24.1	161	19.4
T_7 : 75% RDN + 25%N through Residue + ANGRAU Decomposer	24.5	169	19.7
T_8 : 50% N through Residue + 50% N through GLM	22.7	149	18.4
T_9 : Absolute control	19.6	144	17.5
S Em±	1.2	8.8	0.8
CD (P=0.05)	3.61	26.4	NS
CV %	8.7	9.4	7.1

Table 3. Grain yield, Straw yield ($kg\ ha^{-1}$) and Harvest index (%) as influenced by residue management in *rabi* rice

Treatments	Grain yield ($kg\ ha^{-1}$)	Straw yield ($kg\ ha^{-1}$)
T_1 : 100% RDN (Recommended Dose of nitrogen)	6137.0	7470.0
T_2 : 50% RDN + 50%N through Residue	5120.0	6453.0
T_3 : 75% RDN + 25%N through Residue	5153.0	6787.0
T_4 : 50% RDN + 50%N through Residue + PUSA Decomposer	5150.0	6650.0
T_5 : 75% RDN + 25% N through Residue + PUSA Decomposer	6057.0	7373.0
T_6 : 50% RDN + 50% N through Residue + ANGRAU Decomposer	5223.0	6517.0
T_7 : 75% RDN + 25%N through Residue + ANGRAU Decomposer	5833.0	7177.0
T_8 : 50% N through Residue + 50% N through GLM	5217.0	6390.0
T_9 : Absolute control	3540.0	5107.0
S Em±	163.5	262.7
CD (P=0.05)	490.1	788.0
CV %	5.3	6.8

management practices, with the combined use of inorganic and organic nutrients.

Grain yield

The highest grain yield (6137 kg ha^{-1}) was recorded in T_1 (100% RDN), confirming the advantage of full nutrient application. This was statistically comparable with T_5 and T_7, which yielded 6057 and 5833 kg ha^{-1}, respectively. The lowest yield (3540 kg ha^{-1}) was observed in the absolute control (T_9). The superior yield in 100% RDN was due to better yield attributes and efficient photosynthate production and translocation, supported by adequate nutrient supply (Sharma *et al*., 2015; Bharathi *et al*., 2020). These results agree with Poojitha and Dinesh (2022), Kumar *et al*. (2022), Singh *et al*. (2022) and Chhabra *et al*. (2023). Residue retention practices also enhanced yields, as reported by Ahmad *et al.* (2024) and Huang *et al*. (2013).

Straw yield

Straw yield followed the same trend as grain yield, with T_1 (100% RDN) recording the highest yield (7447 kg ha^{-1}), comparable to T_5 and T_7 (7470 and 7373 kg ha^{-1}). The lowest straw yield was observed in T_9 (5106 kg ha^{-1}). Increased straw yield with balanced fertilization and residue incorporation has also been reported by Gupta *et al.* (2023), aligning with earlier findings by Singh *et al*. (2015a), Robin Kumar et al. (2016) and Yadav *et al.* (2018).

CONCLUSION

The study concludes that partial nitrogen substitution through residue with decomposers (T_5 and T_7) produced growth, yield attributes and nutrient uptake comparable to 100% RDN, reducing reliance on chemical fertilizers. While T_1 remained the most profitable, T_5 and T_7 offered the best economic returns among residue-based options, making them both viable and sustainable. Residue incorporation with microbial decomposers also provides an environmentally friendly alternative to residue burning, enhancing soil carbon, biodiversity and overall ecosystem quality under climate-smart agriculture.

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